

## **Review of CFC-12: Metadata on Distributed Emissions**

*A. McCulloch*

### **Emission Functions**

CFC-12 (CCl<sub>2</sub>F<sub>2</sub>, dichlorodifluoromethane) is now used primarily within refrigeration and air conditioning systems as the working fluid. Some material is released into the atmosphere when these systems are first filled but the bulk of the losses occur subsequently during maintenance, or as the result of accidental damage or when the equipment is finally removed from service and scrapped. There are other minor uses in foam blowing and historical use in aerosol propellant formulations.

As a consequence of the delay between first use and release, it is necessary to calculate emissions from time series of data on production and sales into various end-use categories having different release functions. The calculation method is described in McCulloch *et al.* (2002).

Releases from hermetic refrigeration are normally distributed about an average of 10 years, so that complete emission occurs within 20 years. The emission function for non-hermetic refrigeration is faster, with an approximately normal distribution about a 4.5 year mean and complete emission within 10 years. Due to the nature of the plastic foam matrices, half of the material used in closed cell foam is emitted in the year of manufacture and half in the following year. The emission function for Aerosols and others provides for 50% release in the year of manufacture and the rest in the year following and the corresponding value for open cell foam is 83% in the year of manufacture. Emissions do not depend on the season of the year.

### **Basic Data on Sales**

There is no single data set for global sales of any of the fluorocarbons. That compiled by industry (AFEAS, 2001) is compound specific and audited to ensure quality control, but has incomplete geographical coverage; production in China, India, Korea and Russia is not included. The data on production and consumption (the latter equating to sales) compiled by the United Nations Environment Programme to verify the application of the Montreal Protocol are neither compound specific nor audited although they do cover all parties to the Protocol (UNEP, 2002). UNEP data are reported as the aggregate total of all CFCs in ODPtonnes (Ozone Depletion Potential multiplied by metric tonnes). Submissions by individual countries are incorporated into the UNEP database with no further checks and reported values have been revised, without explanation, several years after they were first submitted.

These data sets have been amalgamated to provide global consumption values with defined quality and uncertainty and the distributed emissions described here were based on McCulloch *et al.* (1994).

## Geographical Distribution of Emissions

The calculated global emissions of CFC-12 were distributed among countries using the distribution of individual national fractions of the world total Gross Domestic Product, as described in McCulloch *et al.* (1994). Within each country, emissions were distributed to individual gridsquares using a population distribution from Harvard University (Jennifer Logan, *personal communication*).

Results are presented here as the percentage distribution among gridsquares. Absolute emission from each gridsquare in 1986 should be calculated by multiplying global emission for 1986 in [Table 1](#) (CFC12EM) by the gridsquare percentages in [Table 2](#) (CFC1286yr1.1a). For other years, the distribution in [Table 2](#) should be applied to the global emission for the appropriate year. While global emissions change relatively rapidly, distribution is affected only by relative economic activity and population dynamics, which have slower rates of change with time. It is expected that the distribution can be applied to the years 1980 to 1990 without significantly increasing uncertainty but this has not been tested. It can be applied to years beyond this range only with caution and new distributions for more recent years are under development.

## Time Series of Global Emissions

Taken from McCulloch *et al.*, 2002 (itself compiled from AFEAS, 2001 and UNEP, 2002), the time series (1930 to 2000) of CFC-12 emissions and their uncertainties is shown in [Table 1](#).

Future emissions will be governed by the controls required by the Montreal Protocol and by the quantity of material currently in the "bank" (that is: material which is in use but has not yet been emitted). A scenario for future releases of CFC-12 was described in Madronich and Velders (1999). This scenario has been updated and will be published in Fraser and Montzka (2003).

## Development

In view of the changes brought about by the Montreal Protocol, it is proposed to revise the distribution functions to provide gridded data for the year 2000.

A. University of Bristol, UK  
mailing address:  
Barrymore, Marbury Road, Comberbach, Northwich, CW9 6AU, UK  
phone/fax: +44-1606-891604  
e-mail: [archie@marbury.u-net.com](mailto:archie@marbury.u-net.com)

## Table

Year	Annual CFC-12 emission, Mg		
	Mean	+ 2 SD	- 2 SD
1930	0	0	-
1931	0	100	-
1932	0	100	-
1933	100	200	-
1934	200	400	-
1935	300	600	-
1936	500	1000	-
1937	800	1700	-
1938	1100	2200	0
1939	1700	3100	200
1940	2200	3900	500
1941	3000	5100	800
1942	3600	5900	1400
1943	4500	7200	1800
1944	6100	11000	1100
1945	7900	14600	1300
1946	13900	19100	8700
1947	21300	25800	16800
1948	24700	28100	21300
1949	26600	28900	24200
1950	29400	31700	27200
1951	32300	35000	29700
1952	33600	36400	30900

1953	37800	41700	34000
1954	42800	47500	38200
1955	48100	53900	42400
1956	56100	63500	48700
1957	63800	71800	55800
1958	66900	75400	58300
1959	74700	83300	66200
1960	89000	97400	80600
1961	100000	108400	91700
1962	115400	123600	107300
1963	135600	143600	127600
1964	157800	165600	149900
1965	177900	187200	168500
1966	199500	211000	188100
1967	225100	238300	211900
1968	252500	266500	238500
1969	281800	297200	266300
1970	307800	324800	290800
1971	331600	349800	313500
1972	362100	382500	341800
1973	401100	424500	377800
1974	435100	459400	410700
1975	423700	445400	402100
1976	413600	437900	389300
1977	401300	434300	368400
1978	376700	413300	340200

1979	375900	413500	338300
1980	379900	415400	344300
1981	394000	427000	361100
1982	403100	430200	376100
1983	417000	441300	392600
1984	439200	464100	414300
1985	449900	472900	427000
1986	460200	484200	436200
1987	463100	492900	433300
1988	451800	488100	415500
1989	418700	458100	379300
1990	367100	396300	337800
1991	336600	363700	309600
1992	319900	342800	296900
1993	300500	317900	283000
1994	277000	-	239800
1995	255500	-	187800
1996	233100	-	140300
1997	207700	-	99800
1998	182000	-	74000
1999	155200	-	53600
2000	134100	-	29300

**Table 1: Global Emissions of CFC-12 (dichlorodifluoromethane) from 1930 to 2000**

Data in Mg (millions of grams or metric tonnes), SD=Standard Deviation  
 Compiled by A. McCulloch ([archie@marbury.u-net.com](mailto:archie@marbury.u-net.com))

Based on:

McCulloch A., P.M. Midgley and P. Ashford

Releases of Refrigerant Gases (CFC-12, HCFC-22 and HFC-134a) to the Atmosphere submitted to *Atmos. Environ.*, 2002.

Production, Sales and Atmospheric Releases of Fluorocarbons through 2000, Alternative Fluorocarbons Environmental Acceptability Study, Arlington, VA, USA, 2001.

Production and Consumption of Ozone Depleting Substances, 1986-2000, Secretariat to the Montreal Protocol, United Nations Environment Programme, Nairobi, Kenya, 2002.

### **References**

AFEAS (Alternative Fluorocarbons Environmental Acceptability Study) *Production, Sales and Atmospheric Releases of Fluorocarbons through 2000*, AFEAS, Arlington, VA, USA, 2001 (see [www.afeas.org](http://www.afeas.org)).

Fraser P. and S. Montzka, Controlled Substances and Other Source Gases, Ch. 1 of *Scientific Assessment of Ozone Depletion: 2002, in preparation*, WMO, Geneva, 2003.

Madronich S. and G.J.M. Velders, Halocarbon Scenarios for the Future Ozone Layer and Related Consequences, Ch. 11 of *Scientific Assessment of Ozone Depletion: 1998, World Meteorological Organization Ozone Research and Monitoring Project Report No 44*, WMO, Geneva, 1999.

McCulloch A., P.M. Midgley and D.A. Fisher, Distribution of emissions of chlorofluorocarbons (CFCs) 11, 12, 113, 114 and 115 among reporting and non-reporting countries in 1986, *Atmos. Environ.*, 28(16), 2567-2582, 1994.

McCulloch A., P.M. Midgley and P. Ashford, Releases of Refrigerant Gases (CFC-12, HCFC-22 and HFC-134a) to the Atmosphere, *submitted to Atmospheric Environment*, 2002.

UNEP (United Nations Environment Programme), *Production and Consumption of Ozone Depleting Substances, 1986-2000*, Secretariat to the Montreal Protocol, UNEP, Nairobi, Kenya, 2002 (see [www.unep.org/ozone](http://www.unep.org/ozone)).

(last modified 02/20/05)