



Toxic gas emissions and oxygen depletion in cargoes of wood pellets, wood chips and pulp wood (timber).

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Cargo hold entrances should have warning labels of potential low oxygen and toxic atmosphere.

Doors should be padlocked!!



# Seven fatalities and several seriously injured within 2 years, just in Sweden.

**June 28, 2005** Fishing vessel "Lyni", in Karlskrona. Two persons die and one is injured after entering a hold with rotting fish remains.

**Aug 19, 2005** Cargo ship "Eken", in Gruvön/Värmland. One crew member dies after entering a storage room adjacent to a hold with timber.

**Nov 16, 2006** Cargo ship "Saga Spray", in Helsingborg. One crew member dies and seven others are injured, one stevedore seriously, after entering a stairways next to an almost empty hold where wood pellets were just discharged.

**Dec 21, 2006** Cargo ship "Noren", in Skellefteå. One crew member dies after entering a storage space adjacent to a hold with timber.

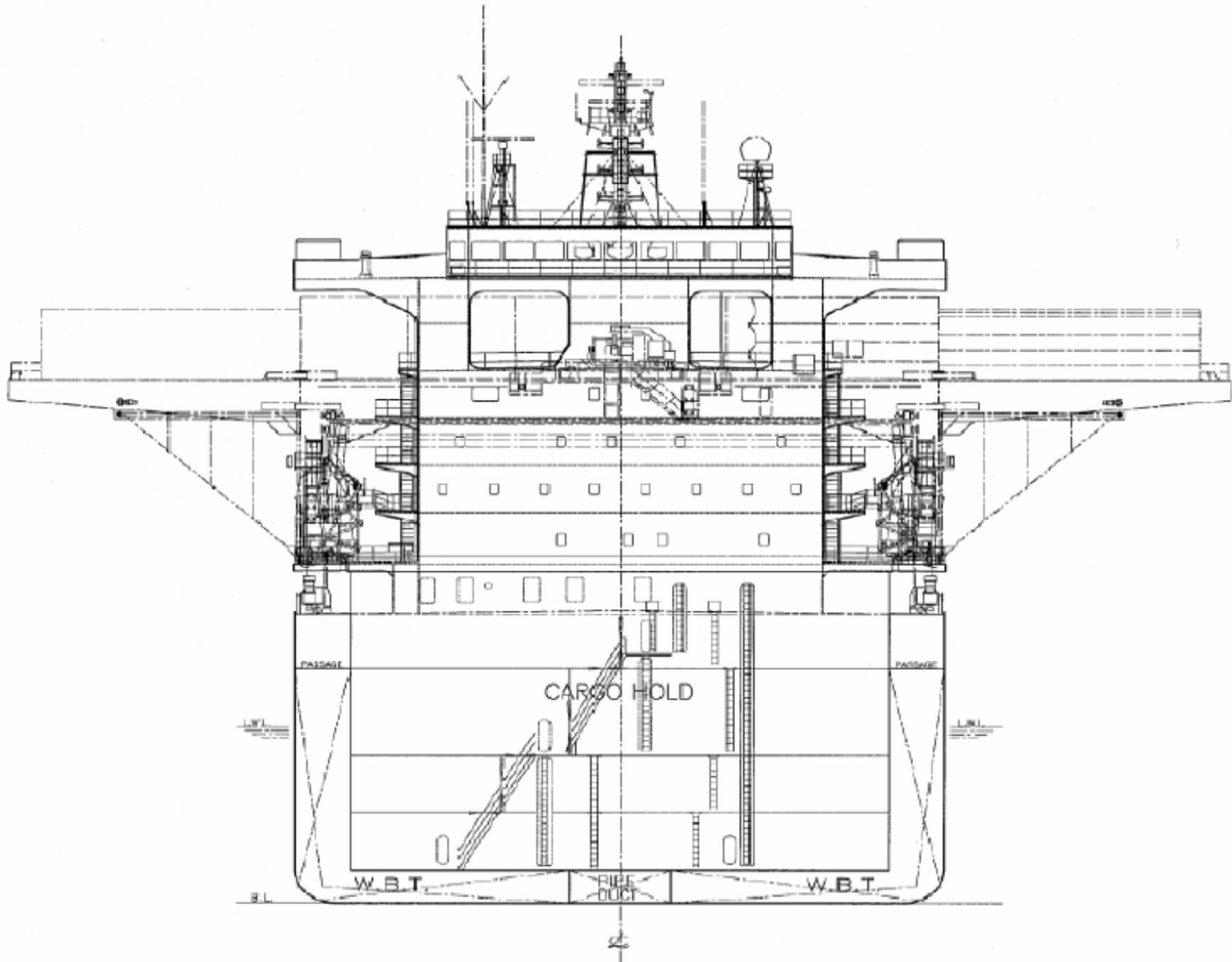
**May 2007** Cargo ship **MS Fembira**, in Timrå. Two persons, a crew member and the captain, die after entering the stairway leading to a hold with pulp wood. The captain tries to rescue the crew member.

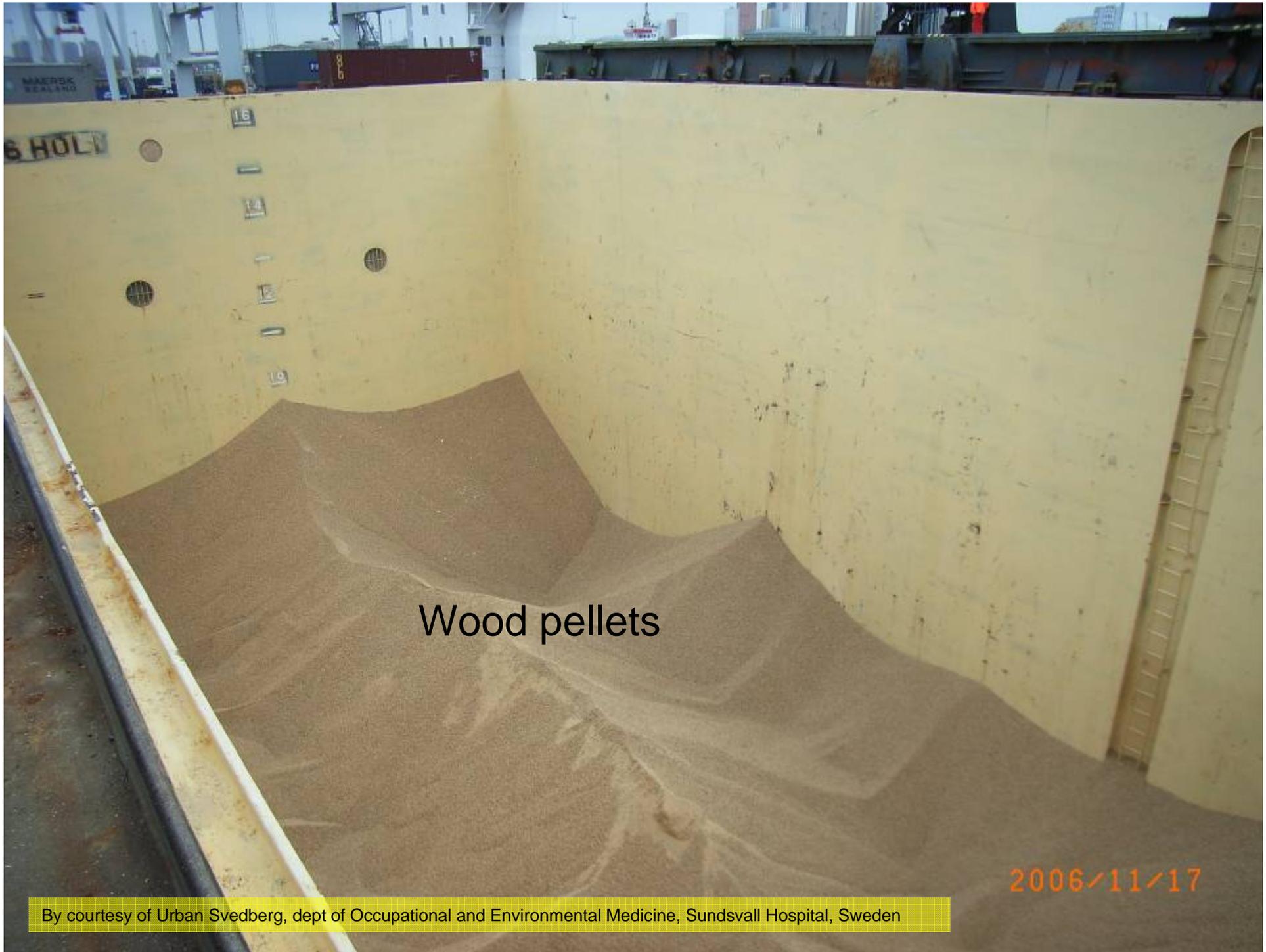
# Who is at risk when an accident happens?

- Ship crew
- Port crew
- Rescue services



By courtesy of Urban Svedberg, dept of Occupational and Environmental Medicine, Sundsvall Hospital, Sweden





Wood pellets

2006/11/17

By courtesy of Urban Svedberg, dept of Occupational and Environmental Medicine, Sundsvall Hospital, Sweden



By courtesy of Urban Svedberg, dept of Occupational and Environmental Medicine, Sundsvall Hospital, Sweden



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This is where people die, in the stairways!

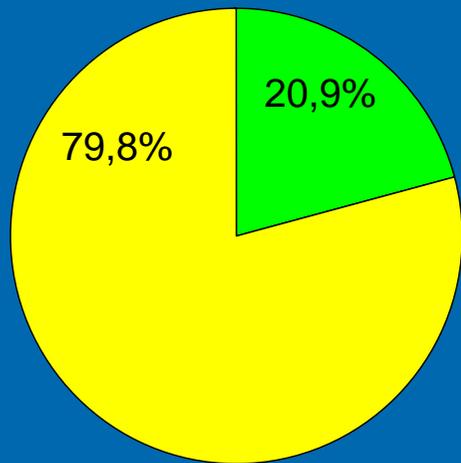


By courtesy of Staffan Melin, DRC, Vancouver, British Columbia, Canada

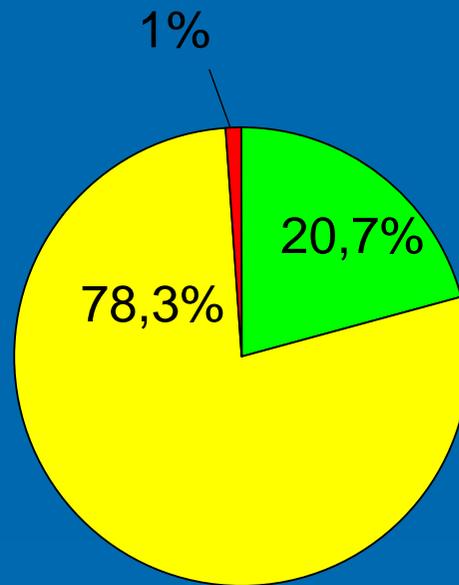
## Results from air measurements on 5 ships with wood pellets\*.

	Ship 1	Ship 2	Ship 3	Ship 4	Ship 4	Ship 5	Ship 5
	Hold	Hold	Hold	Stairway	Stairway	Hold	Stairway
	Nov 06	Jan 07	Feb 07	Feb 07	Mars 07	Okt 07	Okt 07
CO ppm	<b>5850</b>	<b>6980</b>	<b>14650</b>	<b>10960</b>	<b>11510</b>	<b>11950</b>	<b>7710</b>
CO2 ppm	<b>9340</b>	<b>3240</b>	<b>7070</b>	<b>5450</b>	<b>5160</b>	<b>21570</b>	<b>12360</b>
HC ppm	<b>883</b>	<b>523</b>	<b>1474</b>	<b>1094</b>	<b>810</b>	<b>1546</b>	<b>923</b>
Oxygen %					<b>5%</b>	<b>0.8%</b>	<b>8.4%</b>

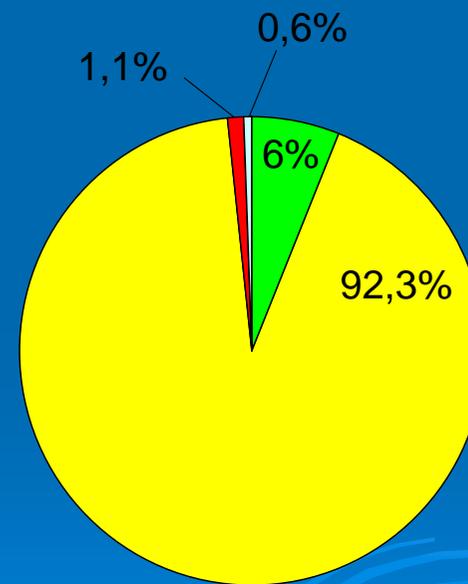
*\*U Svedberg, J Samuelsson, S Melin. Annals of Occupational Hygiene Vol 52 (4) pp 259-266, 2008*



Fresh air



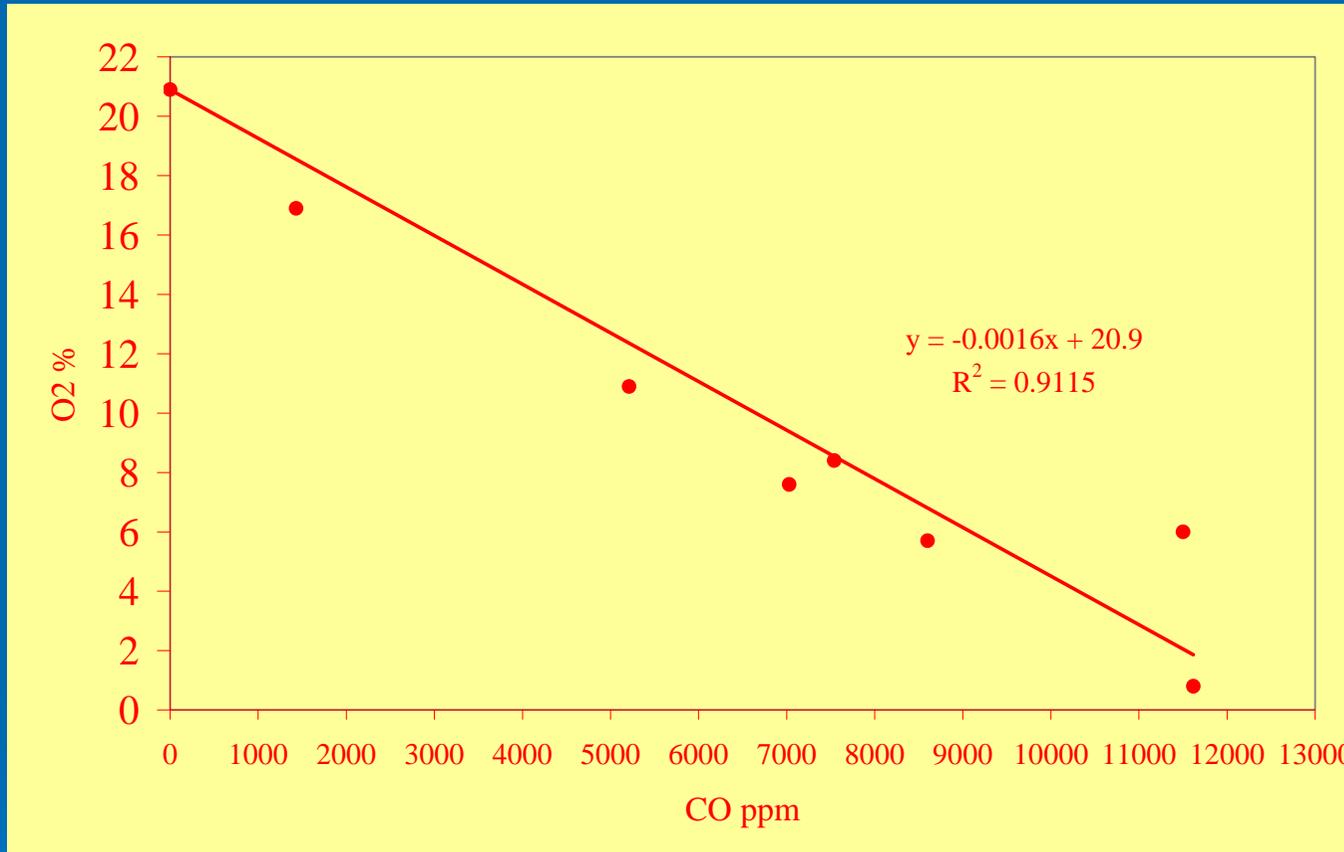
1%CO in fresh air



Stairway Ship #4

- Oxygen
- Nitrogen
- CO
- CO2

The relationship between oxygen and carbon monoxide in holds with wood pellets.



Little or no margin of safety against CO poisoning if Oxygen is measured alone.

## Health effects on man to inhalation of atmosphere deficient in oxygen

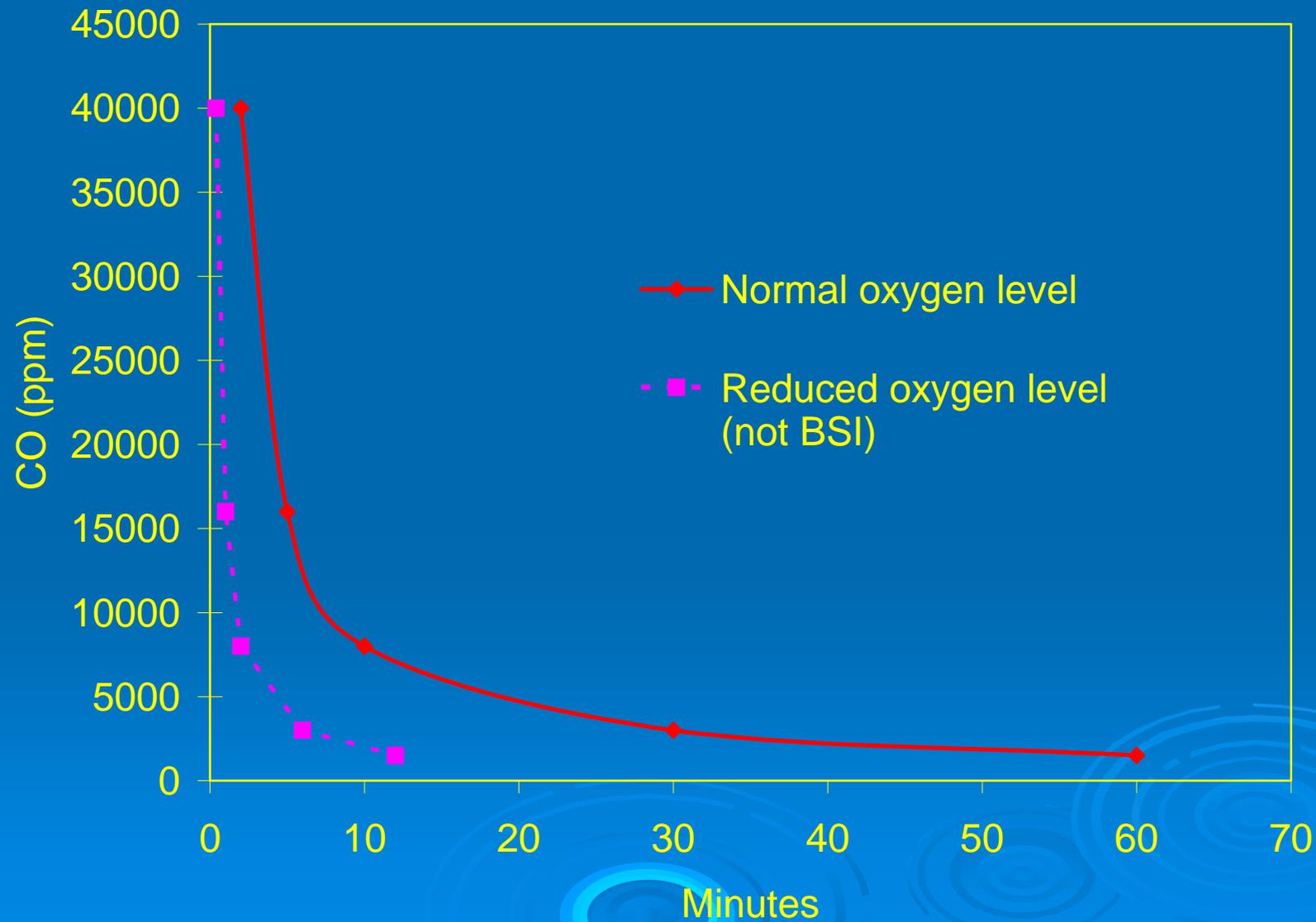
Oxygen level	Altitude eqv	Symptom Effect
21%	0	
19.5%	600 m	OSHA & NIOSH exposure limit
16%	2500 m	Acute height sickness upon rapid ascent
12-16%	2500- 5000 m	Breathing and pulse rate increased, muscular coordination slightly disturbed
10-14%	3500-6000 m	Consciousness continues, emotional upsets, abnormal fatigue upon exertion, disturbed respiration
6-10%	6000- 11000 m	Nausea and vomiting, inability to move freely, loss of consciousness may occur, although aware of circumstances may not be able to move or cry out
<6%	> 11 000 m	Convulsive movements, gasping respiration, respiration stops, death

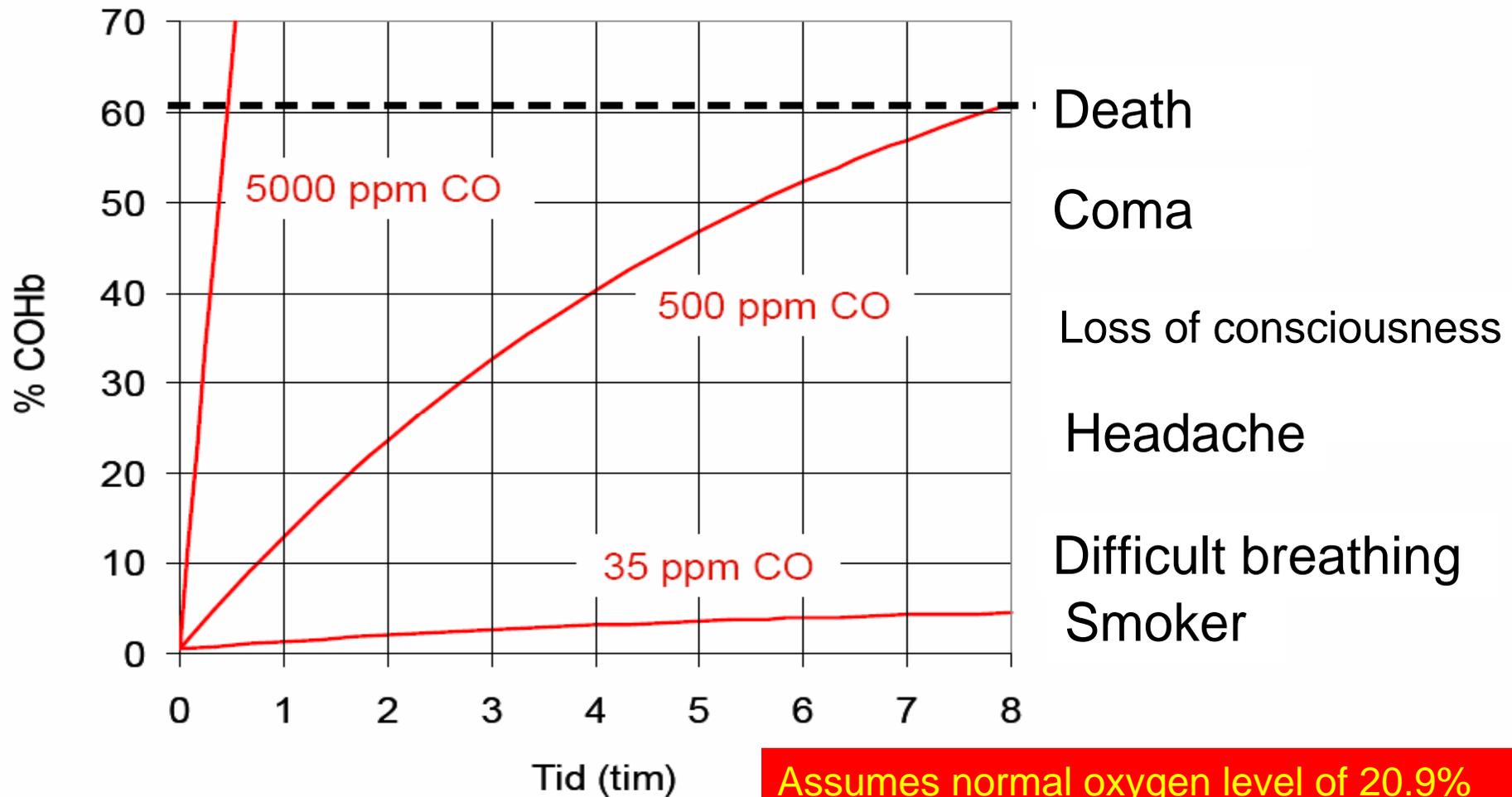
Oxygen level	Time of useful consciousness
7%	1 minute
5%	20 seconds
3.5%	15 seconds

*Patty, vol 3, 2001*

# Lethal exposures to CO

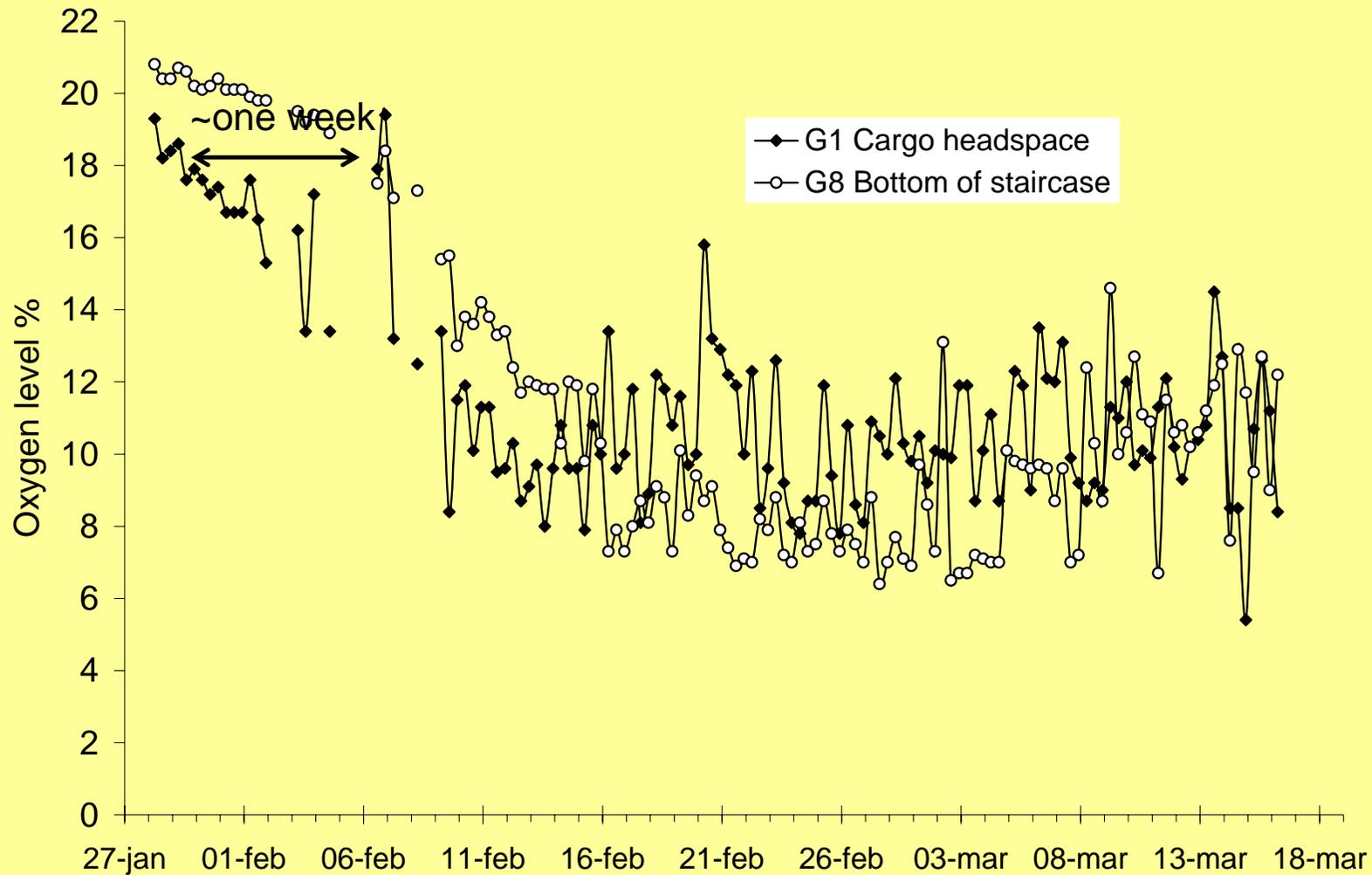
(The British Standards Institution, 1989)





*Coburn, Forster & Kane 1965 och Steinberg & Nielsen 1977*

# How quickly does the oxygen disappear? Results from one voyage with wood pellets loaded in Vancouver and discharged in Sweden.



Accidents in connection with the transport of wood chips and pulp wood, apparently harmless cargoes.



Two people died here!

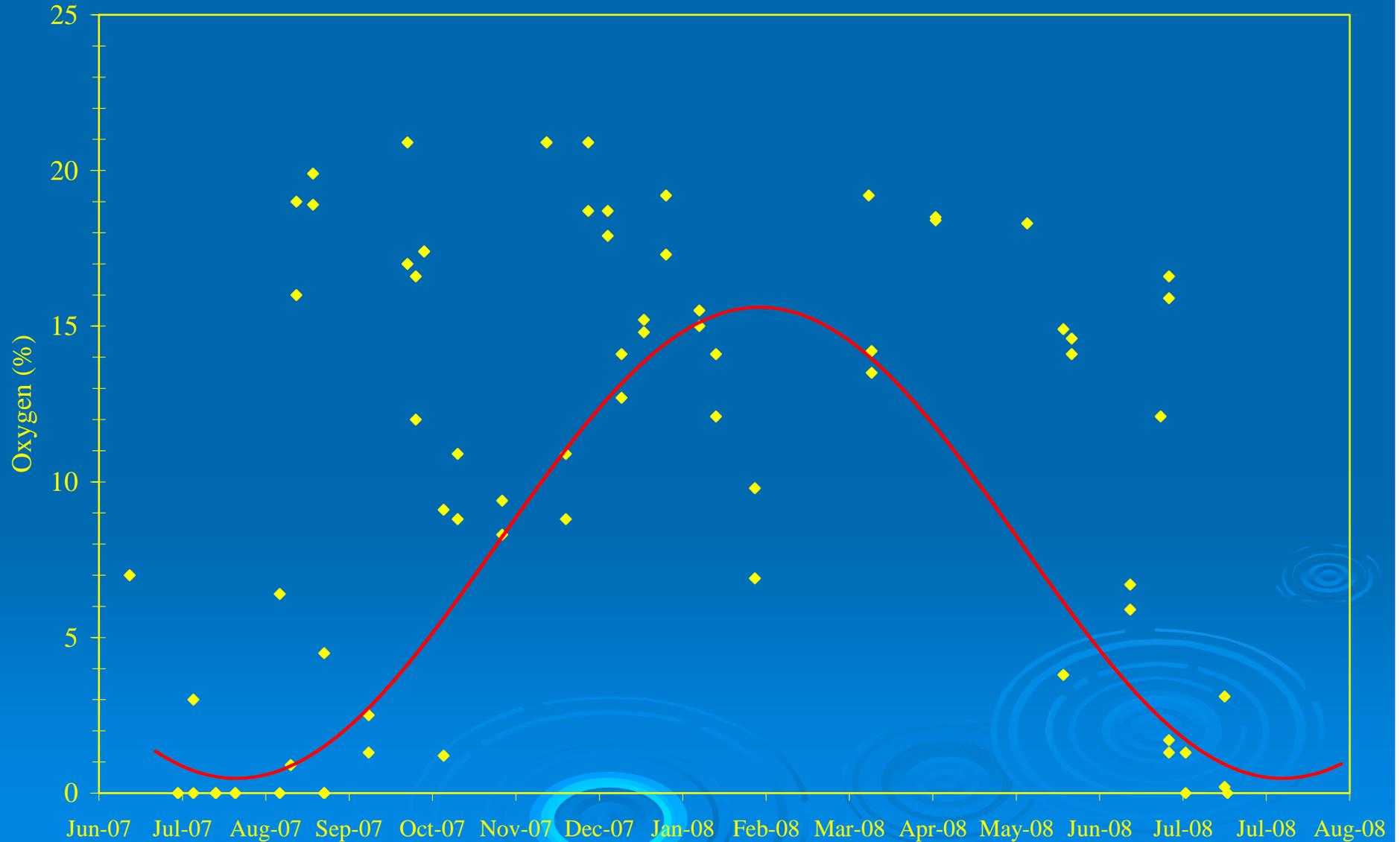
2007 / 6 / 17



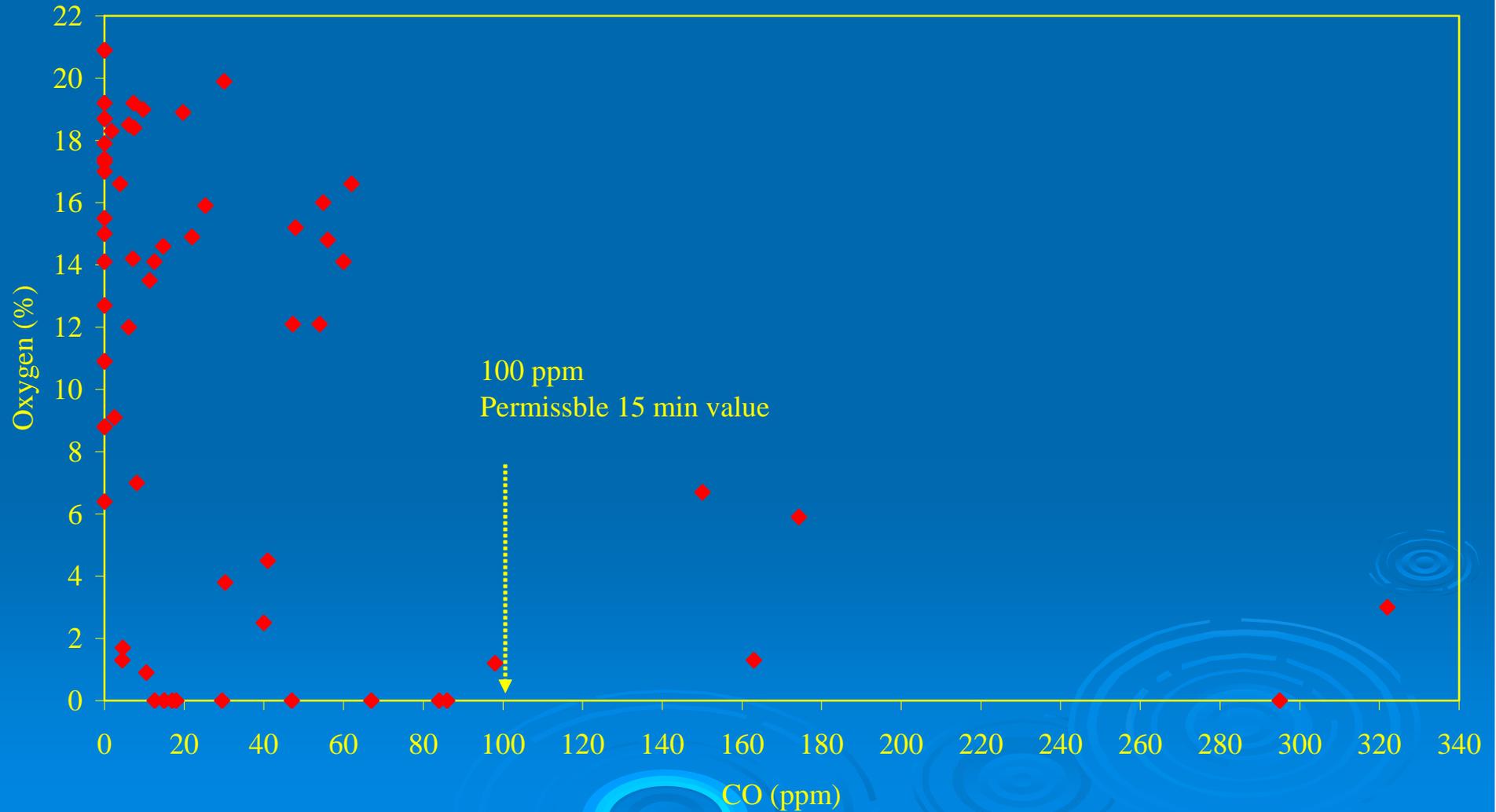
## Results from air sampling in stairways next to cargo holds with wood chips and pulp wood. After 2-3 days at sea!!!

Ship	Cargo	% O <sub>2</sub>	CO <sub>2</sub> ppm	CO ppm	
F	Wood chips	7	30 380	8	
L	Wood chips	0.9	152 000	10	
EH	Pulp wood	16	43 087	55	
Sel	Pulp wood	19.9	28 000	20	
F	Pulp wood	0	153 000	13	
See	Wood chips	12	82 600	6	
F	Pulp wood (birch)	0		18	
F	Pulp wood	0		322	
F	Pulp wood	0		17	
F	Pulp wood	0		86	
F	Pulp wood	6.4		67	
<b>Exposure limit</b>		<b>19,5-20,9</b>	<b>10 000</b>	<b>100</b>	

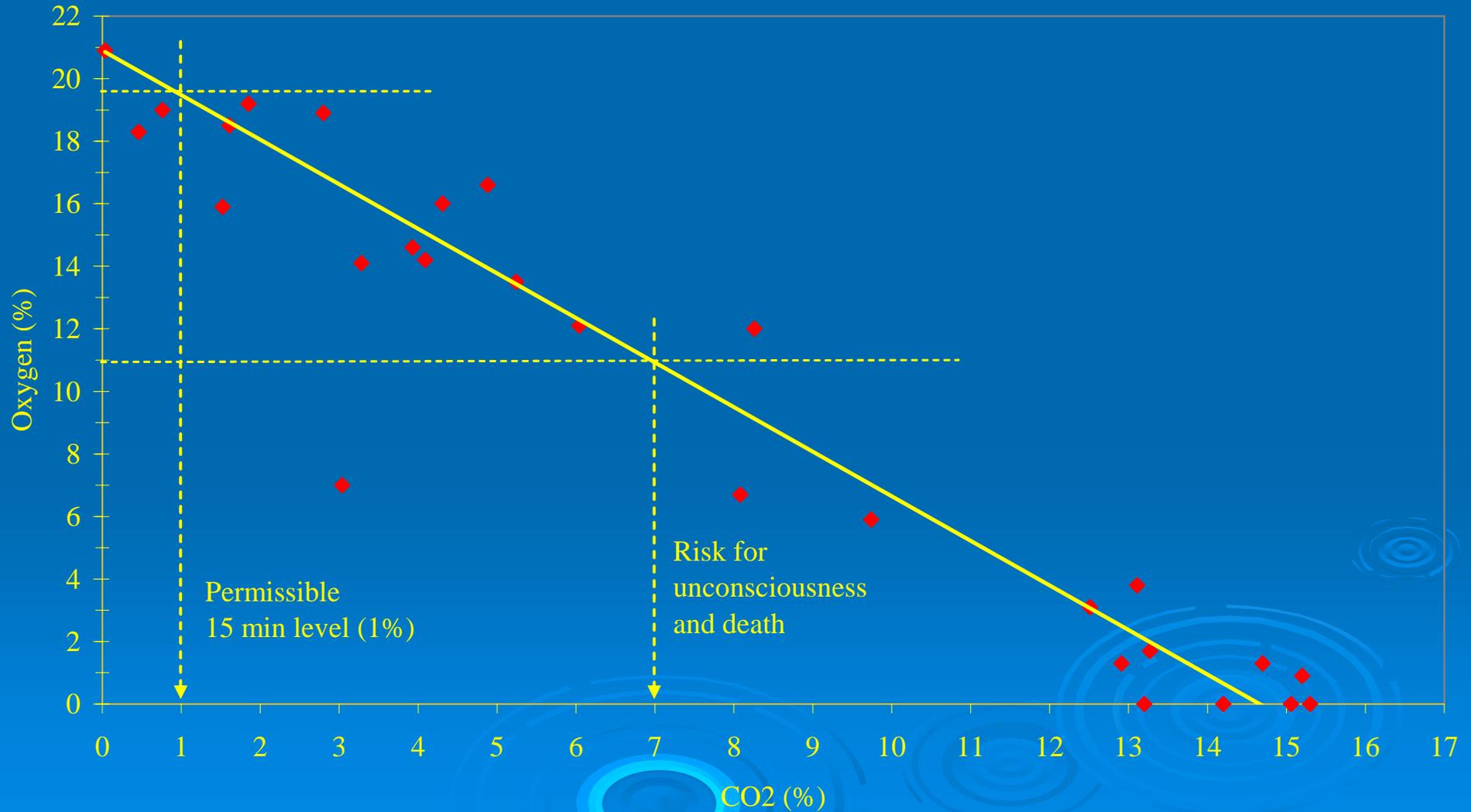
# Seasonal variation of oxygen level in cargoes with wood chips and pulp wood



# Good safety margin against CO poisoning if only oxygen is measured in cargoes of wood chips and pulp wood.



# Good safety margin against CO2 poisoning if only oxygen is measured in cargos of wood chips and pulp wood.



# Summary

## Wood pellets

- Produces high concentrations of CO
- Relatively slow oxygen depletion
- Chemical autoxidative processes

## Wood chips and pulp wood (timber)

- Produces high concentrations of CO<sub>2</sub>
- Relatively fast oxygen depletion
- Microbiological processes

The following products are listed as oxygen depleting in the International Maritime Solid Bulk Cargoes Code (IMSBC Code).  
**All these may cause a dangerous atmosphere in stairways!.**

brown coal briquettes

charcoal

coal

copra

direct reduced iron (B)

ferrosilicon UN 1408

ferrous metal borings (shavings, turnings or cuttings UN 2793)

fish (in bulk)

fish meal (fishscrap)

iron oxide (iron sponge)

metal sulphide concentrates

mineral concentrates

silicomanganese and tapioca peat moss

seed cake

# Ventilation of stairways

2006/11/17

# Different designs of stairways

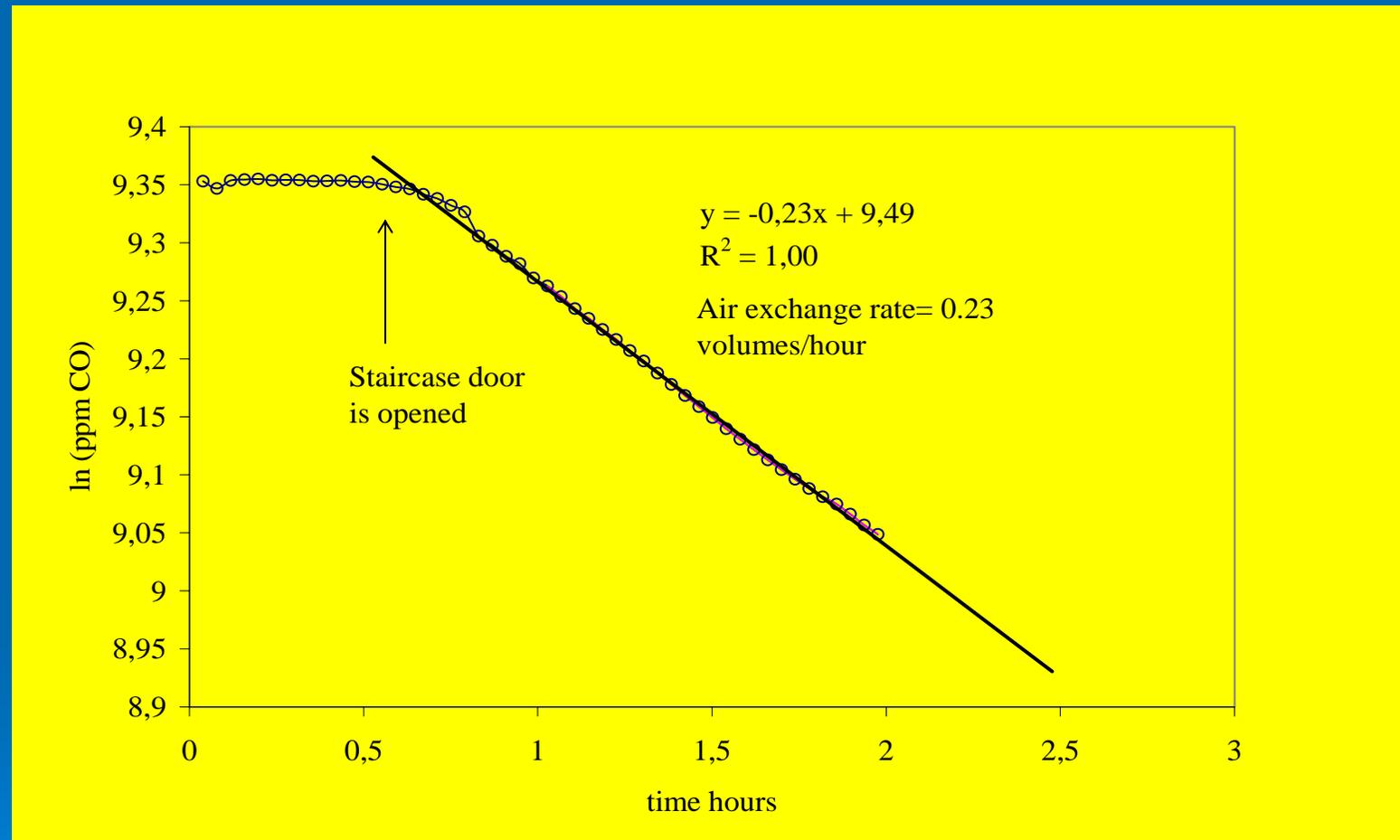
Stairways that are sealed with doors to the hold



Stairways that are open to the hold



# How long do we need to ventilate a stairway by natural ventilation? In this case 21 hours!!



To reach the acceptable 15-min value of 100 ppm (ln 4.6) it takes 21 hours. This example from a stairway, sealed to the hold with the stairway access door open.

## Suggestions regarding ventilation of stairways

The best solution is if ventilation of stairways is balanced with mechanical supply and exhaust air to reduce the risk of toxic supply air being drawn from the hold.

The second best solution is to blow air into the bottom of the stairway thus displacing contaminating air to the outside.

Drawing air from the bottom of stairway should be avoid because of the risk of drawing toxic supply air from the hold.

If the stairways doors are closed after ventilating, renewed ventilation may be required before reentry if hold has not been emptied.

A stairway with open access to hold should never be entered until hold is empty.

Risk of unventilated pockets of air.

Displaced contaminated air should be released outside, not into access rooms or semi-closed spaces.

Risk of fire if wood pellets are ventilated and the temperature is allowed to rise.

**DO NOT VENTILATE WOOD PELLETS AT SEA!!!**



On some ships the access door to the hold is located in a  
enclosed room. Access doors are never gas tight and the  
entry room may have a dangerous atmosphere.



# What should be measured prior to entry into enclosed space?

## Provisional quick manual

	<b>1 Required</b>	<b>2 Required</b>	<b>3 Optional</b>	<b>4 Optional</b>
Wood Pellets	O2 20.9 %	CO <100 ppm		
Wood chips Pulp wood Timber	O2 20.9 %		CO <100 ppm	CO2 <1%

# Measurement equipment

- Hand-held (clip-on) multi gas monitors O<sub>2</sub>, CO, H<sub>2</sub>S, LEL, (CO<sub>2</sub>)
- Equipped with sound, light and vibration alarms.
- Possibility to measure through a long (8m) sampling tube to reach the bottom of stairways without entering.
- Regular calibration and service
- Check performance after shock exposures.





Using enclosed spaces for storage may cause accidental entry into toxic atmosphere.

2008 / 3 / 10

## Suggestions for improved safety in stairways

Eliminate risks caused by the "human factor". Compare with the airline industry where technical devices take over when humans fail.

Keep entry doors to confined spaces pad-locked at all times. Only authorized persons should release key.

Open access doors should be fitted with a chain with a warning sign indicating that ventilation is under process and entry prohibited, thus preventing accidental entry.

Warning signs indicating oxygen deficient area should be placed on the front and back of doors, being visible when the door is closed and open.

Always measure oxygen and dangerous gases before entry into confined spaces.

A gas-monitor should always be worn when entering confined spaces.

## More suggestions

Re-design (on new ships) of stairways and entry doors making access easier. Avoid vertical ladders. Vision a rescue situation.

Fitting of mechanical ventilation in stairways which have doors to the hold.

No entry should be allowed into stairways which have open access to the hold, until the hold is emptied.

Fitting of sampling lines (stainless steel) in stairways to simplify sampling from the outer deck.

Personal protective equipment such as charcoal filters will not protect against CO or oxygen deficiency. SCBA must be worn when entering a dangerous atmosphere.

Storage of tools and supplies in confined spaces should be prohibited, thus preventing accidental entry.

## Even more suggestions

Sometimes it may be safer to lower crew into and out of holds instead of using stairways.

Establishment of strict routines and responsibilities for entry into confined spaces.

Up-grading of the BC-code and harmonizing instructions for all oxygen depleting goods and confined spaces.

Continued education and training of crew

Certification has been suggested



# Hazardous Off-Gassing of Carbon Monoxide and Oxygen Depletion during Ocean Transportation of Wood Pellets

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Five ocean vessels were investigated for the characterization and quantification of gaseous compounds emitted during ocean transportation of wood pellets in closed cargo hatches from Canada to Sweden. The study was initiated after a fatal accident with several injured during discharge in Sweden. The objective with the investigation was to better understand the off-gassing and issues related to workers' exposure. Air sampling was done during transport and immediately before discharge in the undisturbed headspace air above the wood pellets and in the staircase adjacent to each hatch. The samples were analyzed with Fourier transform infrared spectroscopy and direct reading instruments. The following compounds and ranges were detected in samples from the five ships: carbon monoxide (CO) 1460–14650 ppm, carbon dioxide (CO<sub>2</sub>) 2960–21570 ppm, methane 79.9–956 ppm, butane equivalents 63–842 ppm, ethylene 2–21.2 ppm, propylene 5.3–36 ppm, ethane 0–25 ppm and aldehydes 2.3–35 ppm. The ox-