THE CARBON DIOXIDE INDUSTRY AND THE ENVIRONMENT

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Prepared by WG-5 Environment

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Amendments to 101/03

Section	Change
	Editorial to align style with IHC associations
3	Definitions added
4	Update for latest figures and references

NOTE Technical changes from the previous edition are underlined

1 Introduction

In recent years carbon dioxide (CO_2) has increasingly become the focus of public concern as a greenhouse gas. This publication is intended to explain the environmental aspects of carbon dioxide and its uses.

2 Scope and purpose

2.1 Scope

This publication explains the uses and applications of carbon dioxide and the environmental impact of the carbon dioxide industry.

3 Definitions

For the purpose of this publication, the following definitions apply.

3.1 Publication terminology

3.1.1 Shall

Indicates that the procedure is mandatory. It is used wherever the criterion for conformance to specific recommendations allows no deviation.

3.1.2 Should

Indicates that a procedure is recommended.

3.1.3 May

Indicates that the procedure is optional.

3.1.4 Will

Is used only to indicate the future, not a degree of requirement.

3.1.5 Can

Indicates a possibility or ability.

4 Carbon dioxide and life on earth

4.1 The carbon cycle in nature

Carbon dioxide is key to our planet's ecosystem. It is the raw material used by plants to form organic matter by photosynthesis. Respiration, the conversion of oxygen into carbon dioxide, is a further elementary process of nature to maintain life. Carbon dioxide is also a major end product of the decomposition of all organic materials after life has ceased. Even the earth's lime deposits (chalk, marble, limestone etc.) were ultimately created from carbon dioxide. They are simply the skeletons and shells of dead sea animals.

Figure 1 shows the global flow patterns and reservoirs of carbon the carbon cycle (all figures given in billion tonnes of carbon, one tonne of carbon corresponds to 3.7 tonnes of carbon dioxide).

It is estimated that only 1% to 2% of the total carbon dioxide available on the earth is contained in the atmosphere. Vast amounts of carbon dioxide are dissolved in the cold deep water of the oceans. On balance the oceans absorb more carbon dioxide than they release. Every year, approximately 11 billion tonnes of carbon dioxide is removed from the cycle by transport from the surface layers into the deep

waters. However, the ability to accept more carbon dioxide is limited due to the slow self-mixing rate of the oceans.

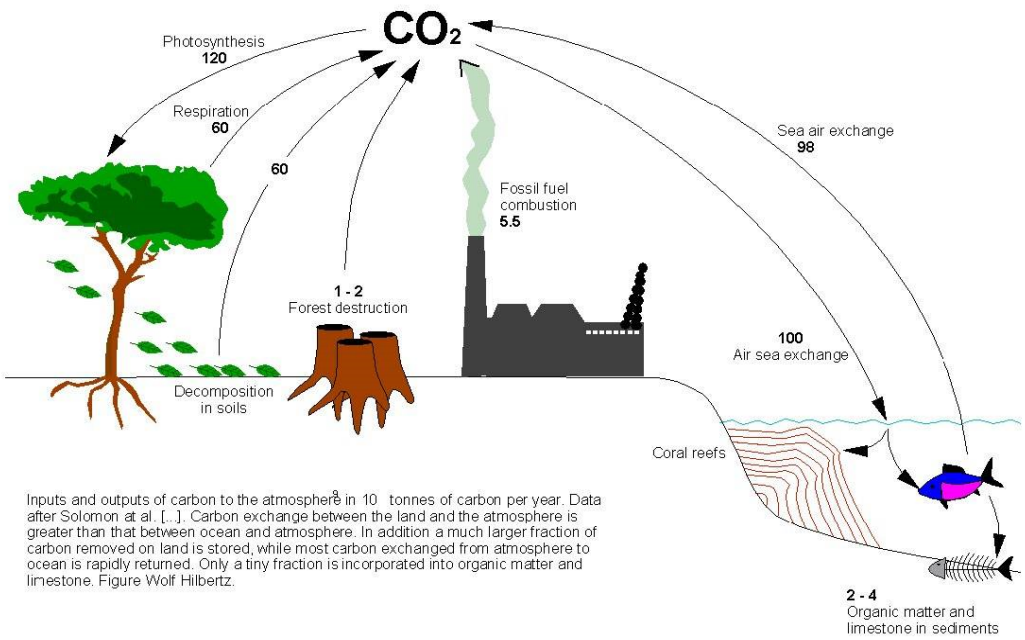
The carbon dioxide concentration in the atmosphere results from the balance between emission and consumption. Over the last century the CO_2 concentration has risen from 280 ppm to the current level of 400 ppm (1 ppm = 1 part per million by volume).

The following processes release carbon dioxide:

- respiration of humans and animals;
- decay of dead biomass (in particular due to the over-exploitation of tropical forests);
- consumption of fossil fuels;
- desorption from the oceans; and
- natural gas fields.

Carbon dioxide is consumed by:

- photosynthesis of plants (for the conversion of carbon dioxide into organic substance); and
- absorption of carbon dioxide by the oceans.



Inputs and outputs of carbon to the atmosphere in 10^9 tonnes of carbon per year. Data after Solomon at al. [...]. Carbon exchange between the land and the atmosphere is greater than that between ocean and atmosphere. In addition a much larger fraction of carbon removed on land is stored, while most carbon exchanged from atmosphere to ocean is rapidly returned. Only a tiny fraction is incorporated into organic matter and limestone. Figure Wolf Hilbertz.

Figure 1 The carbon cycle

The total carbon dioxide equivalent emissions from human activity in Europe is approximately 4.4 billion tonnes according to European Environment Agency (EEA, of which industry accounts for around 19% [1].[1]

4.2 Greenhouse effect

Carbon dioxide and water vapour together with other trace gases in the atmosphere cause the greenhouse effect. Without the natural greenhouse effect the average temperature would have been -18 °C instead of +15 °C. The greenhouse effect reduces the loss of heat through radiation from the earth surface, see Figure 2.

More information can be found in the additional references.

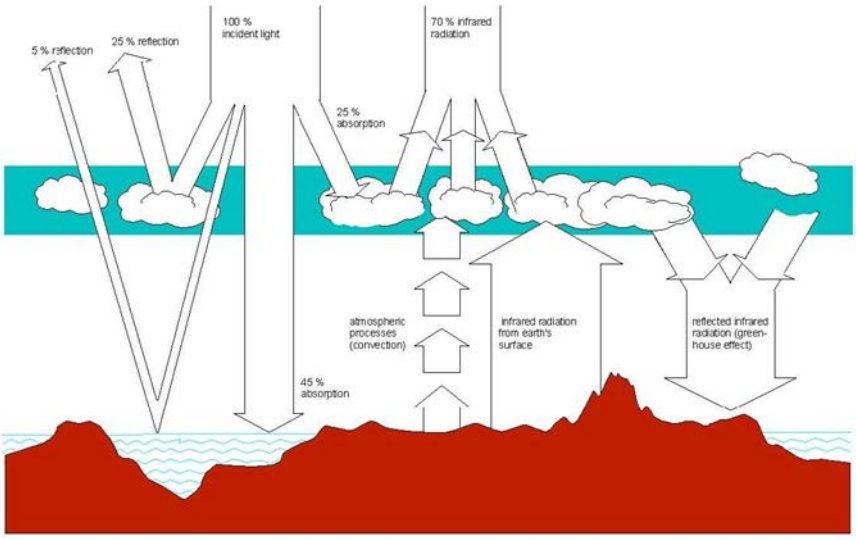


Figure 2 The greenhouse effect

4.3 Impact of mankind on the climate

There are around 40 so-called greenhouse gases, characterised by their strong absorption of infra-red radiation. The most important of these is water vapour, which is responsible for two thirds of the greenhouse effect. This is little affected by mankind's activities. The main greenhouse gases emitted as a result of human activity are carbon dioxide, methane, nitrous oxide and chlorofluorocarbons (CFCs) / Hydrofluorocarbons (HFCs).

The United Nations Intergovernmental Panel on Climate Change (IPCC), set up by the World Meteorological Organisation (WMO) and the United Nations Environment Programme (UNEP) in 1988, is tasked with reviewing the available evidence and articulating the scientific consensus on this issue. The conclusion of the latest report (2018) "*A.1. Human activities are estimated to have caused approximately 1.0 °C of global warming above pre-industrial levels, with a likely range of 0.8 °C to 1.2 °C. Global warming is likely to reach 1.5 °C between 2030 and 2052 if it continues to increase at the current rate. (high confidence)*" [2].

Overall, even if uncertainties exist (and much more research is required), the precautionary principle should be applied. Also, there are clear expectations of society as a whole regarding the issue of global warming and the industry needs to take them into account.

[1] References are shown by bracketed numbers and are listed in order of appearance in the reference section.

5 Carbon dioxide industry and the environment

5.1 Overview of the carbon dioxide industry

The unique properties of carbon dioxide are used in many applications and aspects of daily life. Carbon dioxide is naturally present in nature but most of the time diluted or mixed with other compounds. However, it is under its purified form, as a gas, a refrigerated liquid or even a solid (dry ice) that it is most useful.

Most applications require pure carbon dioxide to be supplied in varying degrees of quantity. Large amounts of carbon dioxide are already available either from natural processes (for example natural wells, biological processes or natural gas fields) or as a by-product of industrial activities mostly related to combustion or chemical reactions. If not recovered, this carbon dioxide will, in most cases, be vented to atmosphere.

Once the most appropriate source of carbon dioxide is selected based on technical (for example purity and / or quality) and economic considerations (for example location from end-market and logistics), the carbon dioxide is cleaned, purified and sometimes transformed into the most useful form to meet customer requirements. Carbon dioxide is also registered as a food additive with the registration number E-290.

The unique properties of carbon dioxide and their application will be detailed in the following sections, however it is important to put in perspective the quantity of carbon dioxide purified by the industry in Europe represents less than 0.1% of the carbon dioxide emitted from combustion.

5.2 Sources of carbon dioxide for the carbon dioxide industry

5.2.1 Chemical processes

Over 80% of the Carbon Dioxide recovered in Europe by the industrial gas industry is obtained from the waste gases from chemical processes. If not recovered, those gases are usually vented to atmosphere., The process gases from the production of ammonia, steam methane reformers and ethylene oxide are preferred for the recovery of carbon dioxide because of their high carbon dioxide concentration (over 98%). The waste gases from the chemical reaction of carbonates provide an alternative but relatively minor source of carbon dioxide.

Carbon dioxide can also be recovered from flue gases from combustion processes with additional concentration and purification systems.

5.2.2 Biological processes

The metabolism of yeast is an economical source of carbon dioxide from the production of alcohol both for human consumption and industrial purposes. The relatively high capital investment necessary for the recovery of carbon dioxide from fermentation processes limits its use to a small number of large breweries and alcohol producers.

Carbon dioxide is also released in other biological processes, such as bacterial degradation in waste dumps and sewage treatment plants. However, this carbon dioxide contains significant quantities of methane and other impurities and is therefore not suitable for industrial applications.

5.2.3 Natural sources

Geological activity has created of underground deposits of carbon dioxide. Some of these carbon dioxide deposits are also of biological origin, caused by the degradation of prehistoric life forms.

The recovery of carbon dioxide from natural deposits is limited to a few regions, such as the USA, Germany, France, Hungary and Russia where suitable geological conditions prevail. The carbon dioxide from natural deposits is normally recovered in conjunction with mineral water but can be also recovered as gas only. Most of the customer specific demands for natural sources of carbon dioxide are related to beverage type applications.

5.2.4 Recovery from natural gas

Some natural gas sources contain natural gas (methane) with a high content of carbon dioxide that can be recovered. The amounts of carbon dioxide, and of critical impurities, are the deciding factor whether a natural gas source may be used for this purpose or not. These sources are common in Asia.

5.2.5 Combustion of oil and gas

In areas where sources of recovered carbon dioxide are outside economical range, oil and gas can be burned with the only purpose to produce carbon dioxide. Special recovery units are provided for this purpose. Combustion is a non-preferred method to generate CO_2 as it adds to man-made emissions of greenhouse gases.

5.3 Applications

The properties of carbon dioxide, such as its inertness and its high degree of solubility in water, make carbon dioxide the ideal gas in many applications in our everyday life. Carbon dioxide (CO_2) is a colourless, non-flammable gas, of neutral odour and flavour. When added to water carbon dioxide forms carbonic acid (H_2CO_3). The name carbonic acid is often inaccurately used as a synonym for carbon dioxide.

In liquid and solid cryogenic form, carbon dioxide is used as a refrigerant down to a temperature of –78 °C.

5.3.1 Environmental protection and safety engineering

5.3.1.1 Water treatment

Alkaline wastewater (for example from dairies, tanneries, beverage producers or from the production of detergent or cement) impairs or prevents the clarification processes in biological sewage treatment. This wastewater can be neutralised by injection of carbon dioxide (substituting mineral acids). The pH value in swimming pools can also be regulated using carbon dioxide. A minimum carbon dioxide content is also essential for potable water. As a mild acid, carbon dioxide in this case can replace stronger and more dangerous acids such as sulphuric acid.

5.3.1.2 Safety engineering

Carbon dioxide can be used as an inerting gas. Carbon dioxide can be used in the storage and use of flammable liquids or dusts to prevent fires and explosions that may be caused by sparks, heat or other ignition sources. Carbon dioxide is used to reduce the oxygen concentration below the flammable or explosive limit. As carbon dioxide is more dense than air, it can be particularly suitable for the blanketing of hazardous materials. Carbon dioxide gas should be used (vaporised from liquid), rather than using carbon dioxide generated directly, for example from liquid cylinders, where dry ice (solid CO_2) is created due to the risk of static generation from the solid particles. See Safety News Letter 76 *The risk of generating static electricity from the use of Carbon Dioxide as an inerting agent* for more information [3]. Carbon dioxide is a well-proven fire-fighting agent in sprinkler systems (used as a substitute for halocarbons).

5.3.2 Food industry and agriculture

5.3.2.1 Protective gas application

Foodstuffs keep longer if they do not come into contact with fresh air. Food producers may strive to exclude atmospheric oxygen from the first processing stage until the products reach the customer. Carbon dioxide can be used to protect products during processing stages, such as grinding, mixing and conveying.

Foodstuffs can also be packaged under protective gases using carbon dioxide commonly as part of a mixture in order to prevent deterioration. The protective gas replaces atmospheric oxygen and inhibits the growth and multiplication of certain bacteria and fungi.

5.3.2.2 Freezing and cooling

Carbon dioxide can be used in liquid and solid form for freezing and cooling of many types of foodstuffs. The protection from the atmospheric oxygen, in conjunction with the rapid freezing, preserves the natural colour, flavour and aroma of the product.

5.3.2.3 High pressure extraction

High pressure carbon dioxide is an excellent solvent for the extraction of biologically active substances from natural products, such as aromatic essences and flavourings from spices. Applications can be found in pharmaceutical, cosmetic and food industries. It can also be used to remove unwanted components from products as well, for example to decaffeinate coffee. There are a wide range of potential applications. In addition, unlike many traditional organic solvents, carbon dioxide is less harmful physiologically.

5.3.2.4 Carbon dioxide fertilisation

The growth of plants in greenhouses is promoted by increasing the concentration of carbon dioxide or by irrigation with carbon dioxide enriched water. The ideal carbon dioxide concentration depends on the vegetables or flowers being cultivated but is usually between 0.06% and 0.12% by volume in the atmosphere. Carbon dioxide is used in many greenhouses to allow better growth of the plant, although only around 1% of the carbon dioxide is absorbed by the plants.

5.3.2.5 Beverage applications

Carbon dioxide can be added to beverages to create the bubbling / sparkling effect of fizzy drinks.

5.3.3 Materials processing

5.3.3.1 Shield arc welding

Pure carbon dioxide, mixtures of argon / carbon dioxide or argon / carbon dioxide / oxygen are used for Metal Active Gas welding (MAG) of steel. The exact composition depends on the particular application. The shielding gas protects the molten weld pool from atmospheric oxygen and can also cause particular metallurgical effects.

5.3.3.2 Laser cutting

Laser cutting using carbon dioxide as the optically active medium permits precise cutting of sheet steel and plastics as carbon dioxide molecules emit a highly focussed infrared beam after electrical excitation.

5.3.3.3 Blow moulding plastic containers

Plastic containers (bottles, cans, pots, canisters, etc.) can be manufactured by blow moulding where a plastic tube is expanded within a heated mould. The mould is then cooled and opened once the plastic has solidified. Cooling the interior with carbon dioxide can accelerate this process. In addition to the faster cooling, carbon dioxide maintains the quality of the plastic used and reduces internal stresses within the product.

5.3.3.4 Calibration mixtures

Carbon dioxide is used as a ‘matrix’ for gas mixtures and as a calibration gas.

5.3.3.5 Medical application

Carbon dioxide is used for cryosurgery, insufflation, laparoscopy and as a respiratory stimulant in medical applications.

5.4 Summary

Carbon dioxide sold by the industry is recovered from existing sources that would otherwise would have been released to atmosphere (with the exception of combustion). Furthermore, the total volumes traded by the carbon dioxide industry are very small compared to the amount of carbon dioxide emitted globally.

Many of the applications of carbon dioxide in our day-to-day life have very positive effects and can have environmental benefits against other alternatives.

This does not mean that the carbon dioxide industry is continuing “business as usual”. Many of the demands for necessary measures make sense, responsible care for nature calls for common sense and for proportional action. The carbon dioxide industry is willing to contribute to the efforts. Most of the progress for the industry can be related to efficient use of energy (which releases carbon dioxide when produced), optimisation of transportation by road and development of best practices to limit unnecessary release of carbon dioxide to the atmosphere during handling operations. It should still be reminded that this would ultimately concern only a tiny fraction of the quantity released by road traffic, the power generating industry and every individual’s energy consumption.

6 References

Unless otherwise specified, the latest edition shall apply.

[1] European Environment Agency, *Data and Maps*, https://www.eea.europa.eu/data-and-maps/indicators/greenhouse-gas-emission-trends-6/assessment-3.

[2] The Intergovernmental Panel on Climate Change, *Global warming of 1.5 °C,* https://www.ipcc.ch/sr15/chapter/spm/.

[3] EIGA Safety News Letter 76, *The risk of generating static electricity from the use of Carbon Dioxide as an inerting agent,* www.eiga.eu.

7 Additional references

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