



## REVIEW ARTICLE / ПРЕГЛЕД ЛИТЕРАТУРЕ

# Environment and health – thirty years of successful implementation of the Montreal Protocol

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## SUMMARY

The Protocol on Ozone Depleting Substances (ODS) was signed in 1987 in Montreal. The main goal of the protocol is the international consensus and action regarding the drastic decrease of production and use of these substances, which results in increased UV radiation and consequently has a negative impact on human health and ecosystem. Besides the review of the “legal and technical” implementation of the protocol until now and the withdrawal of ODS from use, this paper specially stresses the analysis of available research results regarding the positive impact on health, in correlation with the implementation of the Montreal Protocol (MP). Due to the results of the thirty-year-long use until now, the MP is referred to as one of the most successful international agreements, not only in the field of environmental protection, but also in the field of human health protection in relation to it, within a certain context. Besides the reduced negative impact of ultraviolet radiation (UV) to the ecosystem and people, we are also facing a reduced occurring trend of skin cancer, cataracts, and immune system diseases worldwide. Without the MP and its implementation, millions of people would have died because of UV radiation and the previously mentioned diseases. The treatment costs and the pressure to the health system in all the countries worldwide would have enormously increased because of that.

**Keywords:** Montreal Protocol; ozone layer; UV radiation; health

## INTRODUCTION

Wishing to improve the quality of life by economic growth and development, the humanity constantly changes their relation towards natural, economic, and social surroundings. Lately, the conscience regarding the impact of the surroundings to the health and environment is increasing. The information on environment, and as a consequence, the impact to the living world and man (human health), as well as the society in general, represents one of the most recent heritages that resulted from democratization of the contemporary world, and that is consisted within the Aarhus Convention [1, 2].

## DAMAGE TO THE OZONE LAYER AND THE CONSEQUENCES TO THE ECOSYSTEM AND HUMAN HEALTH

Human society depends on complex relations between people and the environment [3]. The ozone layer protects the entire living system of our planet from harmful ultraviolet radiation (UV-B and UV-C) sunrays. The new scientific findings from 1970s have determined that halogenated hydrocarbons (commercially known as freons), due to their chemical features, significantly damage the ozone layer.

The Earth's ozone layer is mainly significant for the protection of life on our planet. If intact, it can prevent 97–99% of the Sun's ultraviolet

radiation (UV). Living tissues of organisms living on dry lands would be extremely damaged by the Sun's UV if the majority of rays were not absorbed by the Earth's atmosphere, and especially the ozone layer [4]. Given that the UV is considered the main cause of skin cancer, cataracts, and some immune system diseases, measuring the entire atmospheric ozone has become a daily practice [5, 6, 7].

Ozone depleting substances (ODS) and other greenhouse gasses, when emitted into the atmosphere, significantly impact the ozone layer depletion by reacting with ozone molecules (O<sub>3</sub>), as presented in Figures 1 and 2.

In comparison to pre-industrialization times, the concentration of carbon dioxide, methane, and nitrogen oxide has doubled in the atmosphere [8]. In the end of the 19th century, a long time after Svante August Arrhenius has proven the greenhouse effect, its overall consequences were covered with a veil of ignorance. Until the 1980s, the issue of the ozone layer was out of the focus of scientists and the wider public [9]. In 1985, the British scientist Joe Farman discovered the ozone “hole” over the Antarctica [10]. It was proven that, at a concentration of 80 ppb, the atmospheric ozone has an especially harmful impact on human health and the entire living world in general. This was especially stressed regarding the urban living conditions, since the diseases occurrence caused by this phenomenon is constantly increasing, thus having an impact on the general public health and

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the health system [11]. The increase in number of pollution sources has driven the attention towards the mechanisms and activities against the most common air pollutants [12].

### THE MONTREAL PROTOCOL AS THE INTERNATIONAL COMMUNITY RESPONSE

International conventions are definitely the most significant mechanisms in the fight for the environment protection, and thus preservation of human health and biodiversity [13, 14]. The International Law on the Environment and a great number of international agreements contain regulations that, in a different way and on a different level, stress the impact of the environment to human health [15, 16]. The Protocol on ODS was signed in 1987 in Montreal (after eight years of negotiations between 197 states), with the help of the United Nations Environment Programme. Since 2004, the MP has also been in motion, with all the following by-laws [17, 18].

The MP identifies the main substances that are depleting the ozone layer and adopts specific restrictions regarding their production and consumption in future, as well as the traffic of 96 different chemicals that are known to have a depleting effect on the ozone layer and that are divided into annexes A to E. Each of these annexes is divided into several groups of similar substances. Since being set in motion in 1989, hand-in-hand with the Vienna Convention for the Protection of the Ozone Layer, the MP is considered as one of the most successful agreements in the field of environment protection [19]. The measurements of the NASA's satellite instruments of the Jet Propulsion Laboratory in Pasadena, California, have shown that, for the first time, the levels of chlorine, which depletes the ozone layer, are dropping, leading to reduction of ozone depletion [20] (Figure 3).

Chlorofluorocarbons (CFC compounds) were unknown until 1930, and until recently, they were massively used in cooling devices, air-conditioning, sprays (propellants in aerosols) and in industrial facilities [21, 22]. The MP was initially dedicated only to chemicals that were identified as ozone-depleting chemicals at that moment [23]. Shortly after the adoption of the MP emerged the need for its evolution in order to have it respond to the changes in science regarding the ozone and the climate, as well as the demands of parties and industries using the ODS and their alternatives, including hydrofluorocarbon (HFC) [24, 25].

The change in the projection of future wealth, the number of habitants of certain countries and their technological agility, has led to increased demands for HFC [26]. The danger emerging from HFC has increased with the boom of air conditioning and refrigerators market within the fast-growing economies such as China and India [27]. New scientific knowledge and findings have conditioned further development and improvement of the MP, in accordance with the current global situation and trends, through five amendments to the Protocol: London (1990), Copenhagen (1992), Montreal (1997), Beijing (1999) and Kigali (2016) [28]. Until now, the Kigali Amendment was ratified by 70

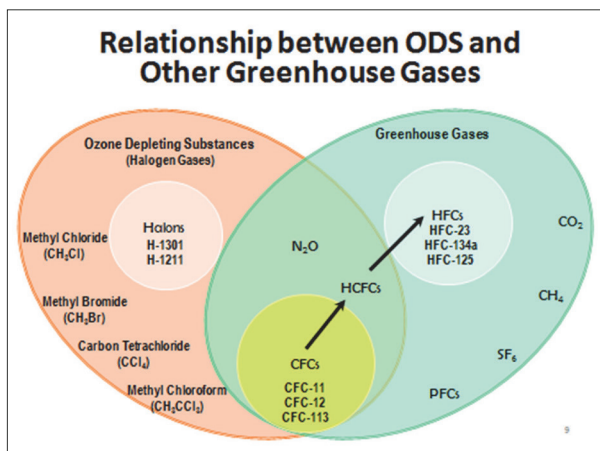


Figure 1. Relationship between the ozone depleting substances (ODS) and other greenhouse gases [6]

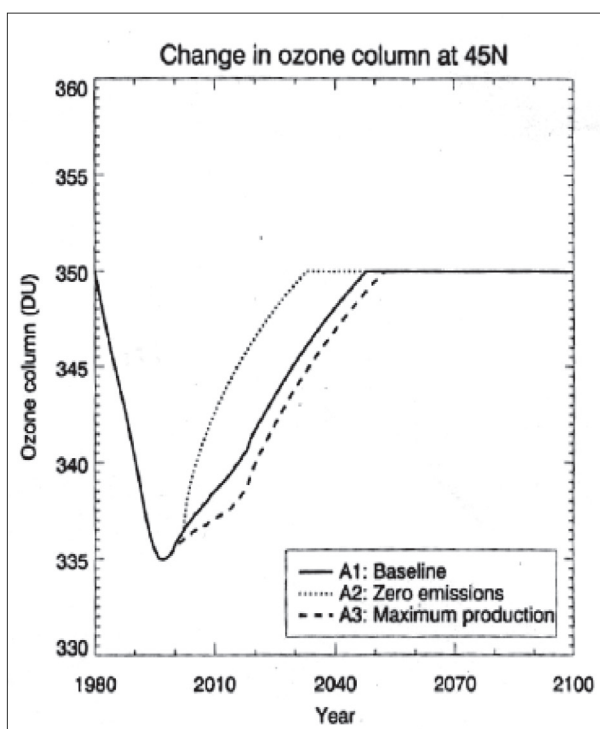


Figure 2. Change of the quantity of ozone expressed in Dobson units (DU) from 1980, with a projection for the future [7]

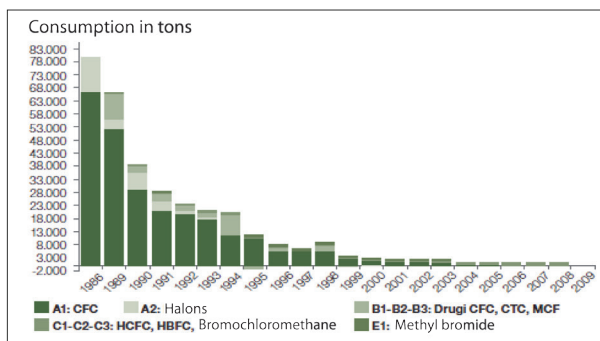


Figure 3. Reduction of ozone depleting substances in the European Union [21]

countries [29]. The countries that have ratified the Kigali Amendment have committed themselves to reduce the production and consumption of the HFC by over 80% within the following 30 years [30, 31]. With the Kigali Amendment, it was agreed that the developed countries, including European countries, should gradually reduce the use of HFC by 2035 by 15%, in comparison to the baseline values from the period of 2011–2013. The observations show that the quantity of HFC within the atmosphere is increasing [32]. Because of that, the main goal of the MP was set to be the reduction of consumption and emission of the HFC with high Global Warming Potential (GWP) by using alternatives containing low GWP.

### IMPLEMENTATION OF THE MONTREAL PROTOCOL AND THE POSITIVE EFFECTS TO HEALTH OF PEOPLE AND THE ENVIRONMENT

The MP was signed more than 30 years ago. According to the UN data and MP measures. Two million people are less likely to suffer from skin cancer annually, in comparison to the previous period, and this shall save the global economy more than two billion dollars by 2050 [33]. The increased rate of occurrence of skin cancer, cataracts, and blindness is a direct consequence of depletion of the ozone layer [9]. It is estimated that by the year of 2100, the stipulated MP measures shall have aided the prevention of 283 million skin cancer cases (including 8.3 million cases of melanoma) and 46 million cases of cataracts, as well as 1.6 million of deaths from skin cancer [28]. The Sun's UV radiation is a proven human carcinogen that causes skin melanoma. Skin cancer is nowadays the most common and the fastest developing disease [5].

Numerous epidemiological researches show that outdoor workers are exposed to a significantly greater risk from developing all types of skin cancer [34]. The results of a Romanian study showed that patients suffering from basal cell carcinoma were occupationally exposed to UV radiation [35]. In the Republic of Serbia (RS), the occurrence and number of skin cancer cases has been increasing lately, along with other forms of cancers, but also the methods for their detection are becoming increasingly successful [36, 37, 38]. The Rulebook on Determination of Occupational Diseases (Official Gazette of the Republic of Serbia, no. 105/03) determines occupational diseases and workplaces, that is, jobs during which such diseases occur, as well as the conditions under which the said disease shall be regarded as an occupational disease.

Various research has shown that UV increases the likelihood of developing certain types of cataracts. Although curable with modern eye surgery, cataracts diminish the eyesight of millions of Americans, and costs billions of dollars in medical care each year. Other kinds of eye damage include pterygium (tissue growth that can block vision), skin cancer around the eyes, and degeneration of the macula [39]. For decades, the human eye has been subjected to ambient radiation, and the full spectre of sunrays contains wavelengths of a significant damaging potential. It is hard to determine

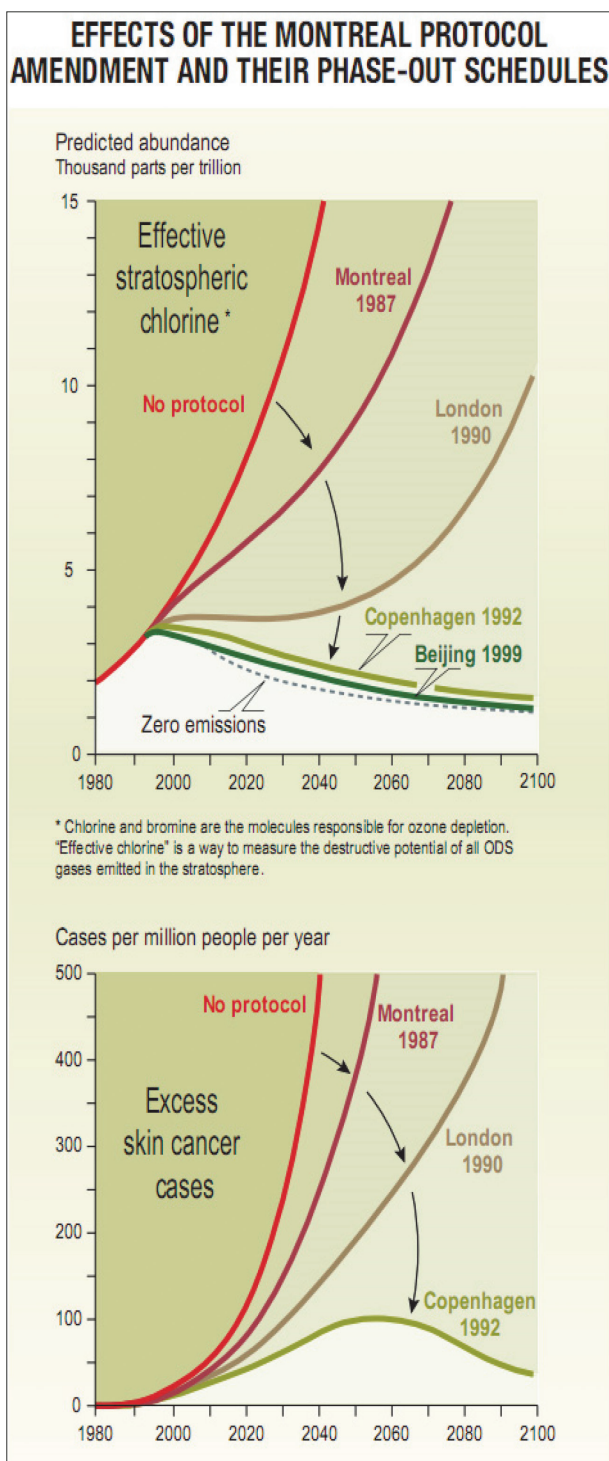


Figure 4. Effects of the Montreal Protocol Amendment [42]

the ocular dose of photodynamic damage to human lenses caused by the UV light. That is a cumulative dose of effects during a long period of exposure [40]. The most common damage to human lenses is a consequence of cumulative effect of sunlight spectrum, to which it is exposed during the lifespan [39]. About 50 million people worldwide suffer from cataracts [41]. The UV also reduces effectiveness of the immune system through the change in activities and distribution of cells responsible for initiation of immunological reactions [42]. "One American dies from skin cancer

every hour. Unprotected exposure to UV radiation is the most preventable risk factor for skin cancer” [43] (Figure 4).

In its newest report regarding the 30 years of the MP application, American EPA stated that this internationally accepted contract prevented the development of more than 45 million of cataracts cases among Americans, reduced skin cancer cases among 280 million of people and saved about 1.6 million of lives in the USA [44]. The result of that was that the healthcare fund was reduced by 4.2 trillion of dollars.

## COMMENT

The implementation of the MP (during the previous 30 years) has contributed to numerous benefits, most notably in the field of ecology, but also in the field of public health. The efforts for the protection of stratospheric ozone shall result in saving 4.2 trillion dollars in the field of social security within the US during the period 1990–2165, and thus it shall prevent an estimated 6.3 million of deaths caused by skin cancer [44].

In the RS, this refers to the widest population, and especially the vulnerable target groups, which are: the youngest age group, youth, beach and pool visitors, and outdoor workers that are exposed to UV radiation on a daily basis. This especially refers to the population category within the RS that is exposed to UV radiation due to their occupation (construction workers, farmers, etc.) or their lifestyle. It is especially important that we work on raising awareness and informing individuals and institutions in the RS regarding the overall negative impact of UV rays to health of the population, and especially those youngest [45]. Finally, this shall confirm the commitment of the RS to the implementation of the Millennium Development Goals, and shall serve as a confirmation of the commitment to the EU integration process [46].

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## CONCLUSION

Looking over the 30 years of successful implementation of the Montreal Protocol, it could be said that, without it, by 2050 the depletion of the ozone layer in the northern hemisphere would have amounted to 50% on 45 degrees, and in the northern hemisphere, it would have amounted up to 70%. The level of UV radiation on the Earth's surface would have been doubled. That would have led to an enormous increase in the number of cases of non-melanoma cancers, melanoma cancers and eye diseases – cataracts.

Failing to do as proposed by the Montreal Protocol would only postpone or even prevent the recovery of the ozone layer. Numerous factors, including ODS and climate change, shall have a significant impact on the ozone layer and thus on human health. Therefore, it is especially significant that all countries comply with the accepted regulations, since, globally speaking, every activity counts and contributes to the overall improvement of the quality of life, population health, and ecosystem.

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## Животна средина и здравље – тридесет година успешне примене Монреалског протокола

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### САЖЕТАК

Протокол о супстанцама које уништавају озонски омотач је потписан 1987. године у Монреалу. Основни циљеви протокола су међународни консензус и акција у вези са драстичним смањењем производње и коришћења ових супстанци који за резултат имају повећано УВ (ултравиолетно) зрачење и последично негативан утицај на људско здравље и екосистем. Поред прегледа досадашње „правне и техничке“ примене протокола и повлачења из употребе супстанци које уништавају озонски омотач, у раду је посебно стављен нагласак на анализу литературно доступних резултата који се односе на позитиван (тима настао) утицај на здравље становништва у корелацији са применом Монреалског протокола (МП). Због резултата досадашње

тридесетогодишње примене, МП спада у ред најуспешнијих међународних споразума у области заштите животне средине, али у одређеном контексту и са здрављем људи које је са тим у вези. Поред смањеног негативног утицаја УВ зрачења на екосистем и људе, као позитивну последицу смањења овог зрачења имамо и смањени очекивани тренд појаве обољења коже, катаракте и имуног система са овим у вези у читавом свету. Без МП и његове примене милиони људи би умрли од последица УВ и наведених обољења. Трошкови лечења и притисак на здравствене систем у свим земљама света би се еномрно повећали као резултат тога.

**Кључне речи:** Монреалски протокол; озонски омотач; УВ зрачење; здравље