

# Principles, approaches, models for managing environmental risk

Haakon Vennemo

Workshop in Anshun, May 20, 2015

# Content

- Introduction
- Managing environmental risk: Principles
- Managing environmental risk: Priorities
- Managing environmental risk: Approaches
- Managing environmental risk: Models and Tools

# Our framework

- Seven steps for regional environmental risk assessment (part A)
- Acute regional environmental risk investigation (part B)
- Accumulated/chronic regional environmental risk investigation (part C)
- Environmental risk assessment from principles to policy (Part D)
- The framework is meant as a management tool
  - By raising awareness about regional risk levels
  - By suggesting cost-effective prevention and mitigation measures

# Chinese provinces, prefectures and cities



# From principles to policy

- For planners seeking a deeper explanation of proposed process and methods
- And/or faces problems that require new/modified methods
- *Economic* approach to environmental risk management

# From principles to policy

- Principles
- Priorities
- Approaches
- Models and Tools
- Policy and Regulatory Instruments

# From principles to policy

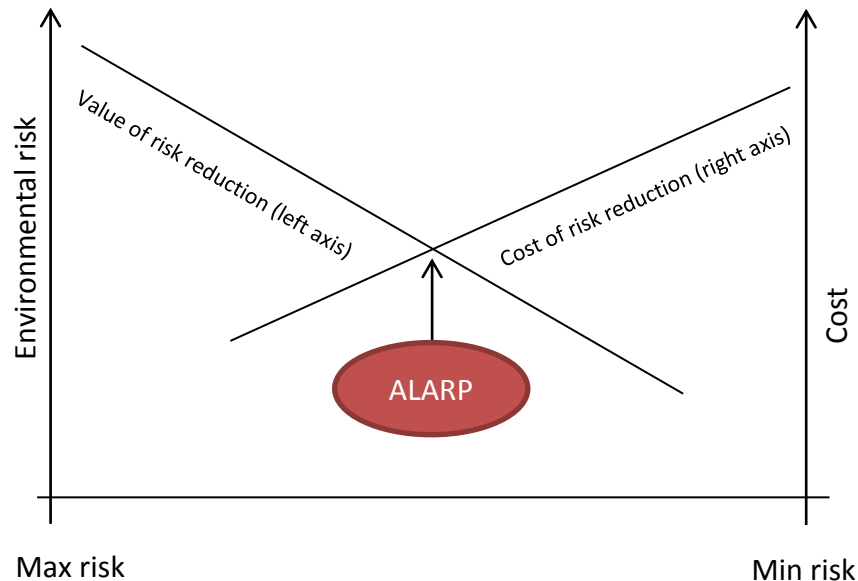
- **Principles**
  - **Priorities**
  - **Approaches**
  - Models and Tools
  - Policy and Regulatory Instruments
- 
- Mostly focus on principles, priorities and approaches today

# Content

- Introduction
- Managing environmental risk: Principles
- Managing environmental risk: Priorities
- Managing environmental risk: Approaches
- Managing environmental risk: Models and Tools



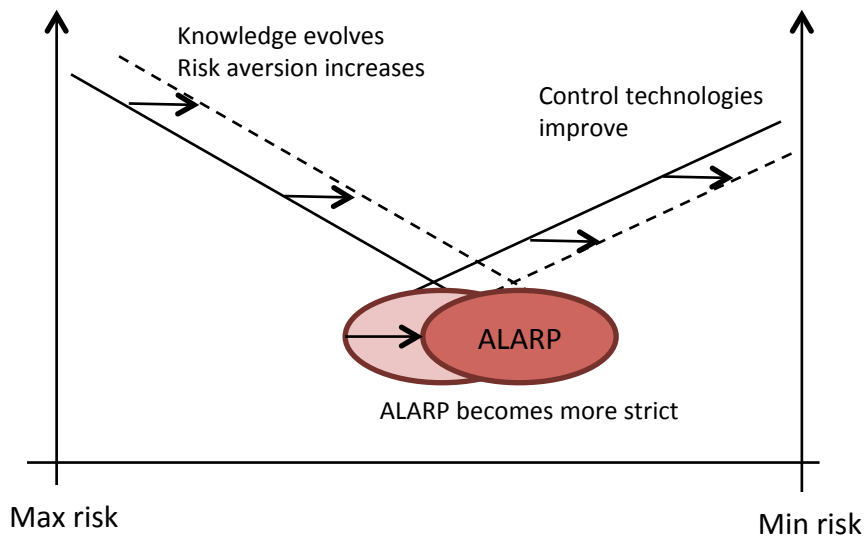
# Optimal, not minimal risk



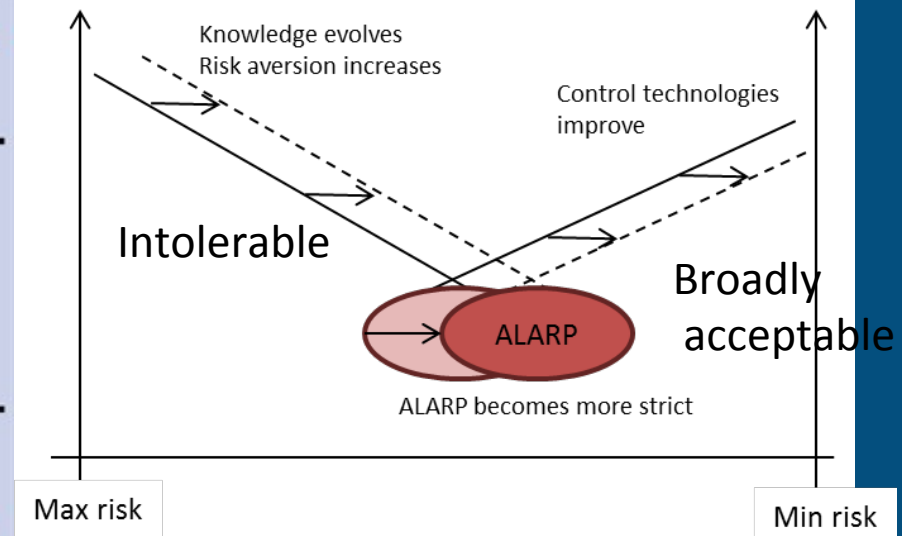
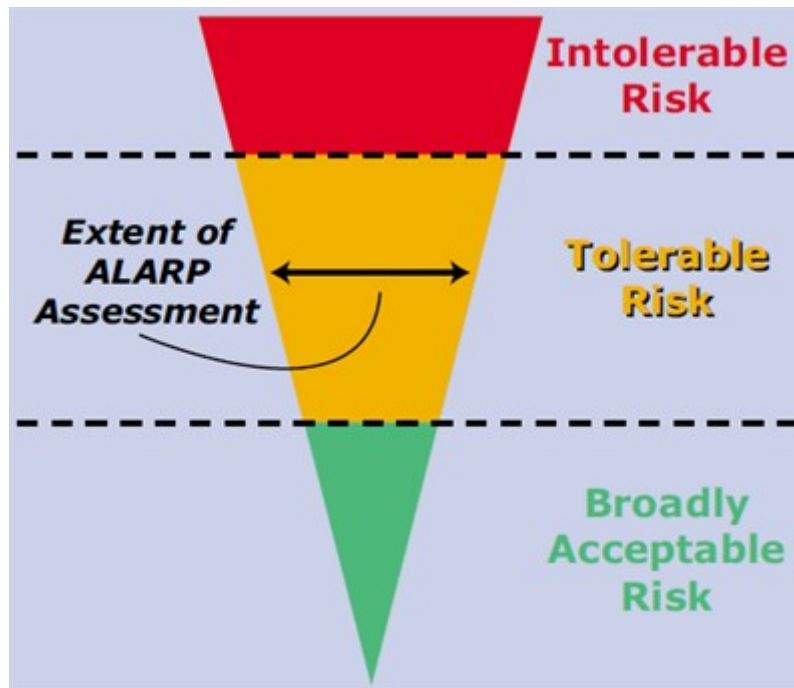
- Does the benefit in terms of risk reduction outweigh the cost?
- ALARP = As Low as Reasonably Practicable

# ALARP changes over time

- Scientific knowledge evolves
- Public understanding of risk improves
- Public's aversion to risk may have increased
- Public's habitual tolerance to risk is probably lower
- The control technologies improve

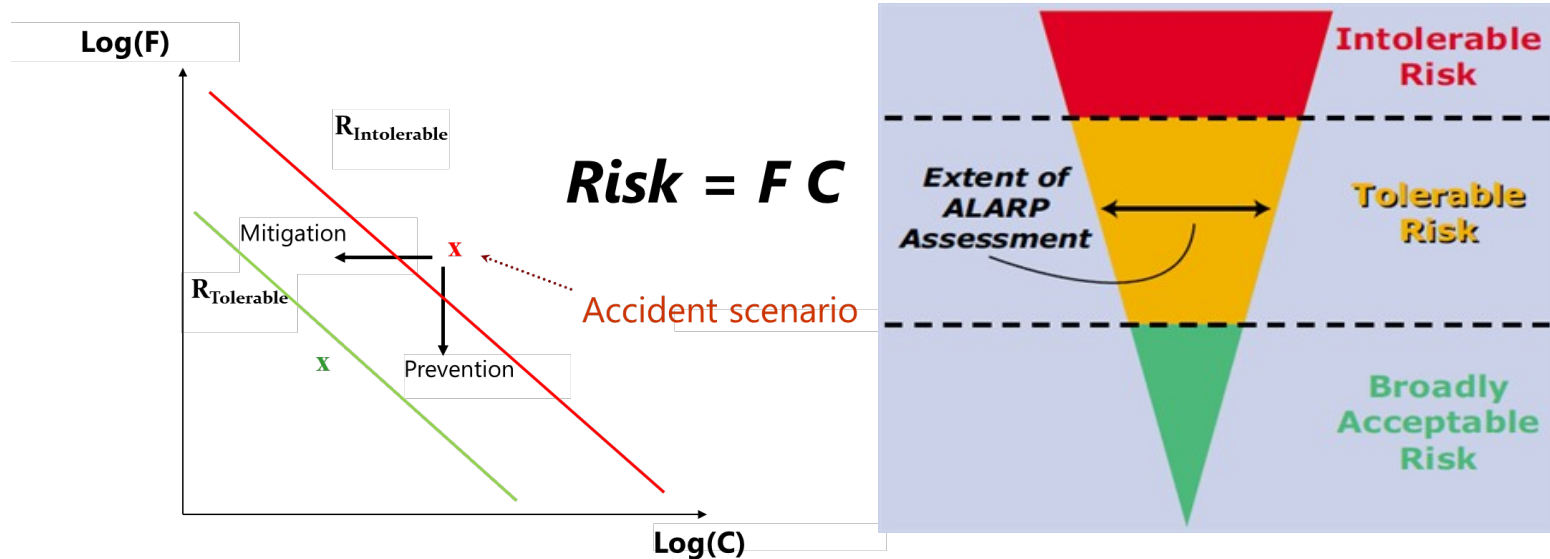


# Optimal risk is an area



- ALARP is difficult (impossible) to pinpoint exactly.

# ALARP, risk prevention and risk mitigation



- $F$  = frequency/probability;  $C$  = consequence
- The accident scenario  $x$  presents intolerable risk. May be mitigated (lower  $C$ , constant  $F$ ) or prevented (lower  $F$ , constant  $C$ )
- More than one consequence:  $\text{Risk} = \sum_{i=1}^N F_i C_i$

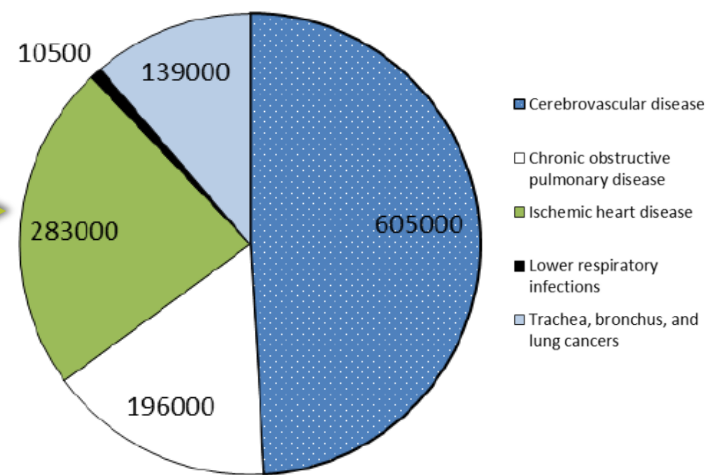
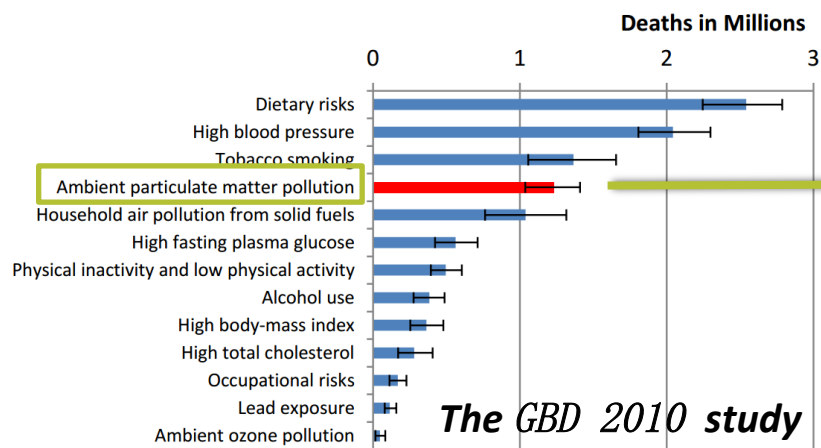
# Content

- Introduction
- Managing environmental risk: Principles
- **Managing environmental risk: Priorities**
- Managing environmental risk: Approaches
- Managing environmental risk: Models and Tools

# Air pollution risks: PM<sub>2.5</sub>



**Global burden of disease (GBD):  
outdoor air PM<sub>2.5</sub> contributed  
annually over to 1.24 million  
premature deaths in China in 2010**



**Chinese deaths attributable to 13 leading risk factors 2010**

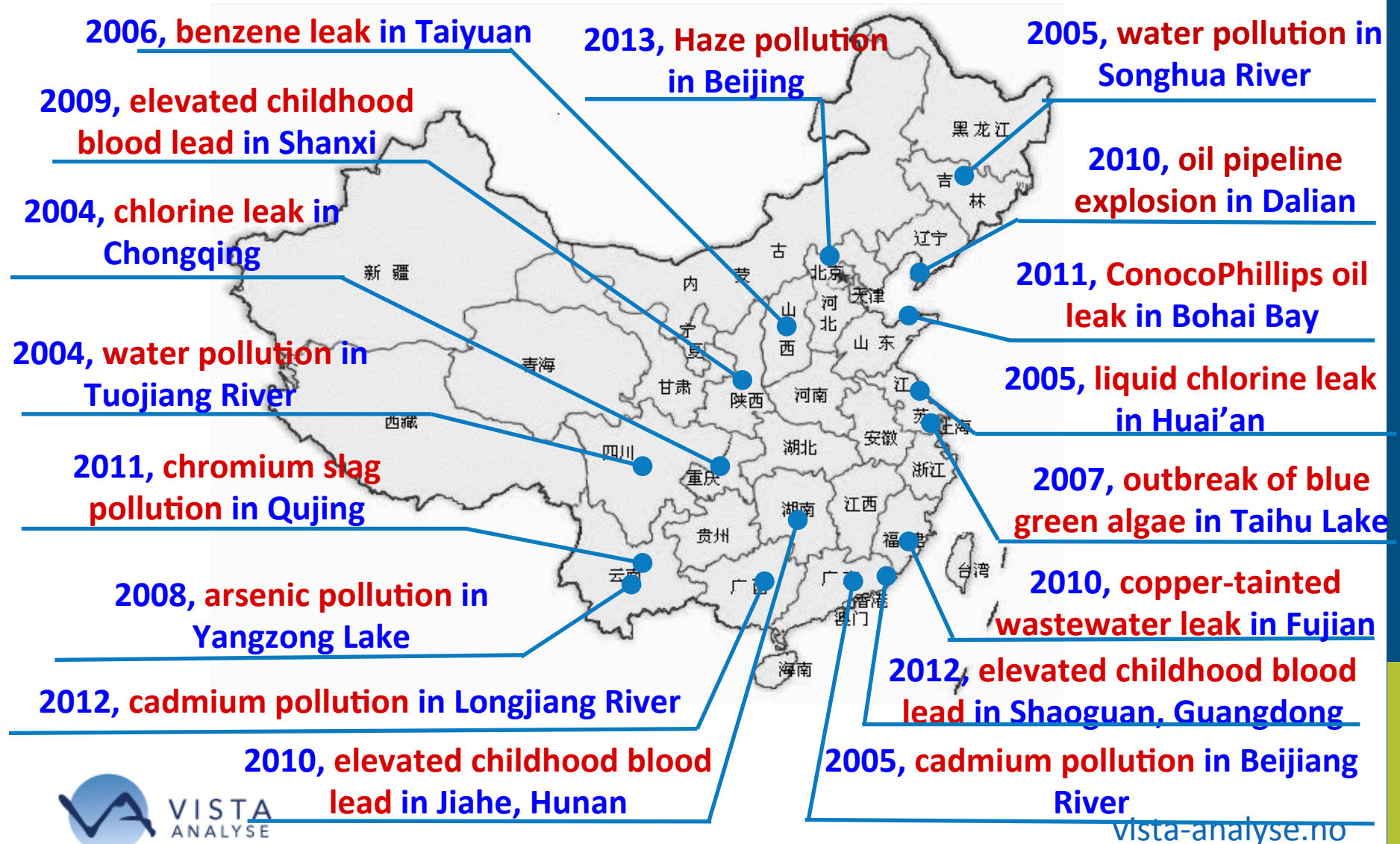
**Deaths attributable to ambient particulate matter pollution in China in 2010**



From: Health Effects Institute, 2013.

[vista-analyse.no](http://vista-analyse.no)

# Pollution accidents in China



# In general, what do we know about consequences

- Classical air pollutants: PM<sub>2.5</sub> !
- Chemical substances
  - MEP Guideline for Risk Assessment of Environmental Accidents in Enterprises (2014): 310 substances
  - MEP List of Hazardous chemicals for prioritized environmental management (2014): 84 substances (all of which are included in the 310).



# International Reference Life Cycle Data System (ILCD)

Rank (worst = 1 etc)	Human cancer toxicity,	Human non-cancer toxicity,	Ecotoxicity, freshwater	Eutrophication, freshwater
1	2,3,7,8-tetrachlorodibenzo-p-dioxin to water	PCB-1254 to water	2,3,7,8-tetrachlorodibenzo-p-dioxin	Phosphorus, total
2	2,3,7,8-tetrachlorodibenzo-p-dioxin to air	Mercury to soil	1,2,3,7,8-pentachlorodibenzo-p-dioxin	Phosphoric acid
3	2,3,7,8-tetrachlorodibenzo-p-dioxin to soil	Mercury to air	Cyfluthrin	Phosphate
4	Photomirex to water	PCB-1254 to air	Estradiol	
5	PCB-1260 to water	PCB-1016 to water	beta-cypermethrin isomer	
6	Heptachlor epoxide to water	PCB-1254 to soil	Cyhalothrin	
7	PCB-1254 to water	Cadmium to soil	Fenpropathrin	
8	DDD to water	Beryllium to air	Antimycin A	
9	Aflatoxin B1 to water	Hydramethylnon to water	Cypermethrin	
10	Toxaphene to water	PCB-1016 to water	Alpha-cypermethrin	

- Altogether 40 000 pollutant-receptor combinations!
- Persistence
- Bio-accumulation
- Toxicity
- Reduction of stratospheric ozone
- Climate change

# In general, what do we know about frequencies?

- Zhang and Zheng (2012) used data on 1632 hazardous chemical accidents 2006-2010 reported by State Work Accident Briefing System (SWAB) and Chemical Accidents Communications (SAWS).
- Li et al (2014) used data on 1400 sudden chemicals leakage accidents 2006-2011 from National Registration Center for Chemicals (NRCC), a department of SWAB. 666 used for study since little or no damage from the others.
- Zhang and Zheng: 67% in fixed facilities, 33% in transport.
- Li et al: 66% in transport
- What to believe???

# In general, what do we know about frequencies?

- 40% of accidents are releases. Next come explosions. Finally fires
- Domino effects occurred in 10% of all cases. Releases followed by explosion
- Flammable liquids are the most common substance in accidents, followed by corrosive gases
- Overlapping functions between departments cause conflict of interest. As a result some enterprises ignore qualification requirement and do not implement safety management regulations

# In general, what do we know about frequencies?

- Training of drivers is not good enough. Overloading, overspeeding, modification of chemical storage containers, illegal operations
- Defect equipment, from ignoring daily maintenance, examination may cause corrosion and ageing to go undetected
- Behind rule-breaking behaviour is found faulty procedures, poor training, persistent use of too long shifts. Point to corporate management failure as the root cause.
- «The strong economic ties between local county governments and chemical small and medium enterprises» another root cause (He et al, 2014)

# In general, what do we know about industry risk?

- 12th 5Y plan for Environmental Risk Prevention and Control of Chemicals
  - Petroleum processing
  - Chemical raw materials
  - Chemical product manufacturing
  - Pharmaceutical manufacturing
  - Non ferrous metal smelting
  - Textile anchoring
- Guidance for implementing pilot work of environmental liability insurance
  - Non ferrous metal mining
  - Non ferrous metal smelting
  - Lead acid battery manufacturing
  - Leather and leather products
  - Chemical raw materials and products manufacturing

# Content

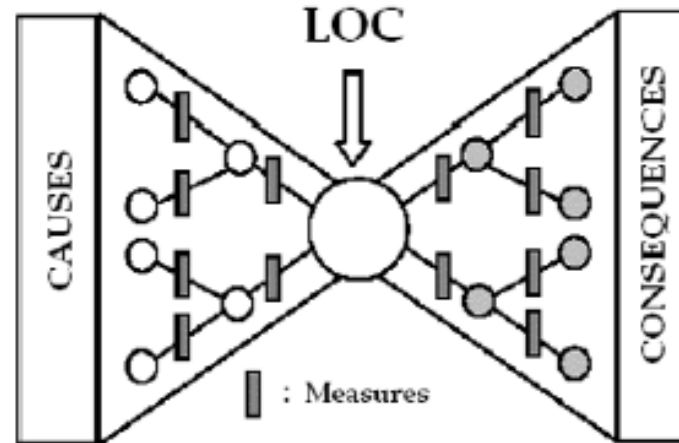
- Introduction
- Managing environmental risk: Principles
- Managing environmental risk: Priorities
- **Managing environmental risk: Approaches**
- Managing environmental risk: Models and Tools

# Three core elements of the approach

- *More information*: Monitoring, inspections and procedures
- Determine *what is acceptable*: Evaluations and assessments
- *Reduce unacceptable* environmental risk: Plans and procedures, from early warning to emergency response
- Behind it all is a *legal framework* and *institutions* with designated responsibilities.
- Plans and procedures must be *implemented*.

# More information

- Many risks are not known by anybody
- Some risks are known by the companies but not by regulators
- Inverted burden of proof (REACH)
- Accident prevention policy (Seveso)
- Designated employees (ISO 14000)
- Disclosure to media, NGOs



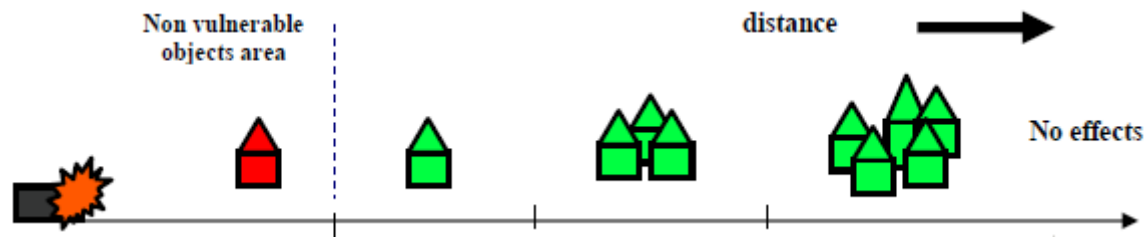
*LOC: Loss of containment*

So much that can go wrong



# Determining what is acceptable

- Tradition air pollution: Air quality standards and emission reduction targets based on cost-benefit considerations
  - In Europe: IIASA
- Hazardous chemicals: Cruder approach
  - Cumbersome process of registration and approval
  - Restrictions on usage – only certain purposes
  - Safe distance requirements



# Determining what is acceptable

- Water pollution: zoning in combination with discharge standards
- Biodiversity: zoning in combination with restrictions on usage
  - No coincidence that national parks are disproportionately located in areas of economic low value

# Reduce the unacceptable

- Emergency response plans
  - Monitoring/forecasting & flagging acute incidents
  - Public alert system
  - To-do plans (hospital, schools etc)
  - Depots
  - Drills
  - Etc
- Ordinary plans
  - Land use plans
  - River management plans
  - Economy-ecology plans and scenarios
- Backed up by models and tools
- Supported by policy

# Content

- Introduction
- Managing environmental risk: Principles
- Managing environmental risk: Priorities
- Managing environmental risk: Approaches
- **Managing environmental risk: Models and Tools**

# Models and tools

- Tools in the form of *lists*
  - Best available technique reference documents (BREF) for determining what constitutes a best available technology (BAT) in a large number of industrial sectors. Environmental regulation often requires BAT.
  - A list of 33 priority substances and 8 other pollutants that define Good Chemical Status of a water body. Good Chemical Status is a concept of the Water Framework Directive of the EU.
  - Annex XIV of the EU REACH Regulation lists Substances of Very High Concern (SVHC).
  - Etc.

# Models and tools

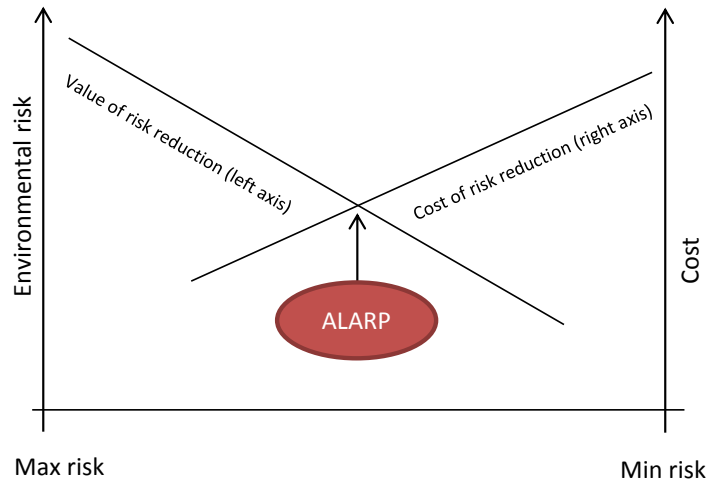
- Models and methods for Acute risk and environmental response
  - MEP 'Guidelines for Environmental risk assessment of Construction Projects' (2004) gives recommended models and methodologies on how to calculate the amount and rate of accidental leakage, such as hazardous substances diffused in water and air, oil slick, etc.

# Models and tools

- Models and methods for Acute risk and environmental response
  - The ALOHA (Areal Location of Hazardous Atmospheres) is a program of the US EPA designed to model chemical releases for emergency responders and planners. It can estimate how a toxic cloud might disperse after a chemical release and also features several fires and explosions scenarios. ALOHA displays its estimate as a threat zone, which is an area where a hazard (such as toxicity, flammability, thermal radiation, or damaging overpressure) has exceeded a user-specified Level of Concern (LOC). Other models with a similar purpose include the Phast model of DNV GL (proprietary) and the ADAM tool of the European Commission.
  - Etc
- Etc

# Conclusions

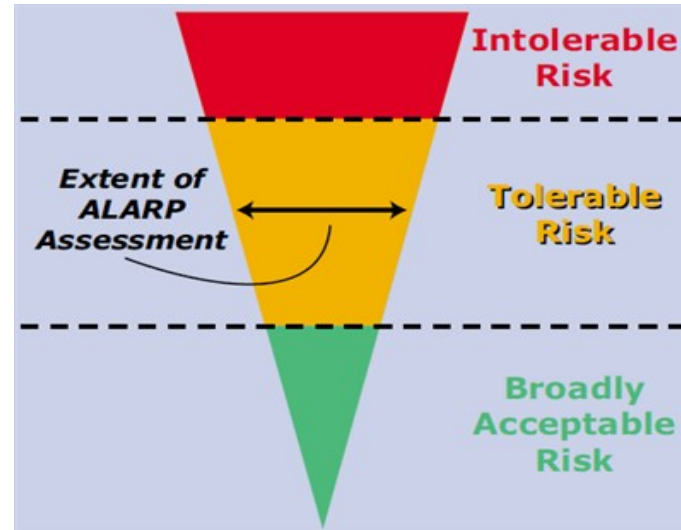
- The goal is optimal environmental risk, not minimal environmental risk





# Conclusions

- Optimal risk is an area of broadly acceptable risk



# Conclusions

- PM2.5 is the most dangerous of the «classical pollutants» to air



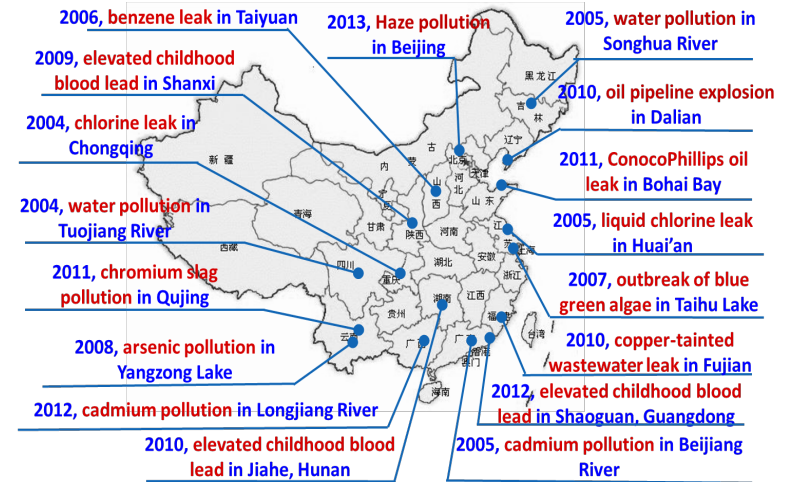
# Conclusions

- There are lists of hazardous substance with the most serious consequences

Rank (worst = 1 etc)	Human toxicity, cancer	Human toxicity, non-cancer	Ecotoxicity, freshwater	Eutrophication, freshwater
1	2,3,7,8-tetrachlorodibenzo-p-dioxin to water	PCB-1254 to water	2,3,7,8-tetrachlorodibenzo-p-dioxin	Phosphorus, total
2	2,3,7,8-tetrachlorodibenzo-p-dioxin to air	Mercury to soil	1,2,3,7,8-pentachlorodibenzo-p-dioxin	Phosphoric acid
3	2,3,7,8-tetrachlorodibenzo-p-dioxin to soil	Mercury to air	Cyfluthrin	Phosphate
4	Photomirex to water	PCB-1254 to air	Estradiol	
5	PCB-1260 to water	PCB-1016 to water	beta-cypermethrin isomer	
6	Heptachlor epoxide to water	PCB-1254 to soil	Cyhalothrin	
7	PCB-1254 to water	Cadmium to soil	Fenpropathrin	
8	DDD to water	Beryllium to air	Antimycin A	
9	Aflatoxin B1 to water	Hydramethylnon to water	Cypermethrin	
10	Toxaphene to water	PCB-1016 to water	Alpha-cypermethrin	

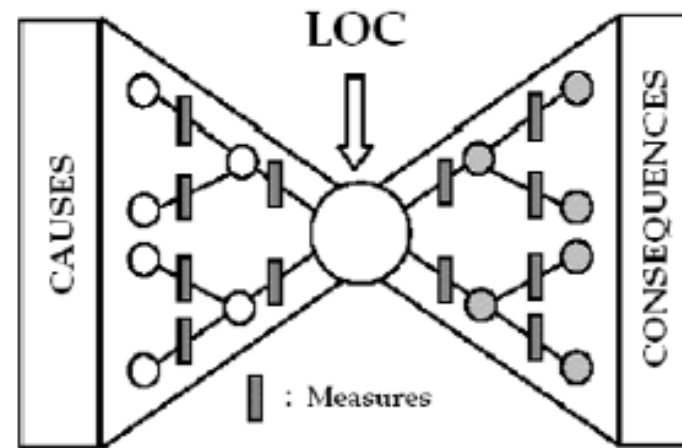
# Conclusions

- Fixed facilities and transport both frequent sources of accidents
- Releases, e.g., of flammable liquids, is a frequent type of accidents
- Internal management failure suggested as a root cause
  - Helped by overlapping responsibilities of departments
  - And strong economic ties between local government and enterprises



# Conclusions

- Elements of the approach are
- Strategy for assembling *information*
- Strategy and rules to in practice determine what is *acceptable risk*
- Strategy and rules for *reducing remaining risk*



# Conclusions

- Elements of the approach are
- Strategy for assembling *information*
- Strategy and rules to in practice determine what is *acceptable risk*
- Strategy and rules for *reducing remaining risk*
- There is a great number of models and tools available on different aspects of risk. From simple lists to advanced computer models

