Update 2021: Environmental Effects Assessment Panel

33rd Meeting of the Parties to the Montreal Protocol
23-29 October 2021
Location: Global

Environmental effects of stratospheric ozone depletion, UV radiation, and interactions with climate change

EEAP Co-chairs:
Janet F. Bornman (Australia)
Paul Barnes (United States)
Krishna Pandey (India)
The EEAP Updates contribute to the full Quadrennial Assessments.

The 2021 Update was revised and refined during the EEAP online meeting (9 – 17 September 2021).

A final version for UNEP/Ozone Secretariat will be provided in December 2021.

Representatives from WHO and WMO attended on one of the EEAP meeting days; and also Sophia Mylona (Ozone Sec).

Ongoing TEAP and SAP communications to augment and streamline our common activities.
To request the Environmental Effects Assessment Panel, in drafting its 2022 report, to pay particular attention to the most recent scientific information together with future projections and scenarios, to assess the effects from changes in the ozone layer and ultraviolet radiation, and their interaction with the climate system, as well as the effects of breakdown products of controlled substances and their alternatives on:

a) The biosphere, biodiversity and ecosystem health, including on biogeochemical processes and global cycles;

b) Human health;

c) Ecosystem services, agriculture and materials, including for construction, transport, photovoltaic use and microplastics
## Interactive effects of stratospheric ozone and climate change on:

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<th>Solar ultraviolet radiation</th>
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### Quad Format

- Summary of highlights
- Executive Summary
- Main text
- FAQs
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<td>Draft outlines; feedback meetings with Co-Chairs</td>
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<td>Refining and revising of drafts</td>
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<td>Revisions completed; presentation at 34th MOP: 31 Oct-4 Nov</td>
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Environmental Effects Assessment Panel

Timetable overview: Quadrennial Assessment
The Update highlights the contribution of the Montreal Protocol to environmental and societal sustainability, and mitigation of climate change aligning with the Sustainable Development Goals.
UV radiation and climate

HIGHLIGHTS

- **2020 Antarctic ozone ‘hole’** of record duration; record-breaking increases in UV-B radiation (UV index (UVI) of 7.8 & 12 recorded - eq. to sub-tropic summer max) but still indications of recovery

- *Effects from expected cooling of the polar stratosphere* from increasing GHGs during the 21st century are projected to dominate atmospheric circulation (affecting temperature and rainfall), while effects from ODS decrease

- **2020 Arctic ozone depletion** contributed to abnormally high springtime temperatures across Asia and Europe

Projected large springtime variability in ozone depletion and UV radiation throughout the 21st century with larger spikes in UV radiation if GHGs and stratospheric water vapour continue to increase throughout this century despite decreasing ODSs.
The Montreal Protocol has reduced damaging health effects of excessive exposure to solar UV radiation by protecting the ozone layer. By avoiding large increases in DNA-damaging UV-B radiation, humans can safely tolerate time outdoors, thereby gaining the benefits of moderate sun exposure.

Benefits:
- Vitamin D production in the skin
- Possible reduced risk/severity of a number of diseases
  Examples: those related to immune function - multiple sclerosis and COVID-19
Human health

COVID-19 pandemic - evidence suggests that vitamin D, UV radiation, and other aspects of climate may play a role

Two mechanisms influencing COVID-19
1) Inactivation of the SARS-CoV-2 virus by ambient UV radiation and/or
2) Vitamin D and nitric oxide produced by exposing the skin to UV radiation could have beneficial effects on immunity and metabolism

Skin cancer continues to be a considerable burden, but some evidence of declining melanoma incidence in certain populations in younger age groups

Eye diseases related to exposure to UV radiation continue to be a major cause of vision impairment globally
Extreme climate events (ECEs) are increasing in severity & frequency. ECEs change exposure of terrestrial ecosystems to solar UV radiation, during and after:

- severe drought (++) UV or catastrophic floods (-- UV)
- temperature extremes (++) UV
- wildfires (++) UV, (-- UV)
- cyclones/hurricanes (++) UV, (-- UV)
- rapid snow/ice-melt (++) UV

Consequences – negative effects for ecosystem stability and productivity, biodiversity, GHG emissions, and seasonal timing of exposure to UV radiation, and carbon storage*

Potential ECEs by technological intervention (geoengineering)

Rapid changes: temp, rain, ozone depletion, air quality, ecosystems
Additional connectivity among evolving climate systems:

- ECEs are superimposed upon ongoing trends of increasing global temperatures & atmospheric carbon dioxide concentrations.

Climate change affects stratospheric ozone depletion and UV radiation, and stratospheric ozone depletion affects climate change.

Environmental effects/consequences.
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HIGHLIGHTS

Extreme climate events (ECEs)

Terrestrial ecosystems

Ozone Change

Climate Change

Heat Waves
Fire
Drought
Floods
Storms
Freezing rain

Phenology
Snow/Ice
Aerosols
Vegetation Structure

Acute and/or Chronic Changes in Solar UV Exposure

Direct and Indirect Effects on Organisms and Ecosystems

Temperature, Moisture, CO₂, Nutrients
Interactive effects from increased rainfall and runoff (dissolved organic matter, DOM) into aquatic systems

Problem with increasing DOM:
- undesirable parasites and pathogens are shielded from disinfection by UV-B radiation → food security and disease risk
- at the surface, UV radiation photodegrades/breaks down DOM, releasing the GHG, methane; micro-organisms then further break down the DOM, releasing carbon dioxide

UV radiation also increases toxicity of some contaminants, e.g., polycyclic aromatic hydrocarbons (PAHs) found in oil spills, some pesticides, etc (cancer risk)
Photoproduction rate of methane from dissolved organic matter (DOM) at the ocean surface (top 150 m). (Figure by Rachele Ossola)
Breakdown products by the action of UV radiation of controlled substances and their alternatives

- **Photodegradation** of per- and polyfluoroalkyl substances (PFAS) into more toxic perfluorocarboxylic acids (PFCAs)

- **Trifluoroacetic acid (TFA)**, an example of PFAS, is a widespread contaminant, and a breakdown product (photodegradation) of hydrofluorocarbons (HFCs), hydrochlorofluorocarbons (HCFCs), and hydrofluoroolefins (HFOs) in the atmosphere

- TFA: recently detected in surface waters, beer, tea, herbal infusions, and indoor dust; but not in toxic concentrations

Risk assessments will continue to be useful
Natural & synthetic materials

HIGHLIGHTS

Montreal Protocol and innovation

Implications of effects of UV radiation and climate change:

- Decreased useful lifetime of natural materials (e.g., wood) and synthetic plastics used outdoors and in textiles (polyester, nylon)

  To counter this decrease, higher levels of UV stabilisation are needed (more costly; increased persistence & leaching)

- Degradation of plastic debris and litter is accelerated with high amounts of UV radiation and high temperatures: environmental consequences

  - accelerated production rate of microplastics and microfibres
  
  Two studies found microplastics (by inhalation) in human placenta and on the foetal side. Foetal translocation not yet demonstrated
UV radiation: mainly responsible for plastic degradation, forming microplastics in the environment

Microfibres from textiles: often account for 80-90% of sampled microplastics in the ocean (polyester and nylon fibres) – UV and mechanical breakdown

Montreal Protocol and innovation

New innovations to protect the environment & human health:
Replacements for plastic and other contaminants (such as polycyclic aromatic hydrocarbons, PAHs)

- Novel, scalable & optically-clear, solar UV-blocking wood composites (i.e., fillers/additives inserted into wood)
- Graphene and its oxides (nanoscale); block UV; electrical and antimicrobial properties; environmental contamination?
- Titanium oxide blocks UV transmission through textiles by absorption, reflection and/or scattering of the UV radiation (protects skin from UV)
Modified textile protecting skin by reflection, scattering, and absorption of UV radiation; TiO\textsubscript{2} also has anti-microbial properties

Courtesy Rashid, M.M., et al. (2021) *Surfaces and Interfaces*, 22, 100890
Ongoing benefits of the Montreal Protocol


The study brings important high-level messages of the significance of the Montreal Protocol, although with large uncertainties in the estimations and the problem of extensive heterogeneity/non-uniformity among plants and their wide range of response to climate and UV radiation.
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**Ongoing benefits of the Montreal Protocol**


**Without the Montreal Protocol, estimated:**

- Increase in UV-B (280–315 nm) radiation by ca 400% over the 21st century without control of the ODSs
- Decrease of 325–690 billion tonnes carbon held in plants by end of century
- Additional 115–235 parts per million of carbon dioxide in the atmosphere
- Additional rise in global mean surface temperature of 0.5–1.0 °C

**HIGHLIGHTS**

Carbon storage by plants
The assessment of environmental effects, including health, continues to reinforce the multiple benefits of the Montreal Protocol in reaching the SDG targets.