BENZENE

E. U. Classification:

F: Readily flammable

T: Toxic

UN N°: 1114

MARPOL classification: C until 31/12/2006
Y from 01/01/2007

SEBC classification: E (Evaporator)

ATOFINA TOTAL Cedre

CHEMICAL RESPONSE GUIDE

BENZENE

PRACTICAL GUIDE

INFORMATION

DECISION-MAKING

RESPONSE

This document was drafted by the Centre de Documentation, de Recherche et d'Expérimentations sur les Pollutions Accidentelles des Eaux (*Cedre*) with financial support from ATOFINA, TOTAL and technical assistance from ASA (Applied Science Associates, Inc USA) and the Technical Committee of ATOFINA.

Published: November 2004

Purpose of this guide

As part of the research funded by the French Navy, TOTAL and ATOFINA, *Cedre* has published a series of response guides intended to mitigate chemical hazards. They can be used to assist in an emergency response, an accident or an incident involving a vessel or a barge carrying hazardous substances likely to pollute the water surface and the water column. These guides are updates of the 61 "mini response guides" published by *Cedre* at the beginning of the 90s and are intended to afford rapid access to vital information, in addition to providing relevant bibliographical sources to retrieve extra information. They also contain the results of scenarios relating to accidents having occurred in the Channel, the Mediterranean and in rivers. These scenarios are only intended to provide response authorities with the emergency information they need. Each accident has to be viewed on it's own merits and the response authorities will not be able to forego on in-situ measures (air, water, sediment and marine fauna) in order to determine exclusion areas. The guides are intended primarily for specialists who know which techniques to use in the event of an emergency in addition to the relevant operational response measures. Even though our main concern is to mitigate the consequences of an oil spill, we cannot afford to overlook responder safety and human toxicology.

To contact the duty engineer at Cedre (7/24)
Please call: 33 (0)2 98 33 10 10

National toxicology surveillance system in the event of a major toxicological threat

A hotline is manned 7/24 by Division 7 of the General Department of Health (SD7/DGS).

During opening hours please call :
Tel.: 01 40 56 47 95
Fax: 01 40 56 50 56

Outside normal working hours please call the Prefecture or other relevant authority

Poison control Centres in France

Angers (Centre Hospitalier d'Angers) Tel.: 02 41 48 21 21
Bordeaux (Hôpital Pellegrin-Tripode) Tel.: 05 56 96 40 80
Grenoble (Hôpital Albert Michallon) Tel.: 04 76 76 56 46
Lille (Centre Hospitalier Régional Universitaire) Tel.: 08 25 81 28 22
Lyon (Hôpital Edouard Herriot) Tel.: 04 72 11 69 11
Marseille (Hôpital Salvator) Tel.: 04 91 75 25 25
Nancy (Hôpital Central) Tel.: 03 83 32 36 36
Paris (Hôpital Fernand Widal) Tel.: 01 40 05 48 48
Reims (Hôpital Maison Blanche) Tel.: 03 26 78 48 21
Rennes (Hôpital de Pontchaillou) Tel.: 02 99 59 22 22
Rouen (Hôpital Charles Nicolle) Tel.: 02 35 88 44 00
Strasbourg (Hôpitaux Universitaires) Tel.: 03 88 37 37 37
Toulouse (Hôpital de Purpan) Tel.: 05 61 77 74 47

Table of contents

What you need to know about benzene

A

Definition

Benzene is a colourless, readily flammable liquid, (flash point: -11.1°C) that burns and produces toxic carbon oxide vapours. Benzene is volatile (vapour pressure: 10 kPa at 20°C) with a boiling point of about 80.1°C. Benzene vapours can explode.

Uses

Benzene is mainly used for producing ethyl benzene which in turn is used for synthesizing styrene which is used to manufacture plastics and elastomeres. It is also used for manufacturing:

- cumene, used to produce phenol that is used to manufacture phenol resins and nylon
- acetone, used as a solvent or used in the pharmaceutical industry
- cyclohexane, which is used for manufacturing resins
- nitrobenzene, which is used for manufacturing aniline
- maleic anhydride
- chlorobenzene.

Benzene is a petroleum by-product and is therefore to be found in petrol.

Risks

- Toxicity: benzene is carcinogenic for human beings. It is also toxic regardless of how it enters the human organism. It is an irritant for eyes and the respiratory tract.
  When present in high concentrations, benzene vapours have an anaesthetic effect and can act on the central nervous system.
- Fire: when approaching a disabled vessel, responders must always proceed downwind and be wearing positive pressure SCBAs and carrying gas detectors.

Behaviour in the environment

When spilled in water, benzene will float (density: 0.88), form a slick on the surface, a small part of which will solubilise. The slick will evaporate quickly and at variable rates depending on wind speed. Benzene vapours are heavier than air and will tend to move very low over the water surface.
Benzene accumulation in aquatic organisms is slight.

First line emergency data

B

First aid information (ICSC, 1993 ; FDS* TOTAL , 2002)

Remove immediately all soiled or spotted clothes

Poisoning by inhaling

Anaesthetic effects may appear if large concentrations of benzene vapour have been inhaled

- Take victim outside in the open air;
- Apply oxygen therapy or artificial respiration if necessary;
- Entrust the victim to a healthcare professional (MD);
- Admit to hospital.

B1

Skin contact: benzene may penetrate the skin

- Remove contaminated clothing;
- Rinse with a lot of water;
- See a doctor or be admitted to hospital in the event of serious contamination.

Eye contact

Can cause irritation in the event of prolonged exposure

- Rinse with a lot of water for several minutes and open eyelids wide;
- Remove contact lenses if possible;
- See a doctor.

Poisoning by ingestion

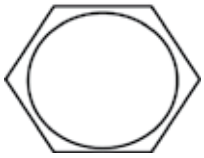
- No liquid must be drunk and do not cause the patient to vomit (as pulmonary aspiration may occur);
- See a doctor. If pulmonary aspiration is suspected (patient has vomited), admit to hospital immediately.

*FDS: Safety Data Card

ID Card [1]

BENZENE

Empirical formula: C_6H_6



Structural formula

Synonyms

Annulene
Benzol
Benzole
Benzolene
Carbon oil
Carbon naphta
Cyclohexatriene
Motor benzol
Phene
Phenyl hydride
Pyrobenzol
Pyrobenzole

Classification U.E.

F: Readily flammable.
T: Toxic.
R11: Readily flammable.
R23/24/25: Toxic when inhaled, in the event of skin contact and ingestion.
R45: Can cause cancer.
R48: Risk of serious effects on health in the event of prolonged exposure.
S45: In case of accident or discomfort, see a doctor immediately.
S53: Avoid exposure. Get special instructions prior to use.

CAS n°: 71-43-2
EC n° (EINECS): 200-753-7
Index n°: 601-020-00-8

Classification for transportation

UN n°: 1114
Class: 3

[1] Additionnal data and sources in annex 1

Physical data

Conversion factor: air (25°C)	1 ppm = 3.249 mg/m³ 1 mg/m³ = 0.308 ppm

B3

Melting point	5.5°C
Boiling point	80.1°C
Critical temperature	288.9°C
Relative density (water = 1)	0.88 at 20°C
Relative vapour density (air = 1)	2.7 at 20°C
Solubility in seawater	350 ± 100 mg/litre at 25°C and 34‰
Solubility in freshwater	1,830 mg/litre at 25°C 1,780 mg/litre at 20°C
Vapour pressure/tension	10 kPa at 20°C 37 kPa at 50°C
Olfactory threshold	In freshwater: 2 mg/litre* In air: 2 to 12 ppm
Gustatory threshold	0.5 - 4.5 mg/litre
Evaporation rate (diethyl oxide = 1)	3 (takes three times longer to evaporate as compared with diethyl oxide)
Diffusion coefficient in water	$9.8.10^{-6}$ cm²/s at 25°C
Diffusion coefficient in air	0.088 cm²/s at 25°C
Henry's law constant	558.16 Pa.m³/mol at 25°C

* Benzene odours can be detected when concentrations are of the order of 2 mg/litre.

Definitions in the glossary
Sources in annex 1

Flammability data

• **Explosive limit by volume** (% in air): Lower limit: 1.2% ou 12,000 ppm Upper limit: 8% ou 80,000 ppm	INRS, 1997
• Benzene can form an explosive mixture with air	FDS ATOFINA, 2002
• Regression speed: 6 mm/min	CHRIS, 1999
• Flash point (in a closed capsule): -11.1°C	INRS, 1997
• Self-ignition point: 538° C	INRS, 1997
• Combustion products: Full combustion, in the presence of excess air, produces carbon dioxide, water vapour and nitrogen oxide. Incomplete combustion produces carbon monoxide, soot and cracking products (aldehyde, ketone, carbon, PAHs).	FDS ATOFINA, 2002
• Reacts dangerously with potassium and strong oxidizers such as chlorine, bromine, iron, nitric acid, ozone, perchlorate, permanganate in the presence of sulphuric acid, chromium trioxide and peroxide.	CSST, 2002
• Decomposition products: Thermal decomposition can lead to the formation of carbon oxides.	CSST, 2002
• Fumes: toxic carbon oxide vapours.	Lewis, 2000

Definitions in the glossary

Toxicological data

Acute human toxicity

- When inhaled: nausea, convulsions, dizziness, sleepiness, headache, dyspnoea, loss of consciousness.
  Neurological symptoms:
  - 25 ppm: no effect;
  - 50 to 100 ppm: headache and asthenia;
  - 500 ppm: aggravation of symptoms;
  - 3000 ppm: can be tolerated for 30 to 60 minutes;
  - 20,000 ppm: death within 5 to 15 minutes;
  - Convulsions can be seen at larger doses
- Skin contact: benzene can be absorbed by the skin and cause irritation.
- Ingestion: abdominal pain, sore throat, vomiting, digestive disorders, neurological disorders (even coma), pneumopathy, convulsions, dizziness, sleepiness, headache, dyspnoea, loss of consciousness.
- Eye contact: feeling moderately burned, but only causes small and temporary epithelial cell lesions.

Chronic human toxicity

- Haematological malignancy and lymphopathy:
  leukemogenic if exposure in excess of 100 ppm.
- Non malignant haematological disorders:
  thrombocytopenia, leucopoenia, hyperleucocytosis, anaemia, polycythemia is rare, bone marrow failure. Symptoms recede in most cases when exposure stops.
- Non haematological toxicity:

- By inhalation: neuropsychic disorder, digestive disorder.
- Skin contact: topical irritation.

Threshold toxicological values

Occupational exposure values
VME: 1 ppm; 3.25 mg/m³ (France)
TLV-TWA: 0.5 ppm; (1.6 mg/m³) (USA)
Ceiling value: 25 ppm; (81mg/m³) (France)
Risk management values for the population at large
IDLH*: 500 ppm (1,624.5 mg/m³) (USA)
TLV-STEL: 2.5 ppm; (8.1 mg/m³) (USA)
TEEL 0: 1 ppm (3.25 mg/m³) (USA)
ERPG 1: 50 ppm (163 mg/m³) (USA)
ERPG 2: 150 ppm (149 mg/m³) (USA)
ERPG 3: 1,000 ppm (3,249 mg/m³) (USA)
MRL inhalation: 0.05 ppm (0.17 mg/m³) (USA)

Specific effects

Carcinogenic effects: demonstrated in humans (E. U. category 1 and IARC group 1).

Effects on fertility: not demonstrated in humans or lab animals.

Teratogenic effects on foetal development: not demonstrated in humans; retardation of foetal growth in lab animals at doses that are toxic for mothers.

Genotoxic effects: not demonstrated in humans, demonstrated in vitro and in mammals.

Proposed AEGLs (USA)

Concentration (ppm)	10 min	30 min	60 min	240 min	480 min	
AEGL 1	127	73	52	18	9	TOBIN et al., 2003
AEGL 2	2,000	1,100	800	400	200	
AEGL 3	9,700	5,600	4,000	2,000	990	

* IDLH is a value commonly used by fire brigades and first aid services when Lethal and Irreversible Effect Thresholds are not available.

Ecotoxicological data

Acute ecotoxicity

Seaweed (*Selenastrum capricornutum*)	CE_{50b}(72h) = 28 mg/litre (freshwater)
Seaweed (*Selenastrum capricornutum*)	CE_{50c}(72h) = 100 mg/litre (freshwater)
Micro crustacean (*Daphnia magna*)	CE_{50} (48h) = 10 mg/litre (freshwater)
Crustaceans (*Palaemonetes pugio*)	CL_{50} (96h) = 27 mg/litre (seawater)
Fish (*Oncorhynchus mykiss*)	CL_{50} (96h) = 5.3 mg/litre (freshwater)
Fish (*Morone saxatilis*)	CL_{50} (96h) = 9.6 mg/litre (seawater)

Chronic ecotoxicity

Seaweed (*Selenastrum capricornutum*)	CE_{10b} (72h)	= 8.3 mg/litre
Seaweed (*Selenastrum capricornutum*)	CE_{10c} (72h)	= 34 mg/litre
Micro crustacean (*Ceriodaphnia dubia*)	NOEC (7days)	= 3 mg/litre
Fish (*Pimephales promelas*, larve)	NOEC (32days)	= 0.8 mg/litre

b: biomass
c: growth rate

PNEC (Predicted No-Effect Concentration)

PNEC (Predicted No-Effect Concentration): according to the *Technical Guidance Document* pursuant to (EC) Regulation1488/94 concerning the risk assessment of existing substances, the PNEC for water is 80 µg/litre. A safety factor of 10 is applied to the smallest value of the three trophic levels (three chronic data sets).

Persistence in the environment

Biodegradation (INERIS, 2000)

After 28 days, 86 to 100 per cent of benzene will have biodegraded (OECD method 301F).
The substance can be considered as readily biodegradable.
A half life of 15 days can be estimated according to the TGD.

Volatilisation (INERIS, 2000)

Benzene separates quickly from surface seawater. It is mobile in soils and vaporises when on the soil surface.
In the atmosphere, benzene exists mainly as a gas and is degraded when it reacts with hydroxyl radicals that are formed photo-chemically.

Behaviour (INERIS, 2000)

Since it is soluble, part of the benzene is present in the atmosphere and is transported groundwards by rainwater.
Benzene can be mediated towards surface water areas by runoff and towards the groundwater table by percolation.

Bioaccumulation (INERIS, 2000)

According to Kow values and the BCF, benzene only bio-accumulates slightly in aquatic organisms.

Organic carbon/water partition coefficient Koc (calculated) = 134 litres/kg (range 18 - 1,023 litres/kg) Koc (measured) = 18 - 1,023	ECB, 2002 Chiou et al., 1983 and Uchrin & Mangels, 1987
The log Kow octanol/water partition coefficient = 2.13 (range 1.83 - 2.19)	Sangster, 1989
Bioconcentration factor BCF = 13, an estimation based on log Kow (2.13) using a (Q)SAR type formula BCF < 10 for the *Leuciscus idus* fish (exposure 8 days) BCF = 11 for the *Clupea harengus* fish (exposure 2 days) BCF < 1 for the *Tapes semidecussa* molusc (exposure 2 - 8 days)	ECB, 2002 ECB, 2002 Korn et al. (1977) in ECB, 2002 ECB, 2002

Classification

IBC classification (IMO, 1998)

- **Risk:** S/P (safety/pollution risk).
- **Type of vessel:** 3.
- **Type of tank:** 2G (integral gravity tank).
- **Tank clearance:** Cont (controlled).
- **Checking tank atmospheres:** no.
- **Electrical equipment**
  class i': T1
  class i'': IIA
  class i''': (flash point > 60° C) : no.
- **Tank level gauge:** C (closed type).
- **Vapour detection:** F-T (flammable and toxic).
- **Fire extinguishing system:**
  A: foam that resists alcohol (or a multi-purpose foam);
  B: ordinary foam, comprising all the foams that do not resist alcohol, in particular fluoroprotein foams and those that form an aqueous film (AFFF).
- **Protecting the respiratory tract and the eyes:** no (there is no special provision in the IBC code).

SEBC classification: E (Evaporator)

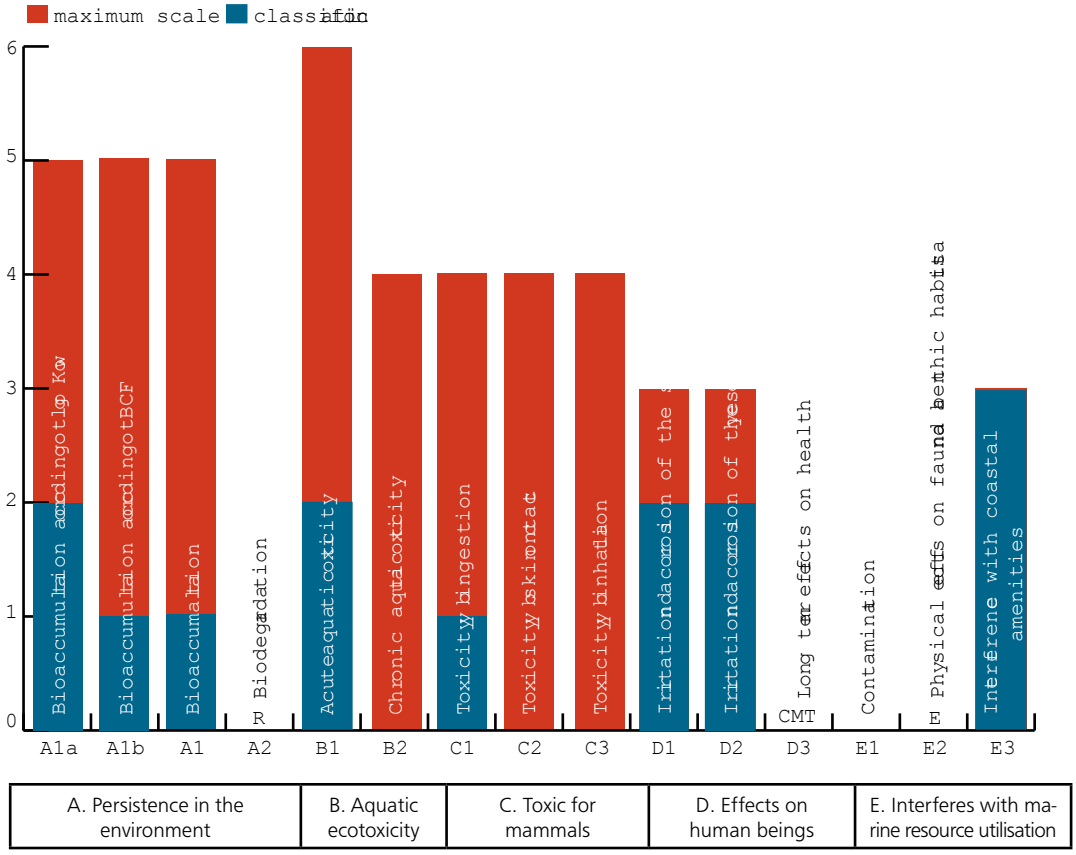
E. U. classification

F: Readily flammable

T: Toxic

R11	Ignites readily.
R45	Can cause cancer.
R48	Serious health risk in the event of prolonged exposure.
R23/24/25	Toxic when inhaled, when in contact with the skin or ingested.
S45	In case of accident or discomfort, see a doctor.
S53	Avoid exposure, get special instructions prior to use.
200-753-7	E.C. labelling

GESAMP Classification (GESAMP, 2002)



A1a: Slight potential to bio accumulate in aquatic organisms
A1b: Very slight potential to bio accumulate in aquatic organisms
A1: Very slight potential to bio accumulate in aquatic organisms
A2: Readily biodegradable

B1: Slight aquatic toxicity
B2: No information

C1: Slightly toxic when ingested by mammals
C2: Negligible toxicity by skin contact with mammals
C3: Negligible toxicity when inhaled by mammals

D1: A skin irritant
D2: An eye irritant
D3: **C** : Carcinogenic
M: Mutagenic
T: Systemic toxicity (after one or several exposures), the substance changes the function or the morphology of an organ or the biochemistry or the haematology of an organism).

E1: According to tests conducted so far, the substance does not taint fish when exposed for 24 hours at a dose of 1 mg/litre.
E2: Evaporator.
E3: Highly disagreeable, amenities must be closed down.

MARPOL classification: C (definition in annex 3) until 31/12/2006
Y (definition in annex 3b) from 01/01/2007

Special risks

Polymerisation: No

Danger (CEFIC, 2003)

Heating a benzene tank may cause a pressure increase and the tank may fail or even explode. Ignition related risks may escalate and cause a fireball. Benzene is known to form an explosive mixture with air.
Benzene vapours are invisible and heavier than air.
They spread over the soil and can penetrate the sewage system and underground areas.

Solidification / Melting

Under certain circumstances (cold water) benzene can solidify and reach its melting point (+ 5.5°C) during the course of the day as water heats up superficially. At this stage, the situation may well become more dangerous as benzene evaporates.

Stability and reactivity

Benzene is stable in normal storage, handling and utilisation conditions (FDS ATOFINA, 2002).
It does not react with water (CHRIS, 1999).

Explosion

Produces		nitric acid	permanganic acid	peroxodisulfuric acid	peroxomonosulfuric acid	diborane	dioxygen difluoride	iodine heptafluoride	uranium hexafluoride	hydrogen + Raney nickel (above 210°C)	nitrile perchlorate	liquid oxygen	ozone	arsenic pentafluoride + potassium methoxide (>30°C)	bromine pentafluoride + acetic acid	iodine pentafluoride	silver perchlorate	sodium peroxide + water	dioxigenyl tetrafluoroborate	bromine trifluoride	chlorine trifluoride
Risk of explosion	when in contact with:		X	X	X	X									X						X
	when mixed with:	X									X	X	X	X		X	X				
Ignition risk							X	X										X	X		
Reacts strongly or glows									X	X										X	

Conditions to be avoided

- A fire may occur if benzene is exposed to a flame or a source of heat (LEWIS, 2000).
- Keep clear of warm surfaces, static electricity and sparks (FDS ATOFINA, 2002).

Transportation, handling, storage

Transportation (FDS TOTAL, 2002)

UN N°: 1114

Land transportation: RID (rail) /ADR (road)

Hazard classification: 33
Class: 3
Packaging group: II
Classification code: F1
Labels: 3

Transportation via inland waterway systems: ADN/ADNR
Hazard classification: 33
Class: 3
Labels: 3
Classification code: F1

Shipping: IMDG code (amendment 31, 2002)
Class: 3
Packaging group: II
Labels: 3
Marine Pollutant (MP): no

Air freight: IATA
Class: 3
Packaging group: II
Labels: 3

Handling (FDS TOTAL, 2002)

- Keep in a well aired place.
- Avoid the formation or the diffusion of vapours, smoke or aerosols in the atmosphere (especially during cargo loading and unloading).
- Avoid contact with the skin and eyes.
- Do not eat, do not drink and do not smoke when using benzene.
- In case of risk of explosion, use appropriate PPEs, especially gloves.
- Avoid the build-up of static electricity by earthing/grounding all equipment.
- Use hard boots and appropriate PPEs that do not generate electrostatic charges.

Materials that are inappropriate for contact with benzene

- Polymer, copper, aluminium, many rubber and plastic materials (INRS, 1997).

Storage (FDS TOTAL, 2002)

- Store far from solar or other sources of radiation.
- Keep clear of sources of heat.
- Use recipients, seals, pipes that resist aromatic hydrocarbons.
- Keep clear of any source of ignition.
- Do not smoke.
- Provide a dyked area.
- Recommended storage materials: ordinary steel, stainless steel.
- Advice on uses: forbid air for transfers.

Results of accident scenarios

C

Reminder of chemical properties

Transportation

Benzene is shipped in tanks in liquid form without an additive.

Specific gravity and vapour tension

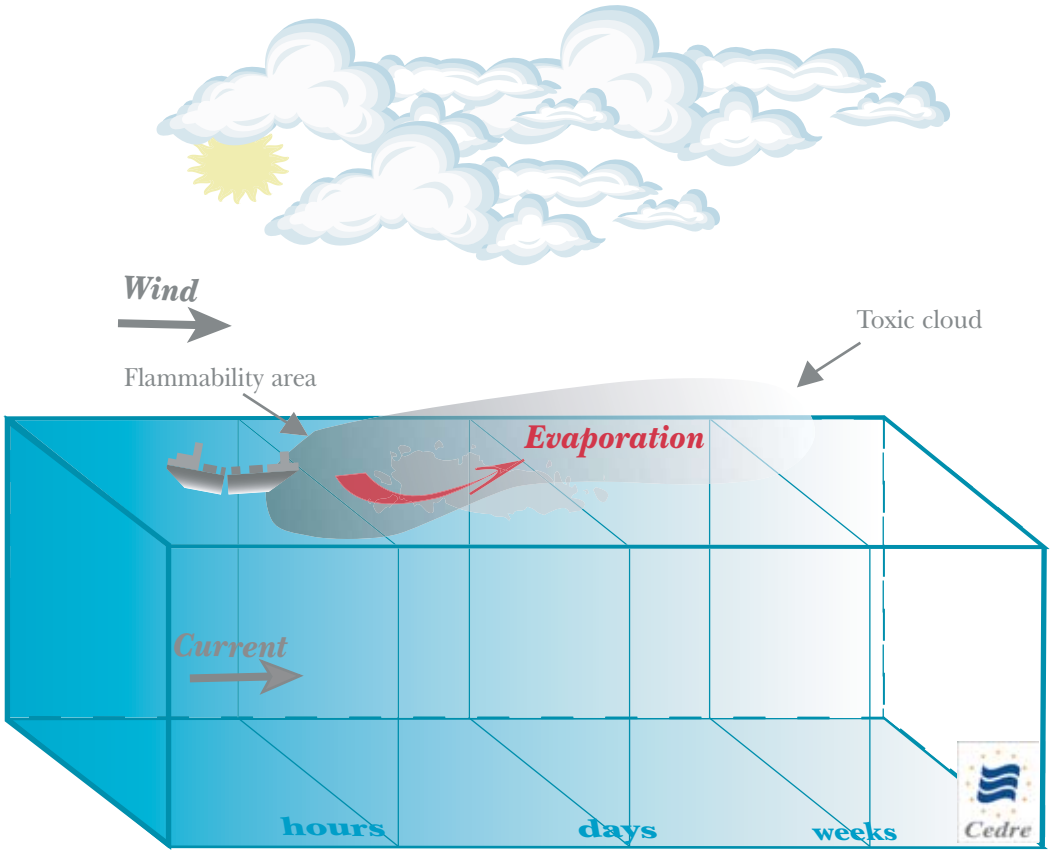
- Relative density: 0.88 at 20°C
- Vapour density: 2.7 at 20°C
- Vapour tension: 10 kPa at 20°C

Solubility

Solubility in seawater: 350 ± 100 mg/litre at 25°C at 34 ‰.
According to the SEBC classification, the solubility and vapour tension of benzene class this product as an evaporator (E)

Behaviour of benzene when spilled in water

- When benzene is spilled in seawater, it appears as a colourless slick on the water surface. As it is hardly soluble, with a specific gravity less than that of water and a high vapour tension, it stays on the surface and evaporates into the atmosphere.
- Benzene vapours are heavier than air in a stable atmosphere so the gas cloud will tend to hug the waves.



Accident scenarios

When a chemical parcel tanker is rammed sideways, the wing tanks are holed and they may contain benzene.

In a case such as this, there are three spill scenarios involving four different quantities of cargo:

10 kg/h
1,000 kg/h
100 t/h
500 t (instantaneous spill)

The scenarios

"In the English Channel"
- location 50°N - 1°W (60 km north of Cherbourg)
- air and water temperature: 10°C
- two wind speeds: 3 and 10 m/s
- wave height: 1 m
- current: 0.5 knot *

"In the Mediterranean"
- location 43° 10' N - 5° 20' E (32 km from Marseille)
- air and water temperature: 20°C
- two wind speeds: 3 and10 m/s
- wave height: 1 m
- current: 0.5 knot

"In a river"
- current 0.5 m/s
- temperature of air and water: 10°C
- wind speed: 3 m/s
- flow rate: 250 m^3/s

A wreck

A wreck is lying on the seabed 100 metres below the surface not far from an inhabited coastline and is leaking slightly. The decision to be taken will include a number of elements:
- Effective solubility of benzene in accident conditions;
- Leakage rate and droplet diameter;
- Currents;
- Access to tanks;

As far as we know, there are no indications enabling us to predict the quantity of product that will be dissolved during upwelling and what the leakage rate will have to be for the benzene to reach the surface in noticeable quantities and evaporate

If the wreck is leaking:
- Take measurements in air and water;
- Plug the holes.

If the wreck is not leaking (or no longer leaking);
- Commence recovery procedures.

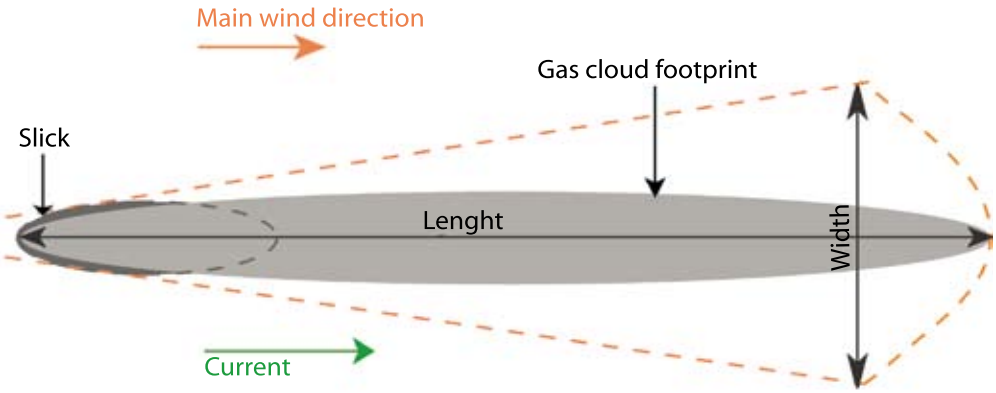
* 1 knot = 1.852 km/h or 0.5148 m/s

Modelling

ALOHA and CHEMMAP have been used to model hypothetical spillages of benzene in water.
ALOHA is a Gaussian type atmospheric dispersion model developed by NOAA (National Oceanic and Atmospheric Administration) and the EPA, (Environmental Protection Agency) in the USA.
ALOHA calculates gas cloud envelopes. The model will calculate the gas cloud envelope and it is important to point out that results are only valid for calm sea conditions.

CHEMMAP is a chemical spill model developed by ASA (Applied Science Associates, Inc (USA)) and predicts the movement and the fate of a chemical that is spilled in sea and freshwater. It indicates the movement of a chemical on the water surface and how it spreads throughout the environment (how it evaporates or dissolves in the water column).

- Weather conditions must be the following:
  - stable conditions (wind speed = 3 m/s under a cloudy sky, stability class E);
  - unstable conditions (wind speed = 10 m/s under a sunny sky, stability class B);
  - average air humidity.
- Surface roughness in this case is 0.06 cm.
- Spillage location is 3 metres above sea surface.
- The gas cloud is delineated as follows:
  - olfactory threshold: 2 ppm;
  - TLV-TWA: 0.5 ppm (weighted average eight hours a day and forty hours a week);
  - IDLH: 500 ppm (Level below which a worker can, without availing himself of a respirator and without impairing his ability to escape to safety in thirty minutes in the event of sudden exposure to a dangerous atmosphere;
  - LEL: 12,000 ppm (Lower explosion limit).



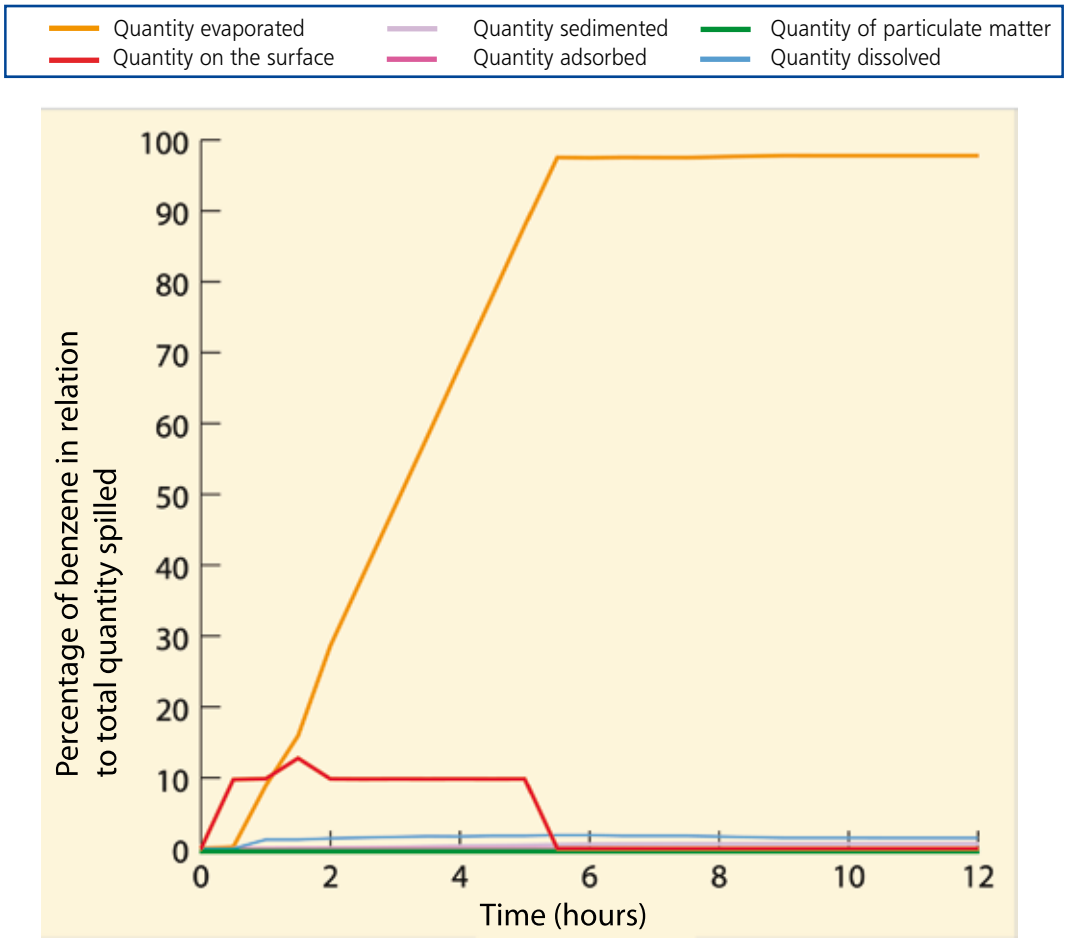
Results of the "English Channel" scenario

Results of the ALOHA model: atmospheric dispersion

Quantity spilled	Wind speed	Concentration (ppm)	Maximum distance reached Length and width	Protection
10 kg/h	3 m/s	0.5 (TLV-TWA)	620 m by 200 m	B
		2 (olfactory threshold)	300 m by 100 m	B
		500 (IDLH)	20 m	C
		12,000 (LEL)	10 m	D
	10 m/s	0.5 (TLV-TWA)	55 m	B
		2 (olfactory threshold)	26 m	B
		500 (IDLH)	< 10 m	C
		12,000 (LEL)	< 10 m	D
1,000 kg/h	3 m/s	0.5 (TLV-TWA)	7 km by 2.2 km	B
		2 (olfactory threshold)	3.5 km by 1.2 km	B
		500 (IDLH)	160 m by 150 m	C
		12,000 (LEL)	26 m	D
	10 m/s	0.5 (TLV-TWA)	1.8 km by 1 km	B
		2 (olfactory threshold)	850 m by 600 m	B
		500 (IDLH)	49 m	C
		12,000 (LEL)	11 m	D
100 t/h	3 m/s	0.5 (TLV-TWA)	> 10 km by 6 km	B
		2 (olfactory threshold)	> 10 km by 5 km	B
		500 (IDLH)	1.6 km by 1 km	C
		12,000 (LEL)	300 m by 300 m	D
	10 m/s	0.5 (TLV-TWA)	> 10 km by 8 km	B
		2 (olfactory threshold)	9.5 km by 6 km	B
		500 (IDLH)	550 m by 400 m	C
		12,000 (LEL)	100 m by 60 m	D
500 tonnes instantaneous spill (10 min)	3 m/s	0.5 (TLV-TWA)	> 10 km by 5.5 km	B
		2 (olfactory threshold)	> 10 km by 5 km	B
		500 (IDLH)	1.1 km by 600 m	C
		12,000 (LEL)	200 m by 150 m	D
	10 m/s	0.5 (TLV-TWA)	> 10 km by 10 km	B
		2 (olfactory threshold)	> 10 km by 8 km	B
		500 (IDLH)	3.7 km by 1.2 km	C
		12,000 (LEL)	730 m by 500 m	D

A	No danger.	C	Use PPEs and an SCBA.
B	Use PPEs and a gas mask.	D	Zone where the benzene concentration has reached explosive limits. Use an SCBA and explosion-proof equipment.

Results of the CHEMMAP model: dispersion of chemicals in water

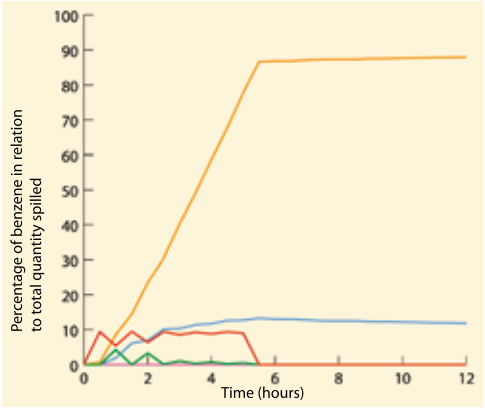


Spill involving 1,000 kg/h of benzene in 5 hours. Wind: 3 m/s

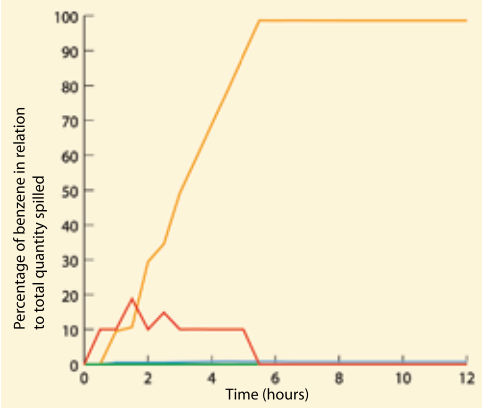
The model simulates a spill representing a tenth of the total quantity every 30 mins for the first five hours.

Example:

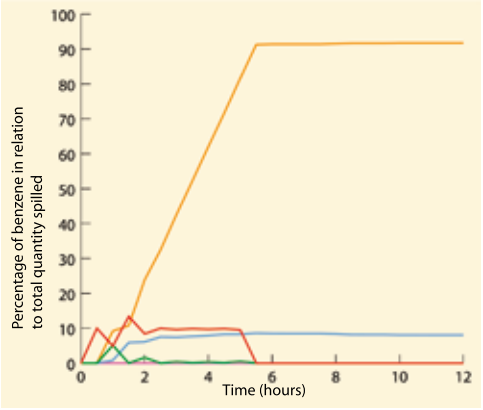
Four hours after the start of a spill, 800 kgs had been spilled at sea and the spill pattern was as follows:
- 68 % of the total quantity (1,000 kg) in the atmosphere (680 kg);
- 10 % on the water surface (100 kg);
- 2 % dissolved (20 kg).



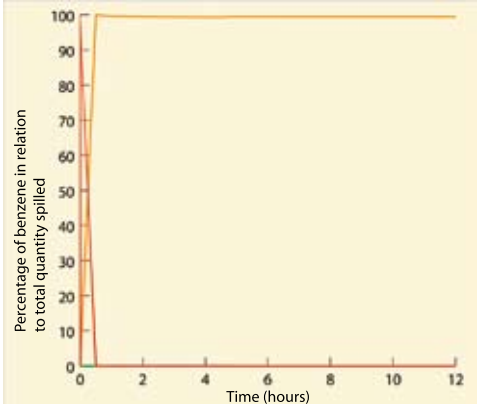
Spillage of 1,000 kg/h of benzene in 5 hours. Wind speed: 10 m/s



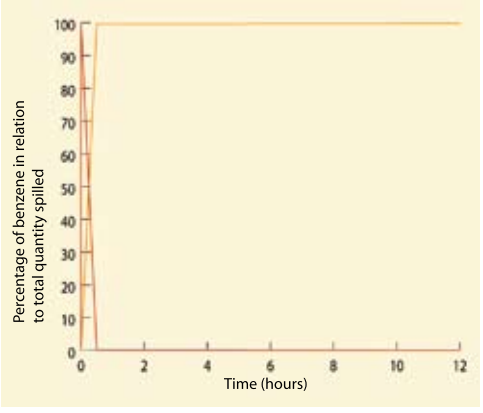
Spillage of 100 tonnes/h of benzene in 5 hours. Wind speed: 3 m/s



Spillage of 100 tonnes/h of benzene in 5 hours. Wind speed: 10 m/s



Instantaneous spillage of 500 tonnes of benzene. Wind speed: 3 m/s



Instantaneous spillage of 500 tonnes of benzene. Wind speed: 10 m/s

The model simulates a spill representing a tenth of the total quantity every 30 mins for the first five hours.

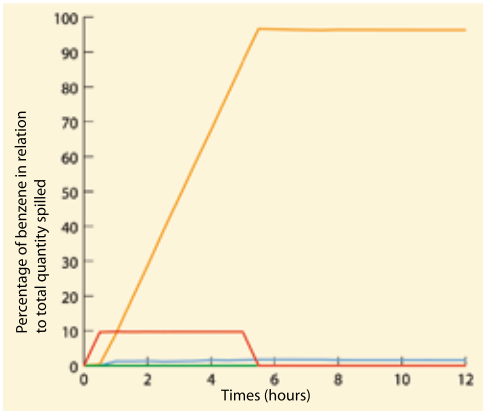
Results of the "Mediterranean sea" scenario

Results of the ALOHA model: atmospheric dispersion

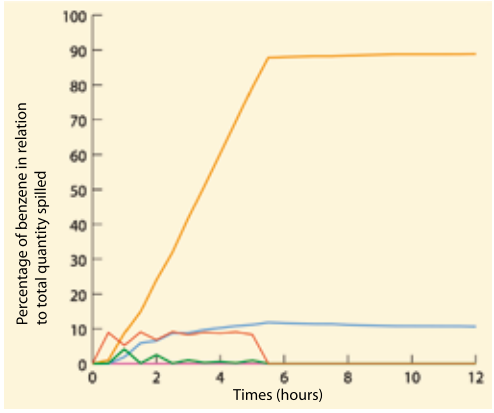
Quantity spilled	Wind speed	Concentration (ppm)	Maximum distance reached Length and width	Protection
10 kg/h	3 m/s	0.5 (TLV-TWA)	640 m by 200 m	B
		2 (olfactory threshold)	300 m by 100 m	B
		500 (IDLH)	20 m	C
		12,000 (LEL)	10 m	D
	10 m/s	0.5 (TLV-TWA)	52 m	B
		2 (olfactory threshold)	26 m	B
		500 (IDLH)	< 10 m	C
		12,000 (LEL)	< 10 m	D
1,000 kg/h	3 m/s	0.5 (TLV-TWA)	7 km by 2.2 km	B
		2 (olfactory threshold)	3.5 km by 1.2 km	B
		500 (IDLH)	180 m by 150 m	C
		12,000 (LEL)	26 m	D
	10 m/s	0.5 (TLV-TWA)	1.9 km by 1 km	B
		2 (olfactory threshold)	850 m by 600 m	B
		500 (IDLH)	50 m	C
		12,000 (LEL)	10 m	D
100 t/h	3 m/s	0.5 (TLV-TWA)	> 10 km by 6 km	B
		2 (olfactory threshold)	> 10 km by 5 km	B
		500 (IDLH)	1.6 km by 1 km	C
		12,000 (LEL)	300 m by 300 m	D
	10 m/s	0.5 (TLV-TWA)	> 10 km by 8 km	B
		2 (olfactory threshold)	9.5 km by 6.5 km	B
		500 (IDLH)	550 m by 400 m	C
		12,000 (LEL)	100 m by 60 m	D
500 tonnes instantaneous spill (10 min)	3 m/s	0.5 (TLV-TWA)	> 10 km by 6 km	B
		2 (olfactory threshold)	> 10 km by 5 km	B
		500 (IDLH)	1.2 km by 600 m	C
		12,000 (LEL)	200 m by 150 m	D
	10 m/s	0.5 (TLV-TWA)	> 10 km by 10 km	B
		2 (olfactory threshold)	> 10 km by 8 km	B
		500 (IDLH)	3.7 km by 1.2 km	C
		12,000 (LEL)	730 m by 500 m	D

A	No danger.	C	Use PPEs and an SCBA.
B	Use PPEs and a gas mask.	D	Zone where the concentration of benzene reaches explosive limits. Use an SCBA and explosion-proof equipment.

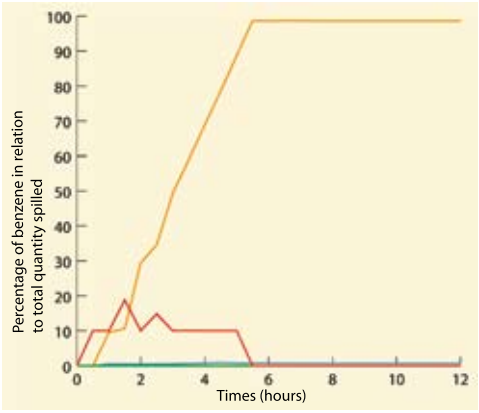
Results of the CHEMMAP model: dispersion of chemicals in water



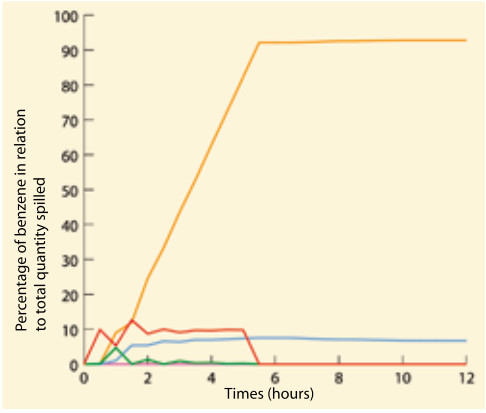
Spillage of 1,000 kg/h of benzene in 5 hours. Wind speed: 3 m/s



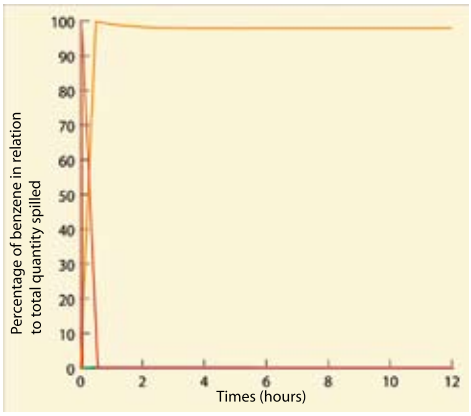
Spillage of 1,000 kg/h of benzene in 5 hours. Wind speed: 10 m/s



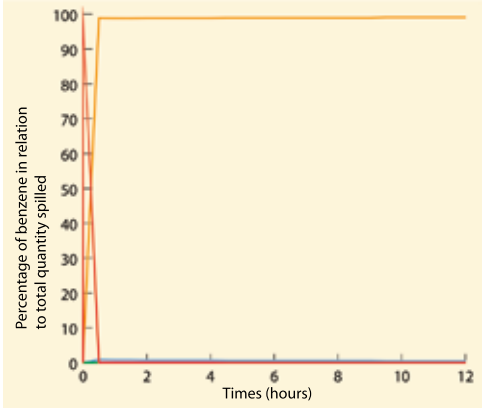
Spillage of 100 tonnes of benzene in 5 hours. Wind speed: 3 m/s



Spillage of 100 tonnes of benzene in 5 hours. Wind speed: 10 m/s



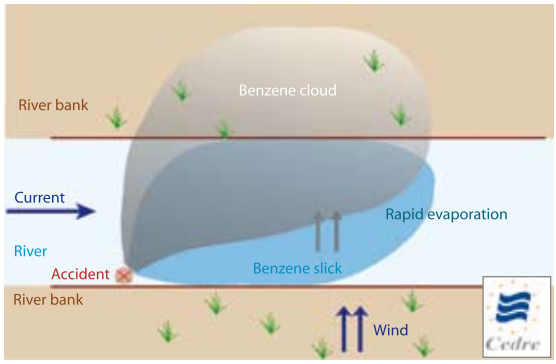
Instantaneous spill of 500 tonnes of benzene. Wind speed: 3 m/s



Instantaneous spill of 500 tonnes of benzene. Wind speed: 10 m/s

The model simulates a spill representing a tenth of the total quantity every 30 mins for the first five hours.

Results of the "River" scenario



Spillage of benzene in a river.
The benzene cloud will disperse more or less depending on current speed (slick drift) and wind speed.

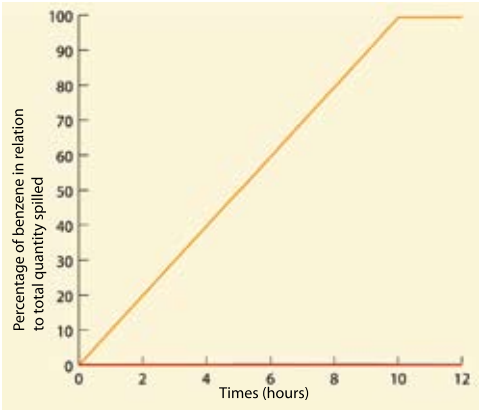
If no fire breaks out during the spill, the slick of liquid benzene, contained by the river banks will spread and evaporate.
In view of the surface current, the surface slick will travel downstream a little.
The amount of time the slick will persist on the surface (same as with the English Channel scenario) will determine the stretch of river likely to be polluted. The river banks likely to be impacted by the toxic cloud will be downwind.

Results of the ALOHA model: atmospheric dispersion

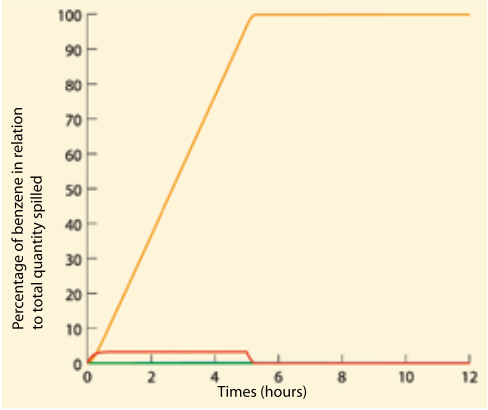
Quantity spilled	Wind speed	Concentration (ppm)	Maximum distance reached Length and width	Protection
10 kg/h	3 m/s	0.5 (TLV-TWA)	620 m by 200 m	B
		2 (olfactory threshold)	300 m by 100 m	B
		500 (IDLH)	19 m	C
		12,000 (LEL)	11 m	D
1,000 kg/h	3 m/s	0.5 (TLV-TWA)	7 km by 2.2 km	B
		2 (olfactory threshold)	3.5 km by 1.2 km	B
		500 (IDLH)	160 m by 150 m	C
		12,000 (LEL)	26 m	D
100 t/h	3 m/s	0.5 (TLV-TWA)	> 10 km by 6 km	B
		2 (olfactory threshold)	> 10 km by 5 km	B
		500 (IDLH)	1.6 km by 1 km	C
		12,000 (LEL)	300 m by 300 m	D
500 tonnes instantaneous spill (10 min)	3 m/s	0.5 (TLV-TWA)	> 10 km by 5.5 km	B
		2 (olfactory threshold)	> 10 km by 5 km	B
		500 (IDLH)	1.1 km by 600 m	C
		12,000 (LEL)	200 m by 150 m	D

A	No danger.	C	Use PPEs and an SCBA.
B	Use PPEs and a gas mask.	D	Zone where the benzene concentration has reached explosive limits. Use an SCBA and explosion-proof equipment.

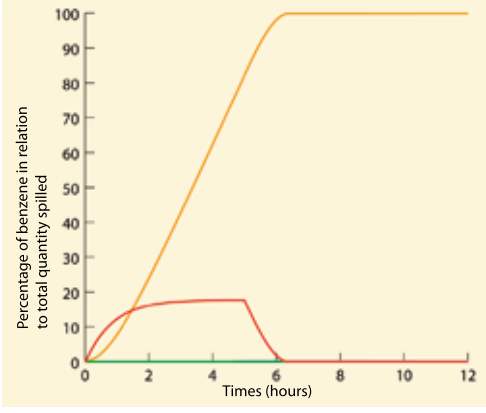
Results of the CHEMMAP model: dispersion of chemicals in water



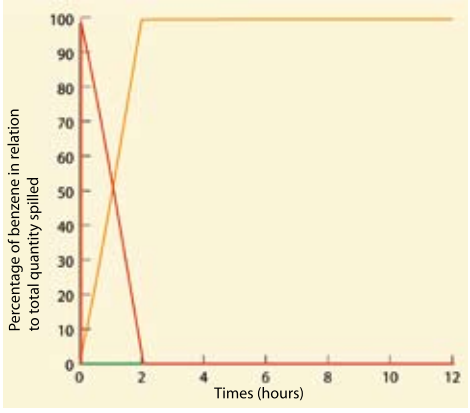
Spillage of 10 kg/h of benzene
in 10 hours. Wind speed: 3 m/s



Spillage of 1,000 kg/h of benzene
in 5 hours. Wind speed: 3 m/s



Spillage of 100 tonnes/h of benzene
in 5 hours. Wind speed: 3 m/s



Spillage of 500 tonnes/h of benzene
for 5 hours. Wind speed: 3m/s

The model simulates a spill representing a tenth of the total quantity every 30 mins for the first five hours.

Consumption scenarios

Since benzene is a volatile substance, hardly soluble and unlikely to bio accumulate to any significant extent throughout the trophic chain, it is hardly probable that it is going to exist in significant concentrations that will be sufficiently potent as to have an impact on a person having eaten contaminated fish or seafood.

Response to chemical spills

D

Examples of benzene spills

Panam Serena

An explosion occurred on 1 January 2004 in Porto Torres (Sardinia), on board the **Panam Serena** as she was unloading her cargo of benzene. A fire broke out on board and the port had to be evacuated. The fire was put out two days later.
Thirteen crewmembers were saved and two were reported missing.
No spill was reported.

Rhone river accident

A convoy comprising a pusher barge and two cargo barges were sailing up the Rhone river on 18 January 2004, when it collided with the pillar of a railway bridge at Voulte-sur-Rhône (France). The convoy belonged to Compagnie de transport fluvial du Havre, and was sailing up the river from Lavera (Bouches-du-Rhône). The pusher barge hit the pillar and sank immediately killing one seaman. The barge with the containers was freed three days later. The second barge containing 2300 m^3 of liquid benzene grounded on the left bank opposite the town centre of la Voulte. There was no leak and the barge was freed on 25 January after the benzene cargo had been transferred onto another barge. During this operation, 500 people living along the riverside were evacuated as a precautionary principle. The empty barge was pulled upstream by three bulldozers and two pusher barges.

The ambient temperature was lower than the melting point of benzene and did not therefore prevent the liquid benzene from being lightered.

Accident involving a benzene barge, La Voulte, 2004

Recommendations regarding response

Is response possible?

If a fire breaks out and becomes a full blown fire, you will need to evacuate everyone within a radius of 800 meters at least and let the fire burn. Otherwise, response is possible providing the following precautions are taken:

- Approach from upwind (wind behind you) and if possible upstream of the current. Responders must use gas detectors, PPEs, dedicated detectors such as a HNU photo-ioniser fitted with a 9.5 Ev lamp or Draeger tubes. If a fire breaks out, use carbon oxide detectors.
- Avoid all sources of ignition, sparks and heat. Use explosion-proof equipment.
- Aerial response is not advised.

Emergency measures in the event of a leak or a spill

- Forbid access to the polluted area and the use of water (human consumption, irrigation and bathing)
- Eliminate possible causes of ignition.
- Avoid all contact with the liquid and do not inhale benzene vapours.
- Plug the leak if possible without endangering human life. If the damaged container is in a closed area, ventilate it well before entering. The materials recommended for plugging leaks are polyester, urethane foam and epoxide resin paste.
- To reduce vapour quantities and protect the strike team that is attempting to plug the leak, several solutions can be envisaged: spray water (this will disperse vapours as well) or else use sorbents or foam.
- If the leak cannot be stopped, transport the damaged recipients to a well ventilated area if possible and then transfer the benzene.
- Explosion risks are high and it may sometimes be better to set the benzene alight providing there is no risk in doing so.

Emergency measures in case of fire

- Do not systematically try to extinguish the flames if the leakage cannot be stopped.
- The following extinguishing agents are recommended: chemical foam, CO^2 or dry powder. It may well be that water will be inoperative on this kind of fire but can be used for cooling operations.
- Hose vapours down with water.
- Cool the containers exposed to flames with water. Do not spray water on the pressure relief valves or on the tank if it's colour is changing.
- Keep well clear of the tank ends and evacuate immediately if the pressure relief valves start whistling.

Response techniques

Transhipment

- If the cargo has to be lighted, a pump can be used or pressurised nitrogen (never use compressed air).
- All equipment must be explosion-proof and spark-proof.
- Never enter the cargo tank.
- Vapour tension will have to be reduced by cooling the tank walls, by ventilating or by spraying water at frequent intervals.

The following equipment is recommended:

- A centrifugal pump, with a 316 stainless steel intake.
- Pipes and connectors must be non welded and made of A 106 steel alloy with chlorinated polyether, polypropylene, PVDC or PVDF seals. Pipe-welded flange joints and threaded connectors are preferable (they tend to leak after a while).
- Cast iron or 316 stainless steel diaphragm pumps with PVCDC or chlorinated polyether resin liners should be used. At normal temperature, viton, asbestos or Teflon® can also be used as liners, seals or packing.
- Materials such as polyethylene, rubber neoprene, hypalon and butyl are not recommended when handling benzene.
- FRAMO TK5, TK6, TK8 pumps and MARFLEX pumps are compliant with the requirements mentioned above providing the neoprene hoses are replaced with 316 stainless steel hoses.

Responding to spills

• At sea

- If response is implemented quickly (before all of the benzene has evaporated) an attempt may be made to contain the slick with booms.
- Theoretically, recovering benzene at sea will only be possible if seawater temperatures are below + 5.5°C, which is the freezing point for benzene. In this case, floating benzene patches can be removed by skimming or absorbed by capillarity with sorbents made of hydrophobic and oleophilic polypropylene microfibres.
  However, benzene has not been seen to solidify in a lab in water tanks at a temperature of 0°C.

• Inland water areas

- Contain the slick with booms or by deflection.
- A number of recovery systems can be envisaged:
  - skimming the slick (will be more effective if water temperatures are low);
  - spraying sorbents (synthetic resin and straw);
  - solidifying the benzene with a universal gelling agent (0.6 g/10 ml);
  - spraying charcoal (at a rate of 10 % of the quantity of benzene that has been spilled) on the area where benzene concentrations in water exceed 10 mg/litre.

• On the ground

- Preventing polluted waters from reaching the sewage system or a river.
- Containing the slick with booms or natural obstacles or deflecting it towards a waterproof surface; A slick can also be "frozen" by a gelling agent, straw, fly ash or cement powder.
- Absorb the rest with soil, vermiculite, sand, sawdust or synthetic sorbents. Pick them up with a spade when they are soaked in benzene and place them in closed metal containers.

Note that benzene may percolate down to the groundwater table and cause extensive pollution.

Choosing PPEs

Afford maximum protection in the event of massive concentrations

Selecting respirators (Fingas, 2000)

Depending on the maximum exposure concentrations (MEC)[2]:
- Gas mask, up to 200 ppm.
- SCBA: no limit.

Wear a chemical suit if vapour concentrations are likely to be high.

Selecting protective clothing (CCHST, 2003)

Wear protective clothing to cover the entire body.

Protecting the face and the eyes: Wear protective goggles if in contact with chemicals. A face mask may also be needed.

Protecting the skin: Wear protective gloves (preferably made of polyvinyl alcohol), overalls, boots and/or other chemical resistant protective clothing. There must also be a safety shower system and an eye fountain for washing eyes in the immediate vicinity of the response area. For some jobs, it may also be necessary to wear a one-piece chemical resistant suit and a respirator. PPEs will have to be changed at least twice a week.

Immediately remove polluted clothes and place them in containers provided for the purpose. Discard or wash them prior to subsequent use. Inform the staff in charge of cleaning them of the dangers related to this contaminant.

Permeation times for various cloths
(Forsberg & Keith (1995), in Fingas, 2000)

BETEX (butyl over neoprene) : 15 min.
Butyl: 30 min (variable).
Natural rubber: 3 min (variable).
Neoprene: 12 min (variable).
Nitrile: 15 min (variable).
PVC: 1 min (variable).
Teflon: > 200 min.
Viton: 9 min (variable).

D4

[2] It is to be noted that MECs can vary from one manufacturer and model to another and that the manufacturer will have to be contacted for more particulars.

Chemical resistance

Materials	Degradation	Permeability	
Nitrile			Poor protection
Neoprene			Not recommended
Polyvinyl alcohol (PVA)	Very slight	No permeability for 6 hour tests permeability > 0.9 µg/cm²/ min 0 to1/2 drop/hour traverses PVA	Highly suitable Not recommended
Polyvinyl chloride (PVC)			
Natural rubber			Not recommended
Linear Low Density polyethylene (LLDPE)	No degradation test	permeation times > 480 min permeability > 0.9 µg/cm²/ min 0 to 1/2 drop/hour traverses LLDPE	Highly suitable
Teflon		permeation time > 200 min	Suitable

Remark: our chemical resistance table is given as an indication. Nothing can replace your own assessment in real live conditions.

Recommendations for use in the event of a spill (Fingas, 2000)

- Open circuit pressure demand respirators afford the best protection. Their protection factor is about 10,000 (e.g. VLE = 20 ppm, protection for up to 200 000 ppm of chemical in ambient air).
- Use an SCBA to confront unknown situations such as unknown or elevated levels of a toxic agent and also for premises where there is a risk of oxygen depletion (closed area).
- Filter air line respirators can be used when concentrations have not reached an IDLH level and when it is unlikely that the levels will increase.
- NB: some facial features such as scars, narrow face, hair (beard) can prevent a snug fit for the face mask and thus impair protection.
- In warm weather: excessive sweating can impair air tightness of the seal between the mask and the skin.
- In cold weather: ice can form on the pressure valve and mist can cover the face piece. If air line respirators are used, place the oxygen cylinders in a warm vehicle prior to use. Dampness can freeze the respirator.
- NB: ordinary prescription glasses cannot be worn inside the mask (special frames exist) but contact lenses are allowed because new model respirators allow air exchange (the lenses in this case do not dry and do not stick to the eye ball).
  Adjustment testing is advised for people who are new to using masks and regular trials for experienced users.

Measures to be taken after using PPEs during a spill

- Decontaminate boots after a response job. Foot baths can be used with a mild detergent. Do not forget to treat the contaminated washing water.
- Decontaminate gloves separately using a bucket and a mild detergent.

Measuring devices and waste treatment

Measuring devices

(ENVIRONNEMENT CANADA, 2001)

Instrument	Manufacturer
815-Z	AIM
D-TECH Kits	EM Science/Strategic Diagnostics Inc
HNU-Hanby Environmental Field Kits	HNU Systems, Inc
Lovibond 2000 Comparator (a)	Lovibond / The Tintometer
M21 (RSCAAL)	Brunswick Defense
Quantix Portable	Quantix
Snapshot	Photovac International, Inc
CMS detectors	Dräeger
MiniWarn	Dräeger

Waste treatment

- Treatment: gravity separate solids from polluted water then skim the surface. If skimming is inadequate, filter the water and use charcoal to adsorb water (1 kg/3.5 kg of soluble matter).
- Elimination: residual benzene must never be poured down the sewer system nor in run off systems.
  Benzene laden waste must be collected in a watertight can and be entrusted to a specialized company for treatment.

Addresses where special industrial waste can be treated in France.

Companies likely to treat such waste can also be found at the following web address:
http://www.observatoire-dechets-bretagne.org/

- GEREP
route Jacquart
77299 Mitry Mory
Phone.: + 33 1 64 27 16 97 / fax: 01 64 27 43 35

- SARP Industries
route de Hazay
78520 Limay
Phone.: + 33 1 34 97 25 25 / fax: 01 34 77 22 25

- SEDIBEX
route industrielle
76430 Sandouville
Phone.: 02 32 79 54 10 / fax 02 35 20 56 92

- EMC Services Division Pec Tredi
avenue Charles De Gaulle
01150 Saint Vulbas
Phone.: + 33 4 74 46 22 00 / fax 04 74 61 52 44

Benzene manufacturers

(CHIMEDIT, 2004)

Atofina, Exxon Chemical, Rhodia chemicals, Solvadis France, BP chemicals, Shell petrochemicals.

Additional information

Bibliography

Documents

ATOFINA. *Fiche de données de sécurité (FDS) : benzène.* N°FDS 004. 2002. 12 p.

ATSDR. *Toxicological Profile for Benzene*. Atlanta : ATSDR, 1997. 463 p.

CEDRE. *Détermination de la solubilité du benzène en fonction de la température et de la salinité de la colonne d'eau*. Brest : Cedre, 2004.

CEFIC. *ERICards, Emergency Response Intervention Cards : transport of dangerous goods.* Bruxelles : Cefic, 2003.

CHIMEDIT. *Guide de la chimie international 2004 et des sciences de la vie*. Paris : CHIMEDIT, 2004. 1238 p.

CHIOU, C.T., PORTER, P.E., SCHMEDDING, D.W. Partition equilibria of nonionic organic compounds between soil organic matter and water. *Environ. Sci. Technol.*, 1983, n° 17, p 227 - 231.

ENVIRONNEMENT CANADA. - Service de la protection de l'environnement. *Le benzène*. Ottawa : Environnement Canada, 1984. 95 p. (collection "ENVIROGUIDE").

FINGAS, M. Equipement de protection personnelle contre les déversements de substances dangereuses. *Bulletin de la lutte contre les déversements*, janvier-décembre 2000, vol 25.

INERIS. *Fiches de données toxicologiques et environnementales des substances dangereuses ; Benzène*. Verneuil-en-Halatte : INERIS, 2000. 42 p. (Version 1).

INRS. *Fiche toxicologique n°49, Benzène*. Paris : INRS, 1997. 6 p.

KORN, S. et al. The uptake, Distribution and Depuration of 14C-Benzene and 14C-Toluene in Pacific Herring, *Clupea Harengus Pallasi*. *U.S. Natl. Mar. Serv. Fisch. Bull.*, 1977, N° 75, p 633 - 636

LEWIS, R. J. Sr. *SAX's Dangerous properties of industrial material, vol. 2. Tenth ed*. New York : John Wiley & Sons, 2000. 1900 p.

IMO *MARPOL 73/78 Edition récapitulative de 2002 : Articles, protocoles, annexes et interprétations uniformes de la Convention internationale de 1973 pour la prévention de la pollution par les navires, telle que modifiée par le Protocole de 1978 relatif.* Londres : OMI, 2002. 547 p.

IMO. *Recueil international de règles relatives à la construction et à l'équipement de navires transportant des produits chimiques dangereux en vrac (Recueil IBC)*. Londres : OMI, 2001. 260 p.

SANGSTER, J. Octanol-water partition coefficients of simple organic compounds. *J. Phys. Chem. Ref. Data.*, 1989, vol. 18, n° 3.

UCHRIN, C.G., MANGELS, G. Sorption equilibria of benzene and toluene on two New Jersey coastal plain ground water aquifier solids. *J. Environ. Sci.Health*, 1987, n° A22(8), p 743 - 758.

Web documents

CHRIS. *Fiche de sécurité sur le Benzène*, [on line-1999],
Available at: http://www.chrismanual.com (page consulted in Aug. 2004).

CSST. *Rapport sur le benzène*, [on line-2002],
Available at: http://www.reptox.csst.qc.ca (page consulted in Aug. 2004).

CCHST. *Information sur l'équipement de protection individuelle contre le benzène*, [on line-2003]
Available at: http://www.cchst.ca/reponsessst/chemicals/chem_profiles/benzene/personal_ben.html (page consulted in Aug. 2004).

ENVIRONNEMENT CANADA. *Mesure de la pollution*. [on line-2001],
Available at: http://www.etcentre.org/databases/fuelcalc_f.html (page consulted in Aug. 2004).

EUROPEAN CHEMICALS BUREAU (ECB). *Draft, Risk Assessment : Benzene*. [on line-2002],
Available at: http://ecb.jrc.it/existing-chemicals (page consulted in Aug. 2004).

ICSC. *Programme International sur la Sécurité des Substances Chimiques, Fiche benzène n° 15*, [on line-1993],
Available at: http://www.cdc.gov/niosh/ipcs/french.htm (page consulted in Aug. 2004).

US DEPARTMENT OF ENERGY'S CHEMICAL SAFETY PROGRAM. *Chemical Safety Program : Revision 19 of ERPGs and TEELs for Chemicals of Concern*, [on line-2002],
Available at: http://tis.eh.doe.gov/web/chem_safety/teel.html (page consulted in Aug. 2004).

U.S.-EPA. *Fact sheet Benzene*, [on line-2003],
Available at: http://www.epa.gov (page consulted in Aug. 2004).

Glossary

Admissible daily dose (ADD)
For humans this dose is the quantity of a substance that can be ingested by an organism in the space of a day for the rest of its life without presenting a health hazard for the organism in question.

Adsorption
Elevation of the concentration of a substance dissolved at the interface of a condensed phase and a liquid phase under the influence of surface forces. Adsorption can also occur at the interface of a condensed phase and a gas phase.

AEGLs (Acute Exposure Guideline Levels)
Defined by the National Research Council's Committee on Toxicology (USA), AEGLs are three levels above which the general population may experience certain effects. These three AEGLs are given for five exposure times: 10, 30 min, 1, 4 and 8 hours.
AEGL 1 : is the airborne concentration (expressed as ppm (parts per million) or mg/m^3 (milligrams per cubic meter) of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic non sensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.
AEGL 2 : is the airborne concentration (expressed as ppm or mg/m^3) of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.
AEGL 3 : is the airborne concentration (expressed as ppm or mg/m^3) of a substance above which it is predicted that the general population, including susceptible individuals, could experience life-threatening health effects or death.

Bioaccumulation
Continued retention of a substance in the tissue of an organism throughout the course of its existence (the bioaccumulation factor increases all the time).

Bioamplification
Retention of a substance in the tissue at increasingly higher concentrations the higher one goes in the food chain.

Bioconcentration
Retention of a substance in the tissue of an organism to the extent that the content of the substance in the tissue exceeds that found in nature at one point in time of the lifetime of the organism.

Bioconcentration factor, BCF
According to EPA guidelines, "the BCF is defined as the ratio of chemical concentration in the organism to that in surrounding water. Bio concentration occurs through uptake and retention of a substance from water only, through gill membranes or other external body surfaces. In the context of setting exposure criteria it is generally understood that the terms "BCF" and "steady-state BCF" are synonymous. A steady-state condition occurs when the organism is exposed for a sufficient length of time that the ratio does not change substantially."

Biotransformation
Biological transformation of substances in a living organism via enzymatic processes.

BLEVE (Boiling Liquid Expanding Vapour Explosion)
A violent vapour explosion of a liquid that is significantly above its usual boiling point at atmospheric pressure after a tank has failed.

Boiling point (cf diagramme on page 44)
(measured at a pressure of 1 atmosphere)
Temperature at which a liquid begins to boil. More specifically: when the temperature at which saturating vapour pressure of a liquid is equal to standard atmospheric pressure (1,013.25 hPa). The boiling point thus measured depends on atmospheric pressure.

Critical pressure
Maximum pressure for which the distinction can be made between a gas and a liquid.

Critical temperature (cf figure on following page)
Temperature at which, when boiling, there is no longer any clear cut transition between the liquid and the gas state.

Daily exposure dose
Dose (internal or external) of a substance in an organism compared to the weight of the individual and the number of days of exposure (in the case of a non carcinogenic substance) and the number of days lived by the organism (for a carcinogenic substance).

Decompositon products
Products stemming from chemical or thermal disaggregation of a substance.

Diffusion coefficient in air (and in water) (cm^2/s at ambient temperature)
A constant that describes the movement of a substance in the gas phase (or liquid phase) in response to a concentration differential in the gas phase (or liquid phase).

Efficient concentration 50 (EC_{50})
Concentration causing a given effect (mortality, growth inhibition...) for 50% of the population under consideration during a given period of time.

Emergency Response Planning Guidelines (ERPG)
The American International Health Alliance, AIHA set three maximum concentrations in 1988 below which a category of effects is not expected for an exposure duration of one hour intended to protect the population at large.
ERPG1: is the maximum airborne concentration below which nearly all individuals could be exposed for up to 1 hour without experiencing other than mild transient adverse health effects or perceiving a clearly defined objectionable odour.
ERPG2: is the maximum airborne concentration below which nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.
ERPG3: is the maximum airborne concentration below which nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.

Exposure limit value (ELV)
Ceiling exposure value measured for a maximum duration of 15 minutes.

Flash point
The lowest temperature at which a substance generates vapours that ignite or burn immediately when approached by a flame.

Foam
Product that forms an abundant amount of foam. The foam layer absorbs most of the vapours, physically eliminates vapours, isolates the chemical from sunlight and ambient air which reduces the amount of heat and subsequent vaporisation.

Henry's law constant
Property of a substance to divide itself into two distinct phases of a binary air/water system.

Immediately Dangerous to Life or Health (IDLH)
Level below which a worker can, without availing himself of a respirator and without impairing his ability to escape to safety in thirty minutes in the event of sudden exposure to a dangerous atmosphere.

Irreversible effect threshold (IET)
Concentration, for a stated exposure duration, above which irreversible effects can occur in the exposed population.

Lethal effect threshold (LET)
Concentration, for a stated exposure duration, above which mortality can be observed in the exposed population.

Lower Explosive Limit (LEL)
Minimum airborne concentration above which vapours ignite.

Marine pollutant
Substance, object or matter likely to cause serious damage to the marine environment when spilled.

MARVS (Max Admissible Relief Valve System)
Indicates the maximum admissible calibration of pressure relief valves of a cargo tank.

Mean exposure value (MEV)
Value that has been measured or estimated for a work station lasting 8 hours and is intended to protect workers from long term effects. MEV can be exceeded for very short periods providing the ELV value (should there be one) is not exceeded.

Median lethal concentration (LC_{50})
Concentration of a substance deduced statistically that should, during exposure and for a given period of time or subsequently, cause the death of 50% of the animals exposed during a given period of time.

Melting point (cf page 44)
Temperature at which solid and liquid state co-exist. The melting point is a constant for a pure substance and is usually calculated at standard atmospheric pressure (one atmosphere).

Minimum Risk Level (MRL)
This level is an estimate of daily human exposure to a chemical which probably has no appreciable risk of non-carcinogenic harmful effect on health for a specific exposure duration.

Miscible
Matter that mixes readily with water.

No Observed Effect Concentration (NOEC)
Concentration measured after chronic toxicity testing and for which no effect has been observed. The substance does not cause chronic toxicity below this concentration.

No Observed Effect Level (NOEL)
The highest dose of a substance that causes no distinct changes as compared with those observed in control animals.

N-octanol/water partition coefficient (Kow)
Ratio of the equilibrium concentrations of a substance dissolved in a two phase system made up of two solvents that virtually do not mix.

Olfactory threshold
Minimum air or waterborne concentration to which the human nose is sensitive.

Organic carbon/water partition coefficient (Koc) (for organic substances)
Ratio of the amount of compound absorbed per unit mass of organic carbon in the soil or in a sediment and the concentration of the same compound in a water solution in a state of equilibrium.

Photo-oxidation
Oxidation of a chemical compound caused by exposure to light energy.

Polymerisation
This term describes the chemical reaction generally associated with the production of plastics. Fundamentally, the individual molecules of a chemical (liquid or gas) react together to form a long chain. These chains can be used for many applications.

Protective equipment
This means the respiratory or physical protection of a human being. Protection levels have been defined, including both protective clothing and breathing apparatus as accepted by response authorities such as the USCG, NIOSH and the EPA (US).
Level A: an SCBA (Self contained breathing apparatus/respirator) and fully air and chemical-tight suit (that resists permeation).
Level B: an SCBA and a suit that protects against liquid spray (splash proof).
Level C: a full face mask or goggles and a suit that protects responders against chemicals (splash-proof).
Level D: overalls without a respirator.

Rate of evaporation or volatility (ether = 1)
The rate of evaporation expresses the number of times that a product takes to evaporate as compared with a benchmark substance (ether for instance) This rate varies with the nature of the product and temperature.

Regression speed
Speed at which a burning liquid slick reduces in thinness.
For a given liquid, this speed is constant regardless of the slick surface (slick diameter bigger than 2 metres). Regression speed allows to estimate the total duration of a fire if no-one tries to extinguish it. For instance for a 1,000 mm thick slick, the regression speed may be 10 mm/minute, the fire lasts for 1000/10 = 100 minutes.

Relative density
Ratio of the mass of a substance to that of water for a liquid or to that of air for a gas.

Relative vapour density
Weight of a volume of vapour or pure gas (without air) compared to that of an equal volume of dry air at the same temperature and pressure. A vapour density lower than 1 indicates that the vapour is lighter than air and will have a tendency to rise. When the vapour density is higher than 1 vapour is heavier than air and will tend to stay near ground level and spread.

Self-ignition temperature
Minimal temperature at which vapours ignite spontaneously.

Solubility
Quantity of a substance dissolved in water. It will depend on salinity and temperature.

Source of ignition
Examples of sources of ignition: heat, sparks, flame, static electricity and friction. Sources of ignition should always be eliminated when handling flammable products or responding to an emergency in risky areas (use explosion proof pumps and VHF walky-talkies).

Surface roughness
Length of a transfer area between the atmospheric layer and a contact surface. This will depend on the mean size of the roughness of the contact area and atmospheric parameters near the water surface. When the sea is calm it is of the order of 0.02 to 0.06 cm.

Surface tension
A constant that expresses the force owing to molecular interaction exerted at the surface of a liquid when it comes into contact with another surface (liquid or solid) and that affects surface dispersion.

Temporary Emergency Exposure Limits (TEEL)

Exposure times when there is no ERPG.
TEEL 0 is the threshold concentration below which a large part of the population will experience no effect on health.
TEEL 1 is equivalent to ERPG1, TEEL 2 is equivalent to ERPG2 and TEEL 3 is equivalent to ERPG3.

Threshold Limit Value (TLV)

Average limit value (weighted as a function of time) that people can be exposed to regularly at work 8 hours a day, 5 days a week without experiencing harmful effects. This value was defined and determined by ACGIH.
TLV-STEL
Mean weighted 15 minutes concentration that must never be exceeded at any time during the day.
TLV-TWA
Man weighted values for an eight hour period per day and forty hours a week.
TLV-ceiling
Ceiling values never to be exceeded not even for an instant.

Unconfined Vapour Cloud Explosion (UVCE)

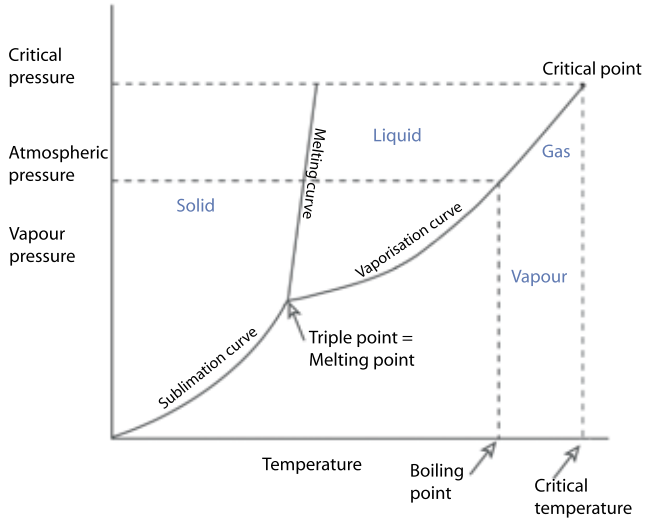
Explosion of a gas cloud or slick of combustible vapours in an unconfined environment.

Upper Explosive Limit (UEL)

Maximum airborne concentration of a compound above which vapours will not ignite for lack of oxygen.

Vapour pressure or tension

Partial pressure of gas molecules in a state of equilibrium with the liquid phase for a given temperature.



Phase diagramme of a pure substance

Acronyms

ACGIH	American Conference of Governmental Industrial Hygienists
ADN	Accords De Navigation
ADNR	Accord européen relatif au transport international des marchandises Dangereuses par voie de Navigation intérieure ("R" sur le Rhin)
ADR	Accords européens relatifs au transport international des marchandises Dangereuses par Route
AEGLs	Acute Exposure Guideline Levels
AIHA	American International Health Alliance
AFSSA	Agence Française de Sécurité Sanitaire des Aliments
ALOHA	Areal LOcations of Hazardous Atmospheres
AFFF	Agent Formant un Film Flottant
APRA	Appareil de Protection Respiratoire Autonome
ATSDR	Agency for Toxic Substances and Disease Registry
BCF	Bio Concentration Factor
BLEVE	Boiling Liquid Expanding Vapour Explosion
CAS	Chemical Abstracts Service
CE	Concentration Efficace
CEA	Commissariat à l'Energie Atomique
CEDRE	Centre de Documentation de Recherche et d'Expérimentations sur les pollutions accidentelles des eaux
CEFIC	Conseil Européen des Fédérations de l'Industrie Chimique
CHRIS	Chemical Hazards Response Information System
CL	Concentration médiane Létale
CME	Concentration Maximale d'Emploi
CSST	Commission de la Santé et de la Sécurité du Travail
CSTEE	Comité Scientifique sur la Toxicité, l'Ecotoxicité et l'Environnement
CTE	Centre de Technologie Environnementale
DDASS	Direction Départementale des Affaires Sanitaires et Sociales
DDE	Direction Départementale de l'Equipement
DIS	Déchets Industriels Spéciaux
DJA	Dose Journalière Admissible
DJE	Dose Journalière Efficace
DRASS	Direction Régionale des Affaires Sanitaires et Sociales
DRIRE	Directions Régionales de l'Industrie, de la Recherche et de l'Environnement
ECB	European Chemicals Bureau
EINECS	European INventory of Existing Chemical Substances
EPA	Environmental Protection Agency
EPI	Equipement de Protection Individuelle
ERPG	Emergency Response Planning Guidelines
FDS	Fiche de Données de Sécurité
HSDB	Hazardous Substances Data Bank
IATA	International Air Transport Association
IBC	International Bulk chemical Code
ICSC	International Chemical Safety Cards
IDLH	Immediately Dangerous to Life or Health concentrations
IFREMER	Institut Français de Recherche pour l'Exploitation de la MER
IGC	International Code for the Construction and Equipement of Ships Carrying Liquefied Gases in Bulk
IMDG	International Maritime Dangerous Goods
IMO	International Maritime Organization
INCHEM	INternational CHEMical industries
INERIS	Institut National de l'Environnement Industriel et des RISques

INRS	Institut National de Recherche et de Sécurité pour la prévention des accidents du travail et des maladies professionnelles
IPCS	International Programme on Chemical Safety
IPSN	Institut de Protection et de Sécurité Nucléaire
IUCLID	International Uniform Chemical Information Database
Koc	Cœfficient de partage carbone organique / eau
Kow	Cœfficient de partage octanol / eau
LIE	Limite Inférieure d'Explosivité
LLDPE	Linear Low Density PolyEthylene
LSE	Limite Supérieure d'Explosivité
MARPOL	MARine POLlution
MARVS	Maximale Admissible Relieve Valve System
MCA	Maritime and Coastguard Agency
MEDD	Ministère de l'Ecologie et du Développement Durable
MP	Marine Pollutant
MRL	Minimum Risk Level
NIOSH	National Institute for Occupational Safety and Health
NOAA	National Oceanic and Atmospheric Administration
NOEC	No Observed Effect Concentration
OCDE	Organisation de Coopération et de Développement Economique
OMI	Organisation Maritime Internationale
OMS	Organisation Mondiale de la Santé
PEC	Predicted Effect Concentration
PID	PhotoIonisation Detector
PNEC	Predicted No-Effect Concentration
ppm	Partie par million
pTBC	para Tertio Butyl Catéchole
PVC	Poly(Vinyl Chloride)
PVDC	Polychlorure de vinylidène
PVDF	Polyfluorure de vinylidène
SEBC	Standard European Behaviour Classification system of chemicals spilled into the sea
SEL	Seuil des Effets Létaux
SIDS	Screening Information DataSet
TEEL	TEmporary Exposure Limits
TGD	Technical Guidance Document
TLV-ceiling	Threshold Limit Values - ceiling
TLV-STEL	Threshold Limit Values - Short Term Exposure Limit
TLV-TWA	Threshold Limit Values - Time Weighted Average
TNO	Toegepast - Natuurwetenschappelijk Onderzoek In english: the Netherlands Organisation for Applied Scientific Research
UIISC	Unité d'Instruction et d'Intervention de la Sécurité Civile
US EPA	United States Environmental Protection Agency
UVCE	Unconfined Vapor Cloud Explosion
VHF	Very High Frequency
VLE	Valeur Limite d'Exposition
VCM	Vinyl Chloride Monomer
VME	Valeur Moyenne d'Exposition
v/v	volume à volume
ZDO	Zone de Défense Ouest

Useful internet addresses

Accord de Bonn, Système européen de classification, [on line],
Available at: http://www.bonnagreement.org/fr/html/counter pollution_manual/chapitre25.htm

AFSSA (Agence Française de Sécurité Sanitaire des Aliments), [on line],
Available at: http://www.afssa.fr

ATOFINA, [on line],
Available at: http://www.atofina.com/groupe/gb/f_elf_2.cfm

ATSDR (Agency for Toxic Substances and Disease Registry), [on line],
Available at: www.atsdr.cdc.gov/tfacts53.pdf

Cedre (Centre de documentation de recherche et d'expérimentations sur les pollutions accidentelles des eaux), [on line],
Available at: http://www.cedre.fr

CEFIC (Conseil Européen des Fédérations de l'Industrie Chimique), [on line],
Available at: http://www.ericards.net

Chemfinder : [on line],
Available at: http://chemfinder.cambridgesoft.com

CHRIS (Chemical Hazards Response Information System), [on line],
Available at: http://www.chrismanual.com

CRIOS (Carcinogenic Risk In Occupational Settings), [on line],
Available at: http://cdfc.rug.ac.be/HealthRisk/default.htm

CSST (Commission de la Santé et de la Sécurité du Travail), [on line],
Available at: http://www.reptox.csst.qc.ca

CSTEE (Comité Scientifique sur la Toxicité, l'Ecotoxicité et l'Environnement), [on line],
Available at: http://europa.eu.int/comm/food/fs/sc/sct/out117_en.pdf

CTE (Centre de Technologie Environnementale du Canada) [on line],
Available at: http://www.etc-cte.ec.gc.ca/etchome_f.html

Environnement Canada : Mesure de la pollution, [on line],
Available at: http://www.etcentre.org/databases/fuelcalc_f.html

European Chemicals Bureau, Risk Assessment, [on line]
Available at: http://ecb.jrc.it/existing-chemicals

Hygiène et sécurité du travail, Listes des Valeurs Limites d'Exposition et des Valeurs Moyennes d'Exposition, [on line],
Available at: http://www.inrs.fr/produits/pdf/nd2098.pdf

ICSC (International Chemical Safety Cards) Programme International sur la Sécurité des Substances Chimiques (Fiches), [on line],
Available at: http://www.cdc.gov/niosh/ipcs/french.html

IDLH Documentation for Immediately Dangerous to Life or Health concentrations, Liste de 387 produits (originale et révisée) [on line],
Available at: http://www.cdc.gov/niosh/idlh/intridl4.html

INCHEM (INternational CHEMical Industries . Inc.), [on line],
Available at: http://www.inchem.org et http://inchem.org/pages/ilodb.html (liste des ERPG)

INERIS (Institut National de l'Environnement industriel et des RISques), [on line],
Available at: http://www.ineris.fr

INRS (Institut National de Recherche et de la Sécurité pour la prévention des accidents du travail et des maladies professionnelles, [on line],
Available at: http://www.inrs.fr/index_fla.html

IPCS (International Programme on Chemical Safety) [on line],
Available at: http://www.ilo.org/public/english/protection/safework/cis/products/icsc

Lyondell, entreprise chimique : [on line],
Available at: http://www.lyondell.com/html/products/products/sm.shtml

NIOSH (National Institute for Occupational Safety and Health), [on line],
Available at: http://www.cdc.gov/niosh/homepage.html

NOAA (National Oceanic and Atmospheric Administration), historical incident search page, [on line],
Available at: http://www.incidentnews.gov/incidents/history.htm

Sécaline (Système d'informations et de conseils sur les produits et déchets toxiques), [on line],
Available at: http://www.secaline.alison-envir.com

SHELL, Fiches de sécurité (MSDS), [on line],
Available at: http://www.euapps.shell.com/MSDS/GotoMsds

UIC (Union des Industries Chimiques), [on line],
Available at: http://www.uic.fr

Université de Nancy-Metz, Fiche de sécurité, [on line],
Available at: http://www.ac-nancy-metz.fr/enseign/physique/chim/sc_fds.htm

US Departement of Energy's, Chemical Safety Program, liste des ERPG, [on line],
Available at: http://tis.eh.doe.gov/web/chem_safety/teel.html

U.S.-EPA (Environmental Protection Agency), [on line],
Available at: http://www.epa.gov

US EPA, liste des AEGLs, [on line],
Available at: http://www.epa.gov/oppt/aegl/chemlist.htm

ANNEXES

Annex 1: Synthesis and additional physical and toxicological information

Annex 2: Fax format card

Annex 3: Classification of noxious liquid substances

Annex 3b: New classification of noxious liquid substances

ANNEX 1: SYNTHESIS AND ADDITIONAL PHYSICAL AND TOXICOLOGICAL INFORMATION

Classification (CHRIS, 1999 & INRS, 1997)

CAS N°: 71-43-2
EINECS N°: 200-753-7
UN N°: 1114
Index N°: 601-020-00-8
Class: 3

Physical data

Conversion factor (air) — INERIS, 2000
1 ppm = 3.249 mg/m³
1 mg/m³ = 0.308 ppm

Molar mass : 78.11 g/mol — ATSDR (1997), HSDB (2000) in INERIS, 2000.

Liquid volume mass: 872-882 kg/m³ at 20°C — TOTAL, 2002
: 873.7 kg/m³ at - 4°C — ENVIROGUIDE, 1984
Volume mass of vapour : no data

Physical state: — INRS, 1997
Appearance: liquid.
Colour: colourless.
Odour: agreeable aromatic.

Density:
Relative density (fresh water =1): 0.88 at 20°C — INRS, 2000
Relative vapour density (air=1): 2.7 at 20°C — INRS, 2000
4 at 90°C — ENVIROGUIDE, 1984
Relative density of an air/vapour mixture at 20°C (air=1): 1.2 ICSC, 1993
Relative density sea water (25°C): no data

Solubility:
Solubility in seawater: (mg/litre) — Cedre, 2004

Average energy	No filtration	800 ± 150
	With filtration	500 ± 50
No energy		350 ± 100

Salinity 34‰, Air temperature 25°C

Solubility in freshwater at 20°C: 1780 mg/litre — FDS TOTAL, 2002
Solubility distilled water at 25°C: 1830 mg/litre — INCHEM (2000),
(Range: 1750-1880 at 20-25°C) — May (1983) Merck (1989), US-EPA (1996) in INERIS, 2000

Solubility in other compounds: — FDS TOTAL, 2002
Soluble in organic solvents, lipids, paraffin wax and oil wax, mineral oil, lube oil.
Solubility of water in benzene: no data

Emulsification: dissolved and emulsioned fraction, — Cedre, 2004
High energy (ultra turax): 740 $^{+}$- 110 mg/litre

Vapour tension: 10 kPa at 20°C — ICSC, 1993
37 kPa at 50°C — FDS TOTAL, 2002

Important temperatures:
Boiling point at 1 atm: 80.1°C — INRS, 1997
Melting point: 5.5°C — INRS, 1997
Flash point (in closed capsule): -11.1°C — INRS, 1997
Self-ignition temperature: 538°C — INRS, 1997
Critical temperature: 288.9°C — CHRIS, 1999

Other properties
Henry's law constant: 558.16 Pa.m^3/mol at 25°C — Mackay (1975, 1979), Pengs (1998) STF (1991), US EPA (1996) Verschueren (1996) in INERIS, 2000
(Range: 4.33 – 5.99.10-3 atm.m^3/mol at 20-25°C)

Diffusion coefficient in air: 0.088 cm²/s at 25°C — STF (1991), US EPA (1996)
(Range: 0.077 – 0.088 cm²/s) — in INERIS, 2000

Diffusion coefficient in water: 9,8.10^{-6} cm²/s at 25°C — STF (1991), US EPA (1996)
(Range: 9.8.10^{-6} - 1.09.10^{-5} cm²/s) — in INERIS, 2000

Dynamic viscosity: 0.6468.10^{-3} Pa.s at 20°C — HSDB (2000), Kirk-Othmer (1978), Prager (1995) in INERIS, 2000

Critical pressure: 48.3 atm — CHRIS, 1999

Surface tension: 28.9.10^{-3} N/m at 20°C — HSDB (2000), Prager (1995), Weiss (1986) in INERIS, 2000

28.18.10^{-3} N/m at 25°C — Kirk-Othmer (1978) in INERIS, 2000

Interface tension/liquid water: 0.035 N/m at 20°C — CHRIS, 1999

Rate of evaporation (diethyl oxide =1): 3 — INRS, 1997

Olfactory threshold:
In air: 2 ppm — CSST, 1991
12 ppm — INRS, 1997
In water: 2 mg/litre — HSDB (1996), ATSDR ,1997

Gustatory threshold:
0.5 - 4.5 mg/litre — HSDB (1996), ATSDR ,1997

Toxicological information

Threshold toxicological levels

IDLH: 500 ppm (1,624.5 mg/m³)	CHRIS, 1999
TLV-TWA: 0.5 ppm (1.624 mg/m³)	CHRIS, 1999
TLV-STEL: 2.5 ppm (8.12 mg/m³)	CHRIS, 1999
Ceiling: 25 ppm (81.225 mg/m³)	INRS, 1999
MRL acute inhalation: 0.05 ppm (0.16 mg/m³)	ATSDR (1997) in INERIS, 2000
VME: 1 ppm (3.25 mg/m³)	INERIS, 2000
TEEL 0: 1 ppm (3.25 mg/m³)	
ERPG 1: 50 ppm (163 mg/m³)	US EPA, 2003
ERPG 2: 150 ppm (489 mg/m³)	US EPA, 2003
ERPG 3: 1,000 ppm (3,250 mg/m³)	US Department of Energy's Chemical Safety Program 2002

General toxicity

Acute human toxicity: INRS, 1997 and ICSC, 1993

- By inhalation: neurological symptoms:
  25 ppm: no effect;
  50 to 100 ppm: headaches and asthenia;
  500 ppm: aggravated symptoms;
  3,000 ppm: tolerated for 30 to 60 minutes;
  20,000 ppm: death within 5 to 15 minutes;
  Convulsions observed at highest doses.
  Nausea, convulsions, vertigo, sleepiness, headaches, dyspnoea, loss of consciousness.
- Skin contact: irritation. Can be absorbed.
- Ingestion: abdominal pain, sore throat, vomiting, digestive problems, neurological impairment (could develop into a coma), pneumopathy, convulsions, vertigo, sleepiness, headaches, dyspnoea, loss of consciousness.
- Eye contact: moderate burning sensation, but epithelial cell lesions are small and transitory.

Chronic human toxicity: INRS, 1997

- Malignant haemopathy and lymphopathy:
  Leukemogenic power for an exposure of more than 100 ppm.
- Non malignant haematological disorders:
  Initial symptoms: Thrombopenia, leucopoenia, hyperleucocytosis, anaemia, rare cases of polycythemia, bone marrow failure.
  In most cases, symptoms recede when exposure is discontinued.
- Non haematological disorders:
  By inhalation: neuropsychic disorders (irritability, attention deficit and memory impairment, depressive syndrome, sleep disorders); digestive disorders (nausea, vomiting, epigastralgia).
  By skin contact: topical irritation.

Specific effects

Carcinogenic effects: demonstrated in humans (E. U category 1 and IARC group 1).
Effects on fertility: not demonstrated in humans or lab animals.
Teratogenic effects and/or on foetal development: not demonstrated in humans; delayed foetal growth experimentally in animals at does that are toxic for the mothers.
Genotoxic effect: not demonstrated in humans; demonstrated in vitro and in vivo in mammals.

Ecotoxicological data

Acute ecotoxicity

Seaweed: *Selenastrum capricornutum* (freshwater)	CE_{50b} (72h) = 28 mg/litre	TNO (2000) in ECB, 2002
Seaweed: *Selenastrum capricornutum* (freshwater)	CE_{50c} (72h) = 100 mg/litre	TNO (2000) in ECB, 2002
Micro-crustaceans: *Daphnia magna* (freshwater)	CE_{50} (48h) = 10 mg/litre	Jansen & Persoone (1993) in INERIS, 2000
Crustacean: *Artemia salina* (seawater)	CL_{50} (48h) = 20 mg/litre	Price et al. (1974) in INERIS, 2000
Crustacean: *Palaemonetes* pugio (seawater)	CL_{50} (96h) = 27 mg/litre	Tatem et al. (1978) in INERIS, 2000
Fish: *Oncorhynchus mykiss* (freshwater)	CL_{50} (96h) = 5.3 mg/litre	DeGraeve et al. (1982) in INERIS, 2000
Fish: *Morone saxatilis* (seawater)	CL_{50} (96h) = 9.6 mg/litre	Meyerhoff (1975) in INERIS, 2000

b: biomass
c: growth rate

Sediments : no results available for benthic organisms (INERIS, 2000).
Terrestrial organisms: no valid test results available for the terrestrial compartment (INERIS, 2000).

Chronic ecotoxicity

Seaweed: *Selenastrum capricornutum*	CE_{10b} (72h) = 8.3 mg/litre CE_{10c} (72h) = 34 mg/litre	TNO (2000) in INERIS, 2000
Micro-crustaceans: *Ceriodaphnia dubia*	NOEC (7days) = 3 mg/litre	Niederlehner et al. (1998) in INERIS, 2000
Fish: *Pimephales promelas* (larva)	NOEC (32days) = 0.8 mg/litre	Russom et Broderius (1991) in INERIS, 2000

Sediment: no results available for benthic organisms.

Terrestrial organisms: no results available.

PNEC (Predicted No-Effect Concentration): according to the Technical Guidance Document pursuant to EC Regulation1488/94 concerning risk assessment for existing substances, the calculated PNEC for water would be 80 µg/litre. A safety factor of 10 is applied to the lowest value of the three trophic levels (three chronic values).

ANNEX 2 : FAX FORMAT CARD

BENZENE

Annulene, Benzol, Benzole, Benzolene, Carbon oil, Coal naphta, Cyclohexatriene, Mineral naphta, Motor benzol, Phene, Phenyl hydride, Pyrobenzol, Pyrobenzole, Bicarburet of hydrogen

C_6H_6

CAS N°: 71- 43 - 2
EC N°(EINECS): 200-753-7
Index N°: 601-020-00-8
UN N°: 1114
Class: 3

First aid information

Inhalation: onset of anaesthetic effects if large concentrations of benzene vapour have been inhaled, take the victim outside into the open air; apply oxygen or artificial respiration if needed, admit to hospital in the event of disorder.

Skin contact: remove contaminated clothes; rinse and wash the skin with plenty of water; see a doctor.

Poisoning by ingestion: no liquid must be drunk and do not force the patient to vomit; see a doctor or admit to hospital if the contamination is serious.

Eye contact: can cause irritation in the event of prolonged contact; rinse first of all with plenty of water for several minutes and widen the eyelids; remove contact lenses if possible; see a doctor.

Physical data

Conversion factor: 1 ppm = 3.249 mg/m³
1 mg/m³ = 0.308 ppm
Relative density (water=1): 0.88 at 20° C
Relative vapour density (air=1): 2.7 at 20° C
Solubility in freshwater: 1,780 mg/litre at 20° C
1,830 mg/litre at 25° C
Solubility in seawater: 350 ± 100 mg/litre at 25° C and 34 ‰
Pressure/Vapour tension: 10 kPa at 20° C
37 kPa at 50° C
Olfactory threshold: in freshwater: 2 mg/litre
in air: 2 to 12 ppm
Evaporation rate (diethyl oxide=1): 3
Diffusion coefficient in water: $9.8.10^{-6}$ cm²/s at 25° C
Diffusion coefficient in air: 0.088 cm²/s at 25° C
Henry's law constant: 558.16 Pa.m³/mol at 25° C
Flash point: -11.1° C
Melting point: 5.5° C
Boiling point: 80.1° C

F: Readily flammable

T: Toxic

R11: Readily flammable.
R45: Can cause cancer.
R48: Risk of serious effects on health in case of prolonged exposure.

R/23/24/25: Toxic if inhaled, by skin contact and ingestion.

S45: In case of accident or discomfort, see a doctor.

S53: Avoid exposure, get special instructions prior to use.

200-753-7: E.C labelling

Toxicological data

Threshold toxicological data

IDLH: 500 ppm (1624.5 mg/m³)

TLV-TWA (8h): 0.5 ppm (1.6mg/m³)

TLV-STEL (15 min): 2.5 ppm (8 mg/m³)

MRL inhalation: 0.05 ppm (0.16 mg/m³) in the event of acute exposure

VME: 1 ppm (3.25 mg/m³)

TEEL 0: 1 ppm (3.25 mg/m³)

ERPG 1: 50 ppm (163 mg/m³)

ERPG 2: 150 ppm (489 mg/m³)

ERPG 3: 1,000 ppm (3,250 mg/m³)

Specific effects

Carcinogenic effects: demonstrated in humans (category 1 E.U. and group 1 - IARC).
Effects on fertility: not demonstrated.
Teratogenic effects and/or on foetal development: not demonstrated in humans.
Genotoxic effects: not demonstrated in humans.

Acute human toxicity

By inhalation: neurological symptoms.
Skin contact: irritation.
By ingestion: abdominal pain, sore throat and head ache, vomiting, digestive disorders, neurological disorders (can lead to coma), pneumopathy, convulsions, vertigo, sleepiness, dyspnoea, loss of consciousness.
Eye contact: moderate feeling of burning.

Chronic human toxicity

Malignant haemopathy and lymphopathy:
- Leukemogenic power for exposures in excess of 100 ppm.

Non malignant haematological disorders:
- Thrombopenia, leucopoenia, hyperleucocytosis, anaemia, rare cases of polycythemia, bone marrow failure.
- In most cases, signs recede when exposure is discontinued.

Non haematological toxicity:
- By inhalation: neuropsychic disorders, digestive disorders.
- By skin contact: local irritation.

Ecotoxicological data

• **Acute ecotoxicity** (mg/litre):

Seaweed (*Selenastrum capricornutum*)	CE_{50b} (72h) = 28 (freshwater)
Seaweed (*Selenastrum capricornutum*)	CE_{50c} (72h) = 100 (freshwater)
Microcrustaceans (*Daphnia magna*)	CE_{50} (48h) = 10 (freshwater)
Crustaceans (*Palaemonetes pugio*)	CL_{50} (96h) = 27 (seawater)
Fish (*Oncorhynchus mykiss*)	CL_{50} (96h)= 5.3 (seawater)
Fish (*Morone saxatilis*)	CL_{50} (96h)= 9.6 (seawater)

• **Chronic ecotoxicity** (mg/litre)

Seaweed (*Selenastrum capricornutum*):	CE_{10c} (72h) = 34
Seaweed (*Selenastrum capricornutum*):	CE_{10b} (72h) = 8.3
Microcrustaceans (*Ceriodaphnia dubia*):	NOEC (7days) = 3
Poissons (*Pimephales promelas*) (larva):	NOEC (32days) = 0.8

• Calculated **PNEC** for water 80 µg/litre

b: biomass; c: growth rate

Persistence in the environment

Soil: benzene is mobile in soil and evaporates on the soil surface. It can then be mediated towards surface and underground waters.

Water: evaporates rapidly.

Atmosphere: mainly in gas form. Benzene is degraded when reacting with hydroxyl radicals formed by photochemical reactions.

Degradation: Readily biodegradable: 86 % to 100 % after 28 days. The estimated half life is 15 days in water (TGD).

• **MARPOL classification:** C until 31/12/2006
Y from 01/01/2007

• **SEBC Classification:** E

• **Octanol/water partition coefficient:**
log Kow = 2.13

• **Organic carbon/water partition coefficient:**

Koc = 134 litre/kg

BCF (fish) < 10 - 11

BCF (mollusc): < 1

BCF (estimated) = 13

Special risks

Polymerisation: no
Benzene is a stable chemical.

Danger
- As the benzene recipient heats up, pressure builds up causing a risk of tank failure or BLEVE.
- Benzene can form explosive mixtures with air.
- Vapours are invisible and heavier than air. They spread along the ground, enter the sewers and underground areas.

Reacts with water: no

Fire:
- Explosive limits in air (%): LEL: 1.2; UEL: 8
- Smoke produces toxic carbon oxide vapours.
- Vapours form explosive mixtures with air.
- Flash point (in a closed capsule): - 11.1°C
- Self-ignition point: 538°C

Stability and reactivity:
- Benzene is a stable chemical under usual storage, handling and utilisation conditions.
- Readily flammable.
- Avoid coming too close to hot surfaces, flames, static electricity or sparks.
- Avoid strong acids and oxidisers, halogens (fluorine, bromine, chlorine, iodine).

Transportation

General data: Class: 3
Flammable liquid
Labels: 3

RID/ADR rail and road transportation
Hazard ID number: 33
Packaging group: II
Classification code: F1

ADN/ADNR
Substance ID number: 1114
Hazard ID number: 33
Identification code: F1

Maritime and air transportation: IMDG/IATA
Packaging group: II

Handling

- Keep in a well aired place.
- Avoid the formation or diffusion of vapour, smoke or aerosols in the atmosphere (especially during loading or unloading operations)
- Avoid all contact with the skin or the eyes.
- Do not eat, do not drink and do not smoke when handling benzene.
- If exposure is suspected, use appropriate PPEs and especially gloves.
- Avoid the build-up of static electricity and ground/earth all equipment.
- Wear hard boots and appropriate PPEs that do not generate static electricity.

Storage

- Store in a place protected from solar or other forms of radiation
- Store far from sources of heat.
- Use only recipients, seals and pipes, that resist aromatic hydrocarbons.
- Keep well away from all sources of ignition.
- Do not smoke.
- Provide a dyked area.

To be avoided: polymer, copper, aluminium.

Recommended: ordinary steel, stainless steel.
Advice for usage: Forbid air during transfers.

ANNEX 3 : CLASSIFICATION OF NOXIOUS LIQUID SUBSTANCES

Dangerous goods (IMO, 2002)

Regulations governing the carriage in bulk of hazardous liquid substances (MARPOL Annex II) provide valuable indications on the hazards that such substances can produce during transportation.
Noxious liquid substances are classified into 4 categories (A, B, C, D) starting with the most dangerous substances (MARPOL A) and ending with the least dangerous ones (MARPOL D).
The MARPOL classification system is based on risk assessment profiles for chemicals transported in bulk by sea, as defined by a GESAMP working group (Group of Experts on the Scientific Aspects of Marine Pollution).

Category A - Noxious liquid substances which, if discharged into the sea from tank washing or defalcating operations, are deemed to present a major hazard to marine resources or human health or can cause serious harm to amenities or other legitimate uses of the sea and therefore justify the implementation of strict pollution response measures.

Category B - Noxious liquid substances which, if discharged into the sea during tank washing or deballasting operations, are deemed to present a hazard to marine resources or human health and can harm amenities or other legitimate uses of the sea and therefore justify the implementation of special pollution response measures.

Category C - Noxious liquid substances which, if discharged into the sea during tank washing or deballasting operations, are deemed to be a minor risk for marine resources or human health or cause, to some extent, harm to amenities or other legitimate uses of the sea and therefore require special operating conditions.

Category D - Noxious liquid substances which, if discharged into the sea during tank washing or deballasting operations, are deemed to be a noticeable risk for marine resources or human health or have a very slight effect on amenities or other legitimate uses of the sea and therefore require certain precautions concerning operating conditions.

ANNEXE 3b: NEW CLASSIFICATION OF NOXIOUS LIQUID SUBSTANCES

Revised MARPOL Annex II (IMO, 2005)

The revised Annex II Regulations for the control of pollution by noxious liquid substances in bulk was adopted in October 2004. It includes a new four-category categorization system for noxious and liquid substances. The revised annex entered into force on 1 January 2007.

The new categories are:

Category X: Noxious Liquid Substances which, if discharged into the sea from tank cleaning or deballasting operations, are deemed to present a major hazard to either marine resources or human health and, therefore, justify the prohibition of the discharge into the marine environment;

Category Y: Noxious Liquid Substances which, if discharged into the sea from tank cleaning or deballasting operations, are deemed to present a hazard to either marine resources or human health or cause harm to amenities or other legitimate uses of the sea and therefore justify a limitation on the quality and quantity of the discharge into the marine environment;

Category Z: Noxious Liquid Substances which, if discharged into the sea from tank cleaning or deballasting operations, are deemed to present a minor hazard to either marine resources or human health and therefore justify less stringent restrictions on the quality and quantity of the discharge into the marine environment; and

Other Substances: substances which have been evaluated and found to fall outside Category X, Y or Z because they are considered to present no harm to marine resources, human health, amenities or other legitimate uses of the sea when discharged into the sea from tank cleaning of deballasting operations. The discharge of bilge or ballast water or other residues or mixtures containing these substances are not subject to any requirements of MARPOL Annex II.