Selection and safe use of alternatives to CTC

Activated Carbon Testing

gtz PROKLIMA

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On behalf of
FFEM

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Disclaimer

Though all care has been taken while researching and compiling the contents provided in this booklet, GTZ Proklima accepts no liability for its correctness.

The reader is advised to confirm specifications and health hazards prior to purchase or use of any substance profiled. No claim is made here in respect of the suitability of any solvent as substitute for CTC in any application. Suitability of a product for a particular application requires to be verified through trials prior to any larger-scale application with due consideration of health and safety aspects.

Information provided here does not constitute an endorsement or recommendation of any brand or product by GTZ Proklima.

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1 The Phase-out of CTC

1.1 About CTC

Carbon tetrachloride (CTC) is a solvent and cleaning agent used widely across many industry segments. Its high solvency power, low cost and the fact that it is non-flammable made it popular in many cleaning applications.

Although CTC is very popular, it is an ozone depleting substance (ODS) like chlorofluorocarbons (CFCs). It destroys the stratospheric ozone layer which protects life on our planet from harmful ultraviolet-B (UV-B) rays. It increases the incidence of skin cancer, eye cataract, suppresses the human immune system, reduces crop yields and affects aquatic life. Another adverse impact of CTC is its contribution to global warming. The global warming potential (GWP) of CTC is about 1,400 times higher than that of carbon dioxide (CO_2), the primary greenhouse gas.

At the workplace CTC is an occupational health hazard. CTC is very toxic and is absorbed by the skin and also in the gastrointestinal and respiratory systems. CTC affects the central nervous system (CNS) severely, causing headache, weakness, drowsiness, nausea and vomiting. Inhalation of high levels can permanently damage the liver and kidneys. The severity of the effects depends on the route and frequency of exposure. CTC is proven to cause cancer in animals and is a suspected human carcinogen.

1.2 The Montreal Protocol

To protect the ozone layer, India, along with more than 190 countries has signed the Montreal Protocol to phase out production and consumption of CTC and other ozone depleting substances. Under this agreement India has committed to phase-out the use of CTC as a solvent completely by 31st December 2009.

As the phase-out is progressing, CTC supplies in the market are dwindling rapidly. Beyond 31st December 2009 CTC will not be

available for solvent uses. Given the reduction of supply, the price of CTC has risen substantially making it costlier today than most of its alternatives.

1.3 Role of GTZ-Proklima

For enterprises there is an urgent need to substitute CTC now. But finding suitable alternatives, especially safer ones, is not an easy task. There is no single alternative which can replace CTC in all its applications and in the absence of sufficient information enterprises may substitute CTC with an even more hazardous substance such as Trichloroethylene or Benzene.

Within the framework of the Multilateral Fund of the Montreal Protocol, the Governments of Germany and France have mandated GTZ-Proklima to provide technical assistance to CTC consuming industries in the Indian textiles and metal cleaning sectors. In addition World Bank, UNIDO and UNDP (on behalf of the Government of Japan) are assisting the country in specific industry sectors with large usage of CTC. These activities are coordinated under the National CTC Phase-out Plan by the World Bank as the lead implementing agency and the Ozone Cell of the Ministry of Environment and Forests, Government of India.

GTZ-Proklima offers technical assistance to industries using up to 10 metric tons or 6,250 litres of CTC per year. In close interaction with affected industries, GTZ-Proklima aims to provide competent guidance in identifying CTC substitutes by addressing environmental, health and safety concerns without compromising on quality and cost effectiveness.

GTZ-Proklima maintains strict independence from any branded or proprietary product.

2 CTC in Activated Carbon Testing

Activated Carbon (AC) is produced by a controlled oxidation process to develop a porous carbon structure, generally characterized by a very large specific surface area (of the order of hundreds of square meters per gram).The specified structure of carbon gives it a very large surface area which allows the carbon to adsorb a wide range of compounds. Activated carbon has the highest volume of adsorbing porosity of any material available to mankind.

Carbon is said to be activated when its superficial structure is modified by appropriate treatment (with heat, chemicals, etc.) in order to make it suitable for certain purposes, such as decolorizing, gas or moisture adsorption, catalysis, ion-exchange or filtering.

2.1 Types of Activated Carbon

There are three different types of activated carbon. Based on the application a specific type of activated carbon is used:

- Powdered Activated Carbon- Used for taste and odour removal
- Granular Activated Carbon- Used for liquid and gas phase application
- Pellet Activated Carbon- Used mainly for gas phase application

Picture 1 : **Powdered**

Picture 2 : **Granular**

Picture 3 : **Pellet**

2.2 Activated Carbon Testing Methods

To measure the effectiveness of the AC based on its application the following chemical test methods are adopted.

Table 1:
Test methods

Sl. No.	Test method	Application
1	Iodine number	Water and liquid adsorption
2	Methylene blue number	Dye adsorption
3	Phenol number	Water treatment (drinking water)
4	Benzene adsorption	Vapour and gas (not in use due to its carcinogenic nature)
5	Carbon tetrachloride activity	Gas phase adsorption

Tests methods such as Iodine Number, Methylene Blue Number and Phenol Number are generally carried out to characterize the AC used for the purpose of liquid phase adsorption. The Benzene adsorption test gives the indication of the pore structure of the activated carbon. However the use of Benzene is strongly discouraged because of the inherent cancer risk. The pore volume of the AC is determined by CTC activity. It is also used for quality control and grading of granular activated carbon.

3 Selecting Alternatives To CTC

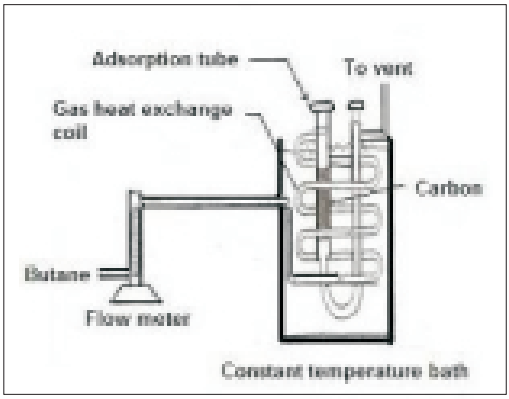
3.1 Selection Criteria

No alternative is ideal in all regards and each one has certain advantages and disadvantages. In order to identify a cost and performance effective substitute for CTC without affecting the environment and health, the substitute should meet the following criteria:

- Non-ozone-depleting substance (non-ODS)
- Non-carcinogenic
- Low toxicity
- Cost effective
- Easy to use
- Locally available

3.2 Alternative TO CTC

Butane Activity test is the only internationally accepted test method for measuring the porosity of the activated carbon.



Picture 4: **Apparatus for Butane activity test**

The butane activity is the ability of the activated carbon to adsorb butane from a mixture of dry air and butane under specific conditions. The mass of Butane absorbed at saturation is noted and calculated as mass of Butane per unit mass of carbon. The detailed test procedure and the specifications of the experimental set up are provided in ASTM standard - D 5742-95 (American Society for Testing and Materials). Once the Butane activity value of the activated carbon is known its CTC activity can also be calculated by using the following correlation:

CTC Activity Number = 2.57 x Butane Activity

Butane is also known as n-butane and is available in liquefied form. It is normally sold in cans and cylinders of various capacities. Since butane is extremely flammable and can cause an accidental fire or explosion it should be handled with extreme caution. The properties of butane are given in the table-2. Please refer to health and safety section of this booklet for more information on storage and handling of butane.

Table 2 :

Properties of n-Butane

Sl. No	Alternatives to CTC
CAS number:	106-97-8
Flash point:	-60°C
Boiling point:	-0.5°C
Specific gravity:	0.579 g/cm3
Vapour pressure:	30 psia @20°C

4 Health and Safety

4.1 Hazard potential of alternatives

Most chemicals are toxic but the degree of hazard varies from one substance to another. Any chemical can be a potential hazard for health and safety. Understanding the properties and risks of alternatives is thus essential for taking informed decisions.

At the workplace the intake of chemicals occurs mainly through inhalation and skin contact. Another major risk on the shop floor level is flammability. While these hazards affect directly and immediately the workplace the environmental hazards like contamination of air and ground water are rather indirect effects not only at the workplace but also on a global scale. Thus this guide rates the hazard of each solvent on these four factors.

Each hazard has been further classified into six grades and each grade is characterized through a corresponding colour shade. The least risk is marked in green, followed by shades of yellow and orange. Red represents the most severe risk.

Table 3:
Hazard Rating

Group	Risk	Inhalation	Skin	Environment	Flammability
E	high	Severely Toxic	Severely Toxic	Very hazardous	Extremly flammable
D		Very toxic	Very toxic		Highly flammable
C		Toxic	Toxic		Flammable
B		Harmful	Harmful	Hazardous	Combustible
A		Irritant	Irritant		Possibly combustible
-	low	none	none	not classified	Non-flammable

Table 4 shows the hazard ratings of n-Butane and CTC for comparison.

Table 4:
Hazard Ratings of n-Butane

Substance	Inhalation	Skin	Environment	Flammability
n-Butane	A	–	—	E
For comparison				
CTC	D	C	E	–

The following section introduces measures to safeguard health and safety while using hazardous solvents.a

4.2 Risk control measures

Butane Activity test should be carried out in a manner that provides the maximum safety required for all personnel performing the operation and the surrounding personnel too. This is mandatory due to the flammability of butane combined with the nature of testing equipment, operations and work conditions involved in activated carbon manufacturing and testing.

4.3 Storage and handling

Though CTC had many adverse health effects it was safe to use because of its non flammability. Proper care should be taken while handling and storage of butane since it is extremely flammable. Butane is classified as a FLAMMABLE substance like LPG, hence all local regulations applicable to storage and handling of flammable gases should be followed. This section deals with safe storage and handling of butane.

- Butane should be stored in a well ventilated area. While dilution by air may be sufficient in most cases, exhaust ventilation may be required. In such cases use spark and fire proof tools and equipments.
- Butane can be stored in liquid form under its vapor pressure at ambient temperatures. It is highly flammable at normal temperatures and pressures.

- Butane container should not be subjected to temperature higher than 52oC. Container may rupture due to heat.
- Minimum safe conditions of storage include dry, cool, secure storage away from heat, sources of ignition.
- Smoking should be prohibited in the storage area.
- Store separately from oxidant gases, chlorine dioxide and nitric acid.
- Keep containers closed and upright when not in use.
- Mark or label "Empty cylinder" and store empty cylinders away from full cylinders.
- Cylinder should be handled carefully and not allowed to fall upon one another, or subjected to undue shock
- Cylinder should be protected from any physical damage.
- Always close the valves and replace safety plugs when the cylinder is empty or not in use.
- Do not heat cylinder by any means to increase the discharge rate of gas from the cylinder.
- Never carry a butane cylinder in an enclosed space such as a car trunk, van or station wagon.
- Ensure users and operators understand the flammability and potential explosive hazards associated with the storage and handling of butane.

Spills and Disposal

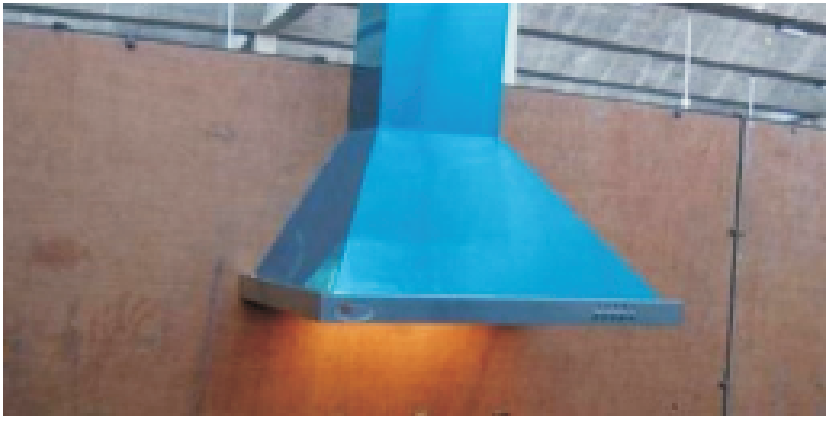
- Butane having very low flash point any spillage or leak may result into a severe fire and/or explosion hazard.
- In case of spill first cut off source of leak. If the release is large, immediately remove all ignition sources and evacuate all non-essential personnel from the area.

- If spillage has occurred in a confined space, ensure that adequate ventilation is there and check for a safe, breathable atmosphere before entering.
- Butane if spilt on clothing may give rise to delayed evaporation and subsequent fire hazard.
- Do not enter a vapor cloud except for rescue. If entering the vapor cloud self-contained breathing apparatus must be worn.
- Vapour may collect in any confined space.
- If the incident is significant seek immediate assistance from local fire authorities.

Disposal: If possible allow to evaporate. Large volumes should be removed by tanker or by controlled burning. Local supplier or fire brigade should be contacted for further advice on disposal.

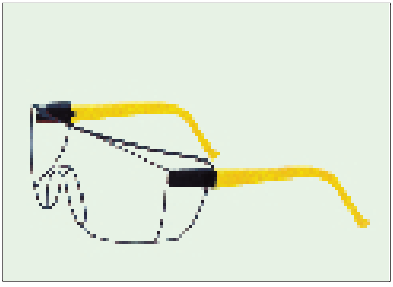
4.4 Checklist

- Butane activity test should be performed in fuming hood or provision should be made to vent off the discharge gas coming out from the sample tubes to a safe environment.
- Consult an MSDS: Demand a material safety data sheet (MSDS) of the solvent from the retailer. Study specifically the sections on health risks, fire risks and first aid.
- Ensure good ventilation: Area where butane activity is being performed should be adequately ventilated. The discharge from the test apparatus should not be directed towards any source of heat and ignition. In the absence of proper ventilation, consider the installation of local exhaust systems (LES). LESs capture the vapour before they disperse into the air of the workplace. Such systems consist of a hood, a duct and an exhaust fan. LESs cannot be bought off the shelf and they have to be sized by experts to meet the specific requirements.

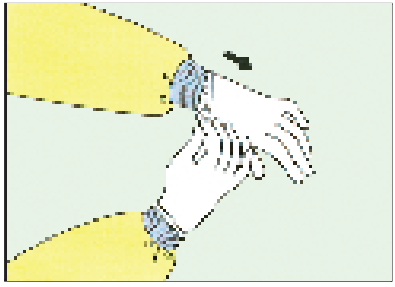


Picture 5: **Local exhaust system**

- **Wear goggles:** While connecting the butane cylinder to the system it may result in splashing of liquid therefore goggles are required for eye protection.



Picture 6: **Safety goggles**



Picture 7: **Protective gloves**

- Wear gloves: Skin contact with butane can occur during handling of cylinders/containers which can cause cold burns. Gloves can protect the skin adequately. Care should be taken in selecting gloves and other protective clothing. Insulated neoprene or impervious oil and cold resistant rubber gloves should be used while handling butane.

4.5 Fire Safety

In case of fire, vacate the area and immediately alert the fire brigade. Ensure that an escape path is always available from any fire. If gas has ignited, do not attempt to extinguish it but if safe to do so, stop gas flow and allow it to burn out. Increase ventilation to prevent a buildup of a flammable/explosive atmosphere. It should be noted that Butane is heavier than air, and thus vapours will tend to flow downwards and accumulate in low-lying areas such as drains and pits at ground level. Use water spray to cool heat-exposed containers, and to protect surrounding areas. As vapours may travel or be moved by air currents it is important to keep ignition sources like sparks, heaters, electrical equipment, static discharges away from the handling point. Fire fighting, personnel safety and first aid equipment should always be available in case of emergencies. And make sure that the personnel are trained in the use of these equipments.

Type of fire extinguishers: Water spray or BC fire extinguisher.

Procedures: Use water to disperse un-ignited gas or vapour. Allow to burn out if possible.

Fire extinguishers with CO2's are designed for Class B and C (Flammable Liquids and Electrical Sources) fires only!

Picture 8: **Carbon Dioxide Fire Extinguishers**

In accordance with regulations and manufacturers' recommendations, CO2 extinguishers should undergo hydrostatic testing and recharge every 5 years.

5 Glossary

This glossary defines terms you are likely to encounter in material safety data sheets (MSDS)

Acute effect: The effect caused by a single short term exposure to a high amount of concentration of a substance.

Aerosols: Liquid droplets or solid particles dispersed in air that are of fine enough particle size (0.01 to 100 microns) to remain dispersed for a period of time.

Alkali: Any of a class of substances that liberates hydroxide ions in and have a pH of more than 7. Strong alkalis in solution are corrosive to the skin and mucous membranes. They are also called bases and may cause severe burns.

Anhydrous: Does not contain water (e.g. anhydrous lime)

Asphyxiation: A condition whereby oxygen in the air is replaced by an inert gas such as nitrogen, carbon dioxide, ethane, hydrogen or helium to a level where it cannot sustain life. Normal air contains 21 percent of oxygen. If this concentration falls below about 17 percent, the human body tissue will be deprived of supply of oxygen, causing dizziness, nausea and loss of coordination. This type of situation may occur in confined work places.

Auto-ignition temperature: The minimum temperature at which a material ignites without application or a flame.

BC fire extinguisher: This is the regular type of dry chemical extinguisher. It is filled with sodium bicarbonate or potassium bicarbonate. The BC variety leaves a mildly corrosive residue which must be cleaned immediately to prevent any damage to materials.

Boiling point: The temperature at which liquid changes to a vapour state at a given pressure (usually 760 mm of Hg or one atmosphere).

Caustic: The ability of an alkali to cause burns.

Chronic (health) effect: An adverse effect on a human body with symptoms developing slowly over a long period of time.

Chronic toxicity: A chronic effect resulting from repeated doses of or exposure to a substance over a relatively prolonged period of time.

Confined space: Any area that has limited openings for entry or exit that would make escape difficult in an emergency, has a lack of ventilation, contains known and potential hazard, and is not normally intended or designed for continuous human occupancy (e.g. a storage tank, manhole of collection conveyances systems in effluent treatment plants).

Dielectric constant: The dielectric constant of a solvent is a relative measure of its polarity.

Explosion proof-equipment: Apparatus or device enclosed in a case capable of withstanding an explosion of specified gas or vapour and preventing the ignition of specified gas or vapour surrounding the enclosure by sparks, flash or explosion and operating at an external temperature so that surrounding flammable atmosphere will not be ignited.

Flammable: A flammable liquid is defined as a liquid with a flash point between 21 and 55 degrees Celsius. It may catch fire on contact with a source of ignition.

Flammable/explosion limits: Flammable / explosion limits produce a minimum and a maximum concentration of gases/ vapours/fumes in air that will support combustion. The lowest concentration is known as the lower flammable/explosion limit (LEL), the highest concentration is known as upper flammable/explosion limit (UFL).

Flash point: Minimum temperature at which, under specific conditions, a liquid gives off sufficient flammable gas/ vapour to produce a flash on contact with a source of ignition.

General exhaust/ventilation: A system for exhausting or replacing air containing contaminants from a general work area.

Hansen Solubility Parameter: A numerical value that indicates the relative solvency behaviour of a specific solvent. This number is calculated (based on volume percentage) from the properties dispersion, polarity and hydrogen bonding of the solvent. Hansen solubility parameter is available for every solvent, any liquid or polymer.

Hazard: A potential to cause danger to life, health, property or the environment.

IDLH – Immediate danger to life and health: The maximum concentration from which one could escape with in 30 minutes without any escape-impairing symptoms or irreversible health effects. Usually used to describe a condition where self contained breathing apparatus (SCBA) must be used

Incompatible: Condition of materials that could cause dangerous reactions from direct contact with one another. Particularly relevant when storing different substances in the same place.

Local exhaust: A system or device for capturing and exhausting contaminants from the air at the point where the contaminants are produced. (e.g. dust in shaving and buffing)

MSDS (Material safety data sheet): Consolidated information on specific identity of hazardous chemical substances, also including information on health effects, first medical aid, chemical and physical properties, emergency measures etc.

OEL, Occupational exposure limit: An exposure level established by a regulatory authority (e.g. OSHA, NIOSH).

Poisoning: Normally the human body is able to cope with a variety of substances within certain limits. Poisoning occurs when these limits are exceeded and the body is unable to deal with a substance (by digestion, absorption or excretion)

Risk: The measured probability of an event to cause danger to life, health, property or the environment.

TLV, Threshold limit value: A concentration threshold in the atmosphere which is set specially for each pollutant. It refers to the limit accepted in the atmosphere of working area.

TLV-STEL, TLV short term exposure limit: Concentration threshold in an atmosphere contaminated with a specific type of pollutant for a 15 minute exposure (if not otherwise specified)

TLV-TWA, TLV time weighted average: Concentration threshold in an atmosphere contaminated with a specific type of pollutant, usually for a continuous eight hour exposure

Toxicity: The inherent potential of a chemical substance to cause poisoning.

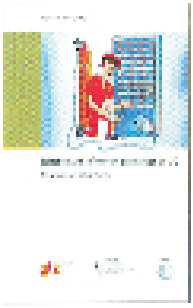
6 Other project publications

Meeting the Challenge provides essential information on the National CTC Phase-out Plan and industry sectors most affected by it. The publication elaborates on 'applications' across sectors affected by the phase-out of CTC and also GTZ-Proklima's mandate, approach and technical assistance to affected industries.

Languages: English, Hindi, Gujarati, Kannada and Malayalam

Solvent Alternatives is a compilation of technical information on a variety of CTC alternatives that are in use in industry across different sectors and applications. The advisory elaborates on the use and potential risks involved therein, with regard to profiled substances.

Language : English



Industry specific guidelines for the substitution of CTC in specific sectors are available. These guidelines inform of alternatives to CTC and their safe use.

Language: English

All publications are available for free download at our website
www.ctc-phaseout.org

Notes

Notes

Ozone Cell, Ministry of Environment and Forests, Government of India, is the central agency coordinating the phase-out of CTC. The cell has established the regulatory framework and national phase-out plan. It ensures that domestic CTC production and import progressively decrease in compliance with national targets.

gtz PROKLIMA

The Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH is an international cooperation enterprise for sustainable development with worldwide operations. GTZ-Proklima is a sectoral program which implements bilateral and multilateral projects in order to assist partner countries in fulfilling their obligations under the Montreal Protocol. With more than 130 projects, GTZ-Proklima is the largest bilateral partner of the Multilateral Fund of the Montreal Protocol. GTZ-Proklima, on behalf of the Government of Germany and under the overall coordination of Ozone Cell, Ministry of Environment and Forests, provides support to Indian industries for smooth transition to a CTC-free world. In the current project GTZ-Proklima holds an additional mandate on behalf of the Government of France which provides financial support through its French Global Environment Facility (FFEM). GTZ-Proklima does not promote any particular product or brand but provides technical assistance to CTC consuming industries.

On behalf of
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On behalf of

National CTC Phase-out Plan

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