



Research centre
for toxic compounds
in the environment

Risk Assessment

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Risk Assessment Outline

- Objectives
- What is risk?
- Human health and ecological risk assessment definitions
- Risk assessment basics
- Where can we use risk assessment?
- Case studies
 - Human exposure to particle-bound PAHs from traditional cooking practices and potential carcinogenic risk
 - Biota exposure to toxic levels of uranium downstream of a mine



Objectives

- Introduce you to the concept of risk as it relates to environmental chemistry/science/management
- Describe the risk assessment process for human health and ecological risk assessment
- Show examples of human health and ecological risk assessment



What is risk?

- “(Exposure to) the possibility of loss, injury, or other adverse or unwelcome circumstance; a chance or situation involving such a possibility.” [Oxford English Dictionary]
- In an environmental science context risk can be defined as the “*chance of harmful effects to human health or to ecological systems resulting from exposure to an environmental stressor**”. [US EPA]

***Stressor** = can be physical, chemical, or biological; may induce an adverse response. Term ‘agent’ is also sometimes used.

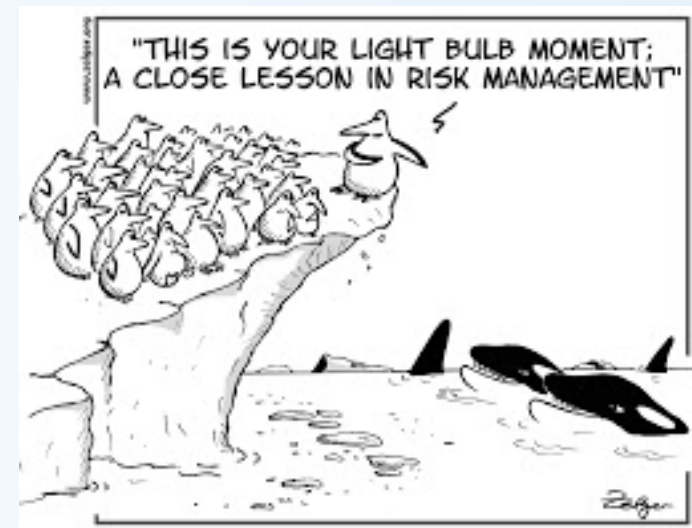


<http://blog.statefoodsafety.com>
(accessed 19/11/2015)



Human health and ecological Risk assessment definitions

- Human health risk assessment: estimating the nature and probability of adverse health effects in humans potentially exposed to environmental stressors, in the past, now and in the future
- Ecological risk assessment: determining risk (magnitude and likelihood) posed by a stressor to ecosystem health
- Sometimes we see the term environmental risk assessment used instead of ecological risk assessment



Risk Assessment Basics

Framework for conducting risk analysis

Risk Assessment

- 1. Identify problem:** Describe the environment; What are the potential stressors? What are the exposure pathways?
- 2. Analyse information:** Assess extent and effects
- 3. Risk Characterisation:** Probability of occurrence and severity; uncertainties

Adapt risk assessment over time based on monitoring

Adapt risk management based on monitoring results

Risk Management

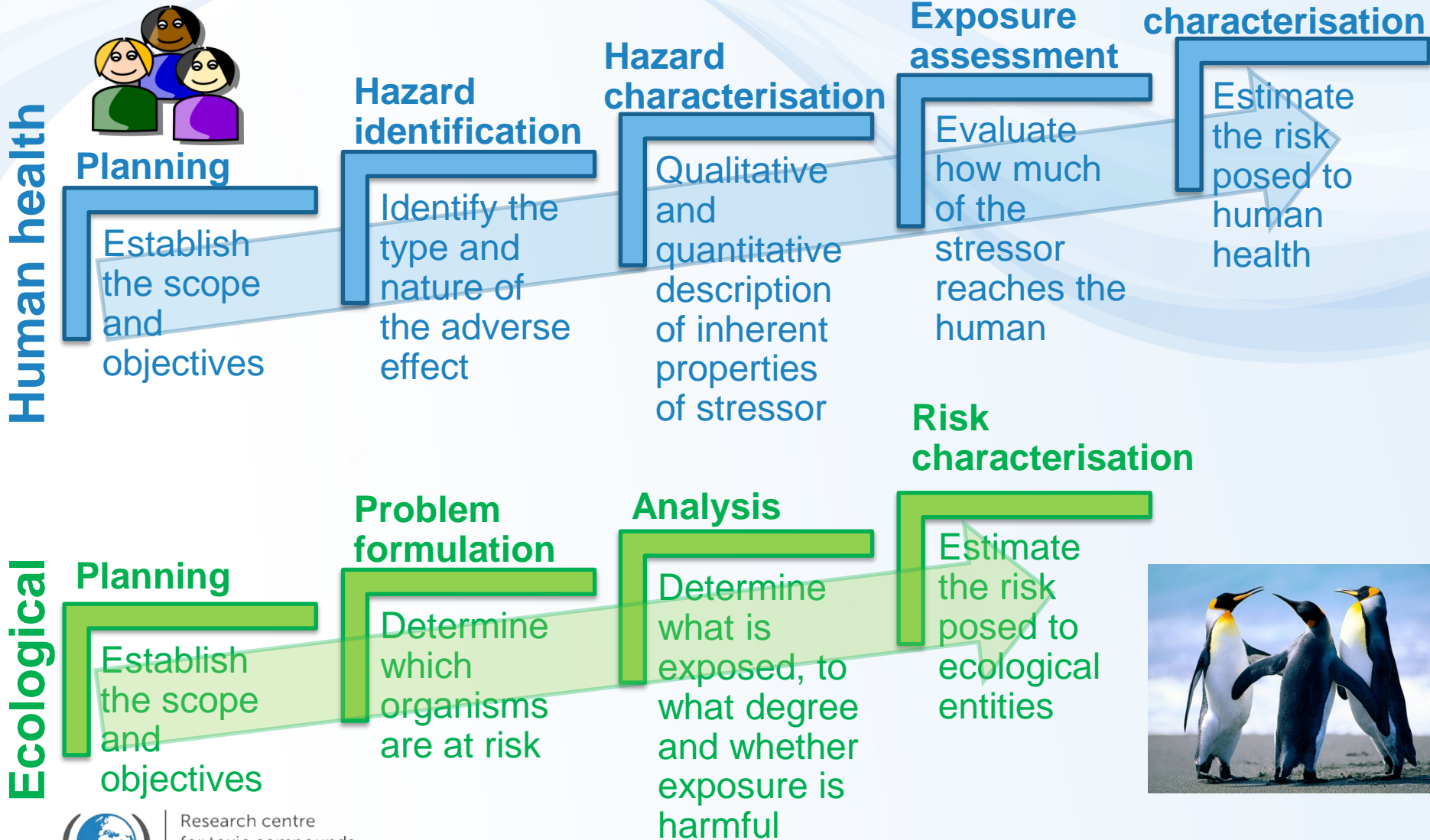
Monitoring

Risk Communication



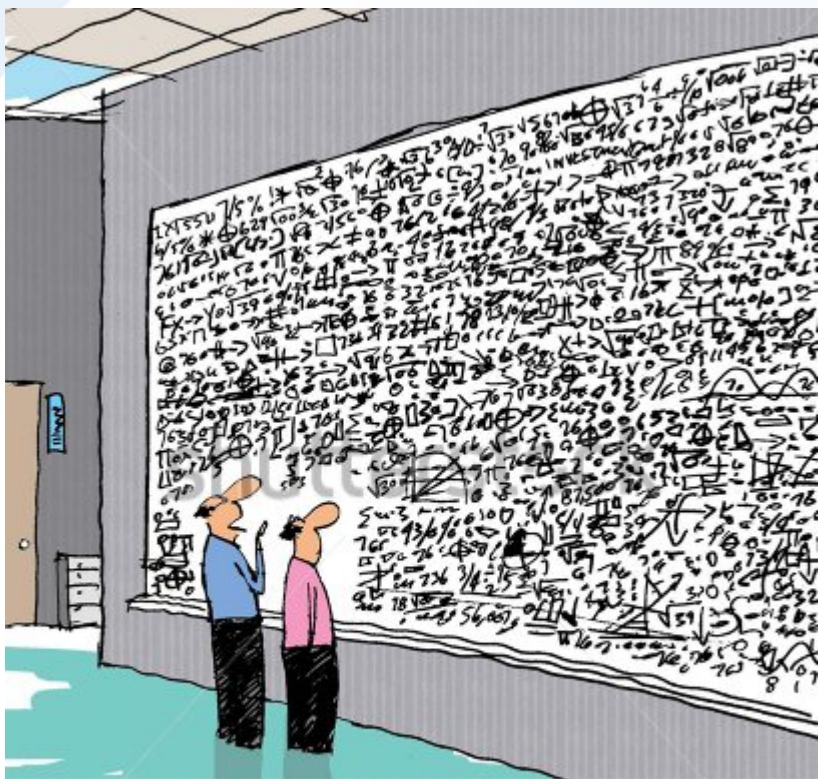
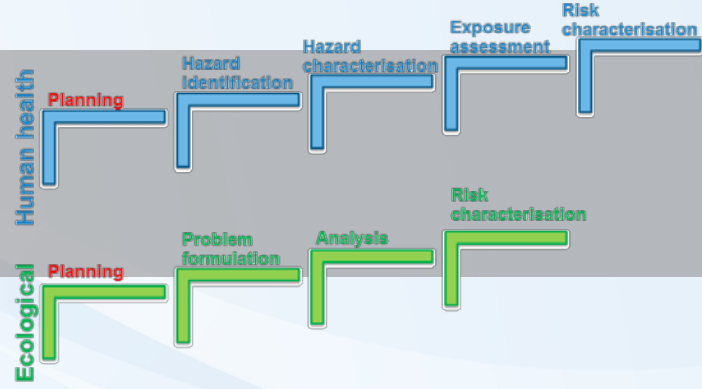
Risk Assessment Basics

Risk assessment paradigm (US EPA model)



Risk Assessment Basics

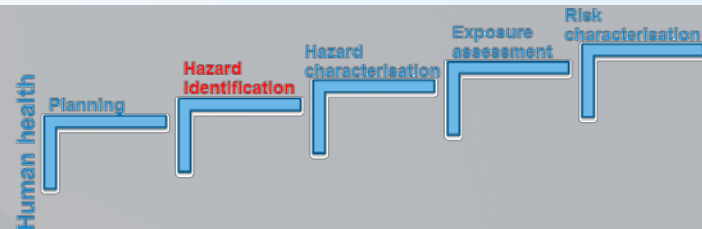
- Planning



"....and that in a nutshell is the plan, any questions?"

- ### Questions we need to ask at the beginning
- Who/what/where is at risk?
 - What is the environmental hazard of concern?
 - Where do these environmental hazards come from?
 - How does exposure occur?
 - What is the fate of the hazard in the body and impact of, e.g., age, sex, etc.
 - What are the health/ecological effects?
 - How long does it take for hazard to cause a toxic effect? Does it matter when the exposure occurs in the lifetime of a human/organism?

Risk Assessment Basics



- Human health risk assessment

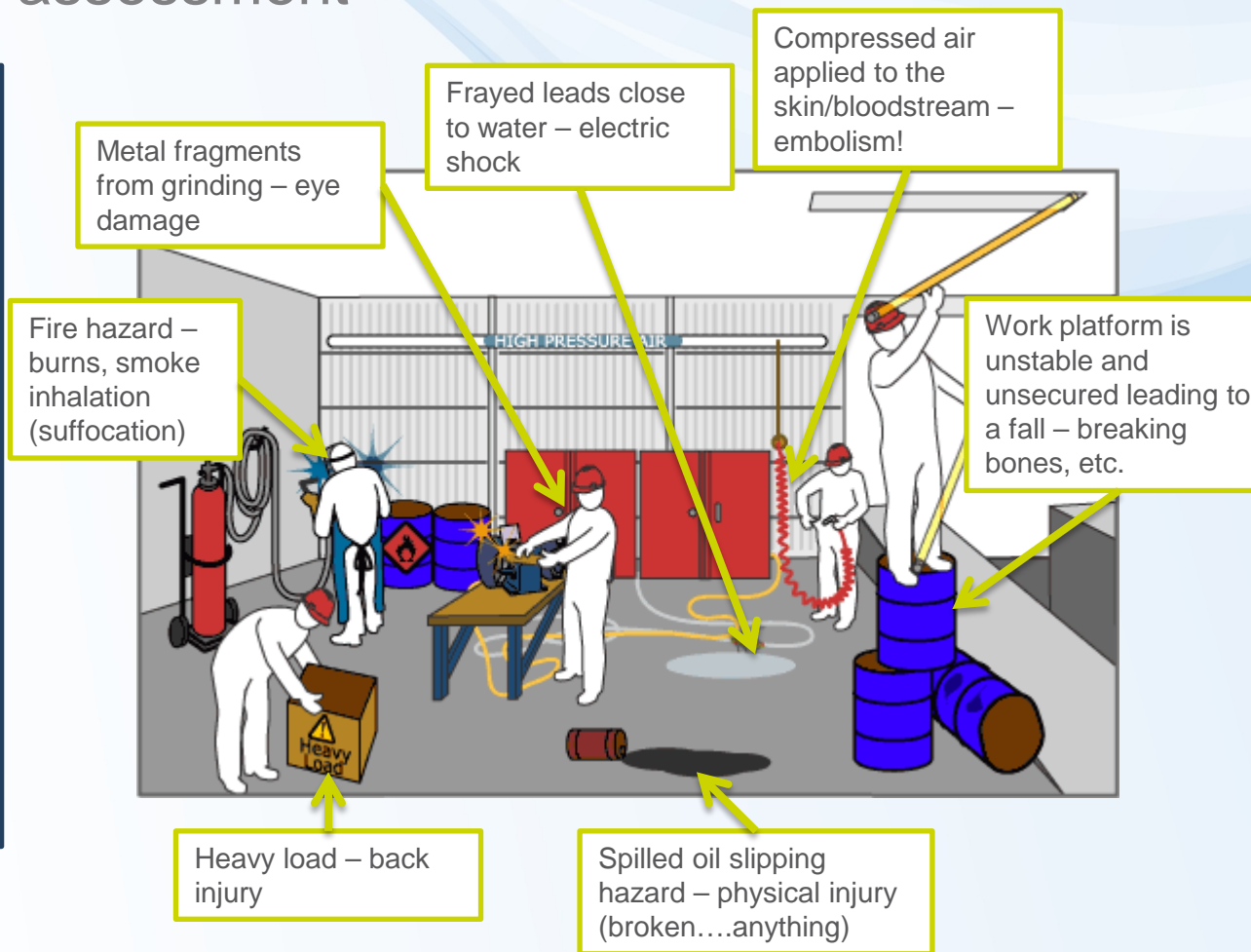
Hazard identification

- Determine whether exposure to a stressor can cause an adverse effect
- Carcinogenic or non-carcinogenic

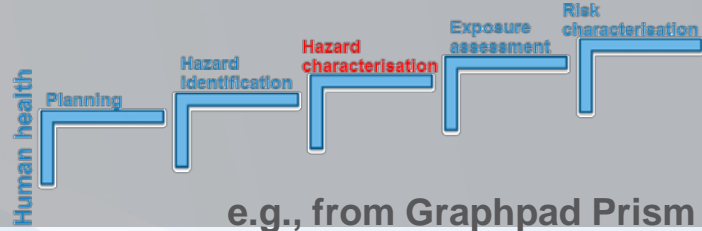
Available data

- Clinical or epidemiological studies (human)
- Other animal studies
- QSAR

TOXNET – toxicology data network; focused mainly on chemical hazards



Risk Assessment Basics



- Human health risk assessment

Hazard identification

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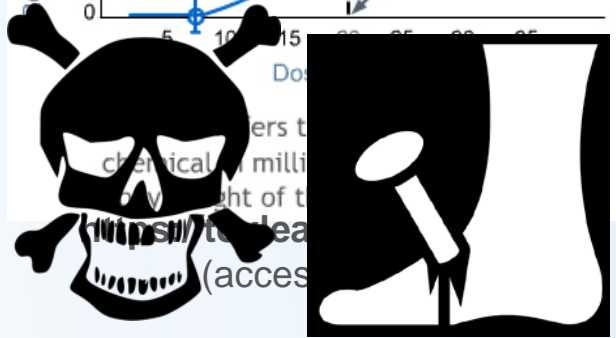
Hazard characterisation

- Describe the likelihood and severity of adverse effect with amount and condition(s) of exposure to, e.g., chemical agent
- Use existing, or develop guidelines

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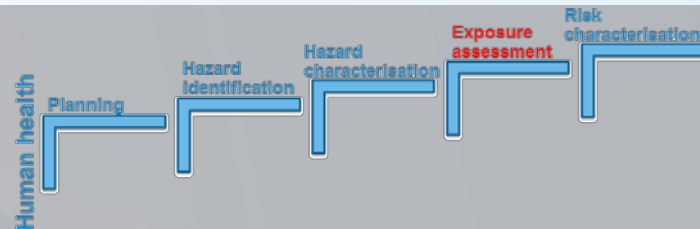


Adverse effects



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Risk Assessment Basics



- Human health risk assessment

Properties of the

inhalation exhaled air ingestion



Exposure assessment

- Measure or estimate the magnitude, frequency and duration of exposure to, e.g., biological agent
- Considers exposure pathway and route, as well as size, nature and type of populations exposed

Available data

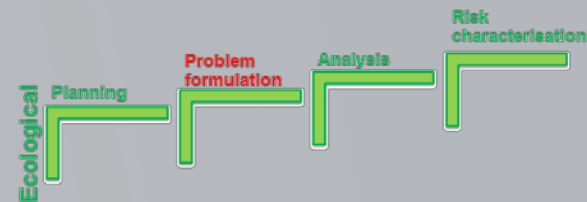
- Measured directly/estimated using environmental concentrations + fate/transport + estimated intake)

<http://www.slideshare.net/AngelAlhamad/different-route-of-exposure-of-toxicant> (accessed 20/11/2015)



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Risk Assessment Basics



- Ecological risk assessment

Process based on two major elements:

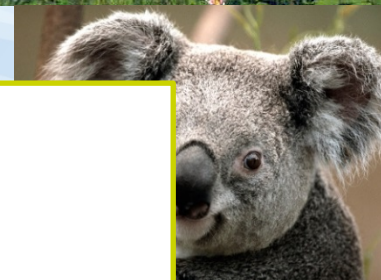
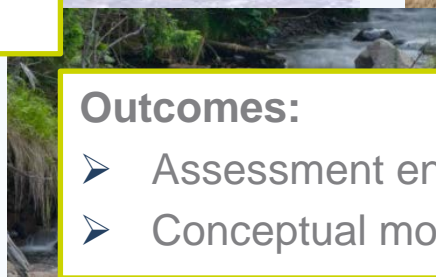
- characterization of effects
- characterization of exposure

you are protecting and what attributes of entity are at risk

- Your ecological entities might include: Species (polar bear), ecosystem (stream), valued habitat (wetland), etc.

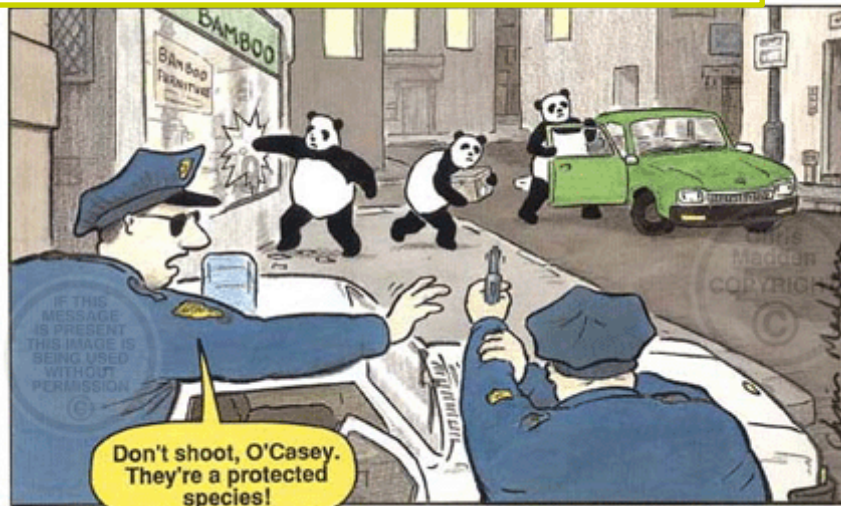
What to protect?

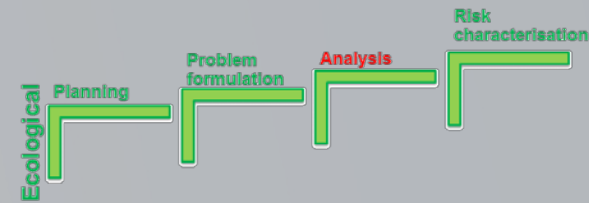
Think of ecological relevance, susceptibility to stressors and relevance to management goals



Outcomes:

- Assessment end-points
- Conceptual models





Risk Assessment Basics

- Ecological assessment

Problem formulation:

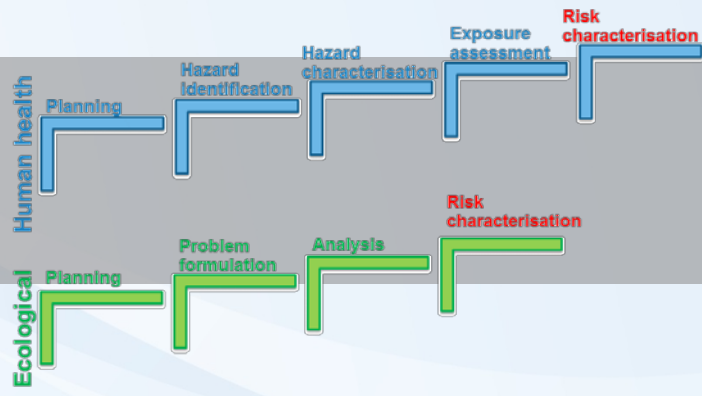


Analysis:

- Characterisation of exposure and ecological effects
- Degree of exposure and ecological responses of plants and animals exposed to stressors
- Guidelines can be used or can also be developed
 - ECTOX database has ecotox data
- Determining exposure levels
 - Area use/home range; food ingestion; bioaccumulation rates; bioavailability; life stage



Risk Assessment Basics

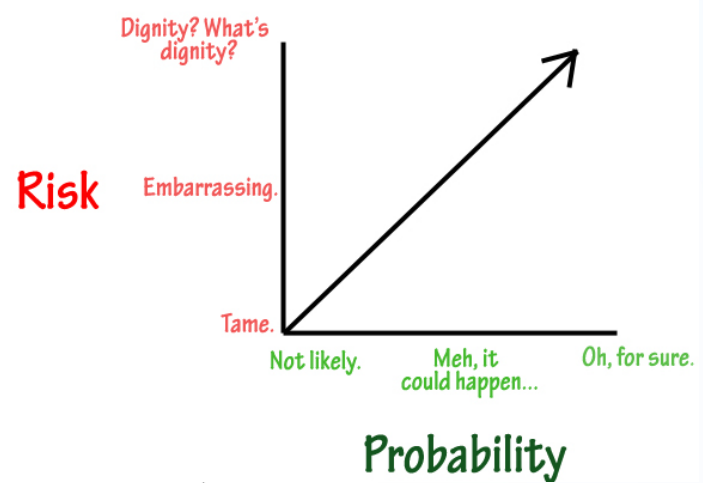


- And finally.....risk characterisation



$RISK = HAZARD \times EXPOSURE$

Bad Decisions



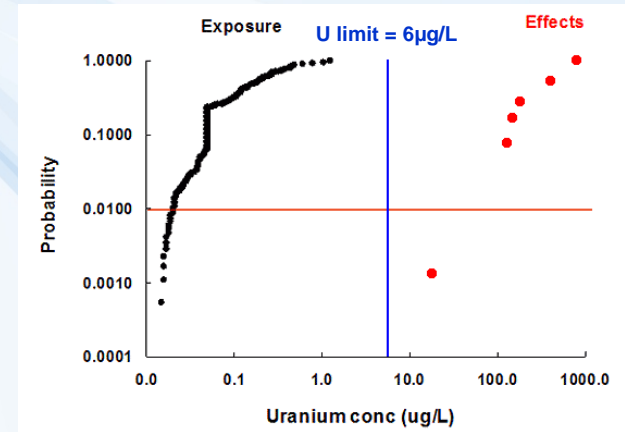
risk characterisation = risk estimation + risk description

- Risk estimation: using the results of preceding steps in risk assessment estimate the risk
- Risk description: an interpretation of risk results. The level of harmful effects, as well as likelihood/probability of adverse effects, on humans or other organisms
- ***It is very important*** to include how the risk was assessed, the degree of confidence in the risk estimates, any assumptions made, as well as summarise limitations and uncertainties
- Citations must be used to support risk estimates and any interpretation of adverse effects
- Information is used for decision making

Risk characterisation

- Risk characterisation can be quantitative or semi-quantitative assessment (e.g., ranking risk)
 - Quantitative: case study examples
 - Semi-quantitative risk assessment
 - Helps set priorities when assessing multiple stressor risks and considers uncertainties.
 - Needs to be scrutinised and reviewed by experts

e.g., 1 null hypothesis testing and likelihood estimation



e.g., 2 Risk matrix of consequences versus likelihood

Likelihood	Consequences				
	Insignificant 1	Minor 2	Moderate 3	Major 3	Unknown 4
A (Almost certain)	High (H)	H	VH	VH	U (H)
B (Likely)	Medium (M)	H	H	VH	U (M)
C (Possible)	Low (L)	M	H	VH	U (L)
D (Unlikely)	L	L	M	H	U (L)
E (Unknown (U))	U (L)	U (L)	U (M)	U (H)	U

e.g.,3 Risk matrix of impact versus probability

		Impact				
		Very Low 1	Low 2	Medium 3	High 4	Very High 5
Probability	Very High 5	5	10	15	20	25
	High 4	4	8	12	16	20
	Medium 3	3	6	9	12	15
	Low 2	2	4	6	8	10
	Very Low 1	1	2	3	4	5

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Adapt risk management based on monitoring results

Risk Management

Monitoring

Risk Communication



Risk Assessment Basics

- Further reading
 - For guidance on conducting risk assessment or risk analysis refer to government or non-government agencies (within your study region is best)
 - Some places to start on the web:
 - US EPA (<http://www2.epa.gov/risk>)
 - World Health Organization (WHO) (2010) WHO Human Health Risk Assessment Toolkit: Chemical Hazards (ISBN 978 92 4 154807 6)
 - UK Department for Environment, Food and Rural Affairs (DEFRA) (https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69450/pb13670-green-leaves-iii-1111071.pdf) – has some good case studies
 - Good journal source:
 - Environmental Health Perspectives



Where can we use risk assessment?

- Human health

- Will an upgrade of a sewage treatment plant increase nuisance odours and pose a risk to health of the local community through recreational activities?
- What is the risk to children from lead dust exposure near to a smelter?

- Ecological

- How would construction, operation and decommissioning of a gold mine impact downstream aquatic ecosystems?
- Will invasive species increase during construction of a pipeline?



Case study 1: Carcinogenic risk from exposure to particle-associated PAHs



• Planning

- The scope is people using primitive or traditional cooking practices in residences or commercial kitchens in Pakistan. PAH associated to dust is the stressor. Potential adverse effect of cancer was nominated as a health effect.
- An assessment endpoint was devised and used to evaluate impacts from potential particle-bound polycyclic aromatic hydrocarbon (PAH) exposure in the vicinity of primitive or traditional cooking
- Assessment endpoint = reduction in incidence of disease. Disease measured as cancer incidence over a lifetime for residents or kitchen workers in vicinity of primitive or traditional cooking, Pakistan.

Case study modified from Kamal et al. 2015
(*Environ Sci Pollut Res* (2015) 22:12644–12654, DOI
10.1007/s11356-015-4444-4)



Case study 1: Carcinogenic risk from exposure to particle-associated PAHs

- Hazard identification and characterisation
 - Solid fuel combustion a major source of household energy in Pakistan. When burnt solid fuel produces particulate matter, particularly when stoves are poorly functioning and ventilation is bad.
 - Wood and coal identified as a major source of PAHs. PAHs are toxic to humans (assigned a toxic equivalency factor (TEF) relative to benzo(a)pyrene).
- Exposure assessment
 - Exposure wasn't directly measured. Instead levels of PAHs in samples of dust from workplace and domestic kitchens in Pakistan with primitive or traditional cooking practices were determined. An equivalent toxicity was calculated for each dust sample.

exposure routes considered



+



+



Case study 1: Carcenogenic risk from exposure to particle-associated PAHs

- Risk characterisation
 - Probabilistic incremental lifetime cancer risk (ILCR)
 - The ILCR model can be used in estimating the incremental probability an individual develops a tumour over an average lifetime (70 years)
 - ILCR compared to US EPA acceptable risk range (1×10^{-6} – 1×10^{-4} or 1 per 1,000,000 or 1 per 10,000)

International Agency for Research on Cancer



World Health
Organization

<http://www.iarc.fr/>



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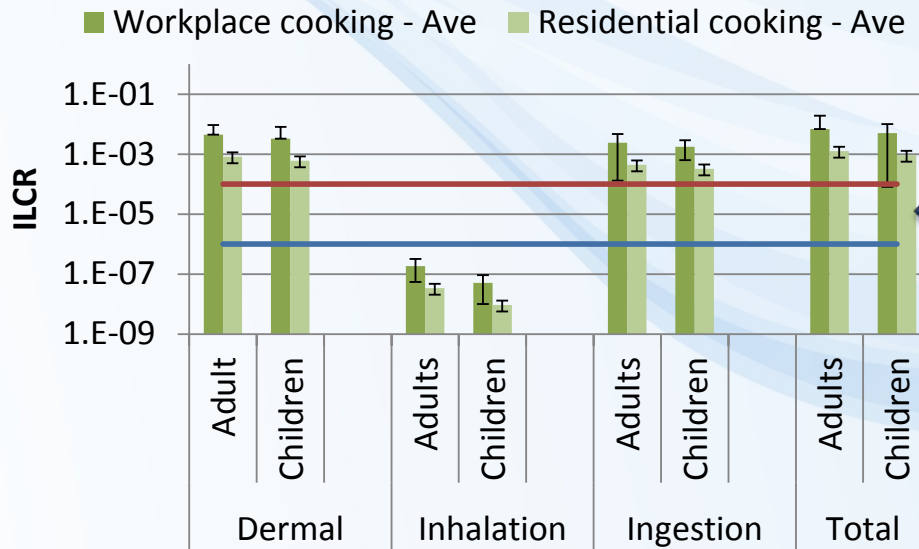


Case study 1: Carcinogenic risk from exposure to particle-associated PAHs

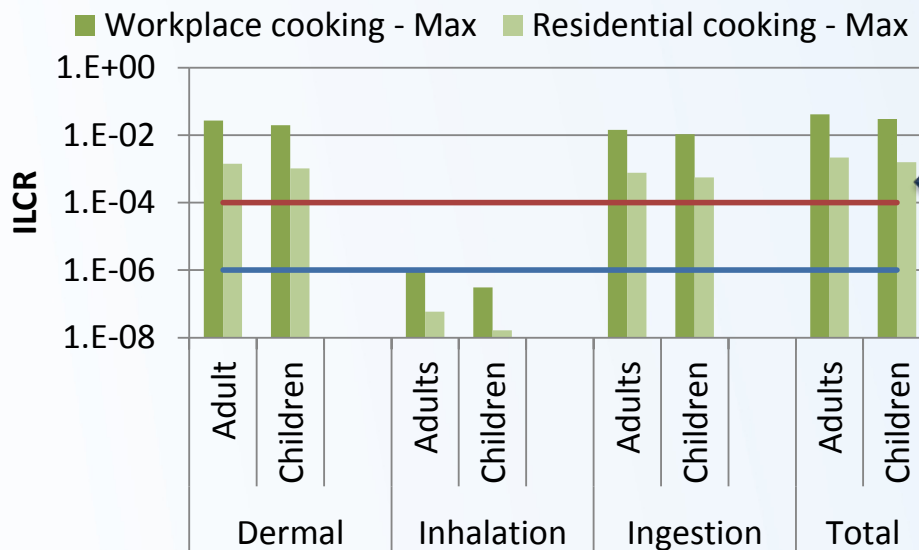
- US EPA guide 1×10^{-6} (1 per 1,000,000)
- US EPA guide 1×10^{-4} (1 per 1 per 10,000)

- Risk characterisation
 - Cancer risk over a lifetime
 - Average - Adults and children $>1/1000$
 - Worst case – (adults, workplace cooking) $>1/100$

– Unacceptable risk of cancer in adults and children exposed to particle associated PAHs derived from primitive cooking stoves



Average scenario total ILCR exceeds acceptable risk



Worst case scenario total ILCR exceeds acceptable risk



Biota exposure to toxic levels of uranium (U) downstream of a mine



(<https://www.environment.gov.au/science/supervising-scientist/research/ecological-risk>)



Magela Creek



Case study modified from Australian Government Department of the Environment

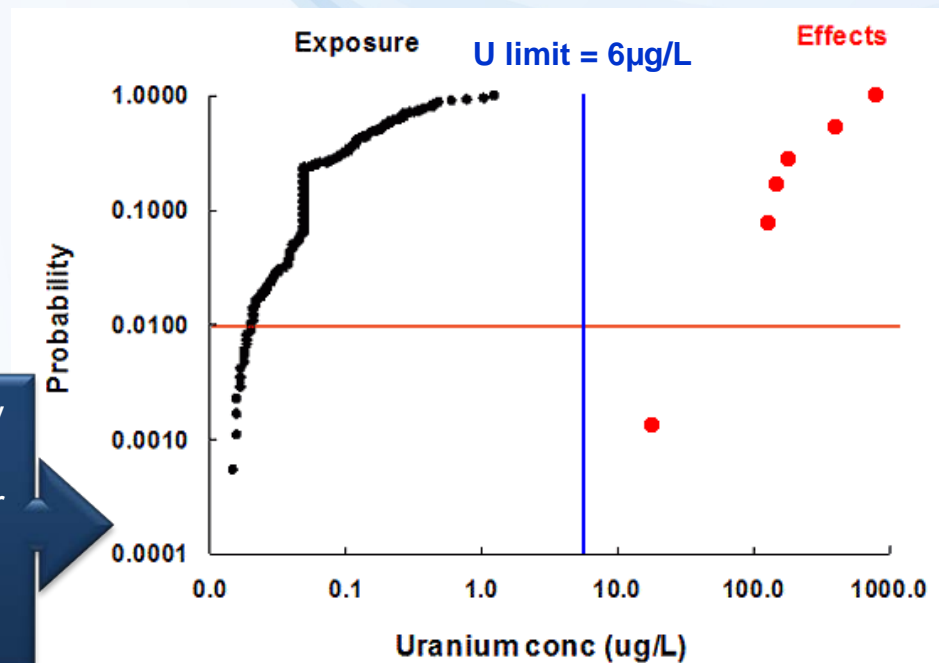
- Planning and problem formulation
 - Scope is an aquatic ecosystem downstream of a U mine. Stressor is available U. Potential adverse effects include death, illness or change in behavior.
 - Surveys conducted to establish aquatic species present (ID: sensitive species)
 - An assessment endpoint was devised and used to evaluate impacts from potential uranium contamination downstream of the mine
 - Assessment endpoint = conservation of biological diversity of the region. Species abundance in Alligator Creek catchment surveyed during the mine operation and decommissioning

Biota exposure to toxic levels of uranium downstream of a mine

- Analysis
 - Exposure estimated using environmental U concentrations measured in Magela Creek
 - Effects observations measured using ecotoxicity tests (6 native species; NOEL)
 - A U limit was derived to using the ecotox data (99% species protection)
- Risk characterisation
 - Null hypothesis testing and likelihood estimation based on frequency information for effects and exposure



Cumulative probability for exposure to U in Magela Creek, and for potential effects of U on 6 species of native species (NOEL)



- Risk of adverse effects from exposure to U as a result of mine discharge was assessed to be low



Questions/discussion





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International conventions for persistent, toxic, mobile and bioaccumulative chemicals

International conventions for PTMB chemicals

- Objectives
- Basic concepts of PTMB chemicals
- Key conventions dealing with PTMB chemicals
- Global monitoring of PTMB chemicals



Basic concepts of PTMB chemicals



- You will remember these from a previous lecture(s)

- What is persistent?

Lasting for years or even decades before degrading into less dangerous forms. High resistance to degradation (abiotic and biotic)

- Which toxic compounds?

Everything is, right? Even water? High toxicity at very low concentrations

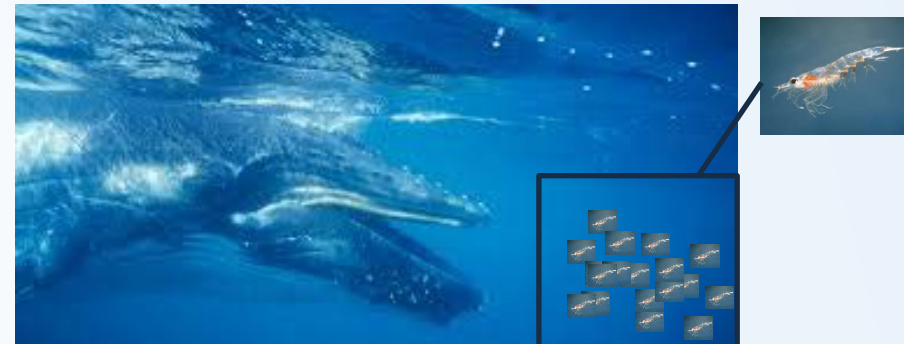
- How mobile?

Moves to remote areas far from sources

- What is bioaccumulative?

Toxic substance taken up at a higher rate than being removed from an organism. Lipophilic compounds (they like lipids).

Biomagnification through the food web results in higher trophic organisms accumulating more PBTs through consumption of lower trophic organisms



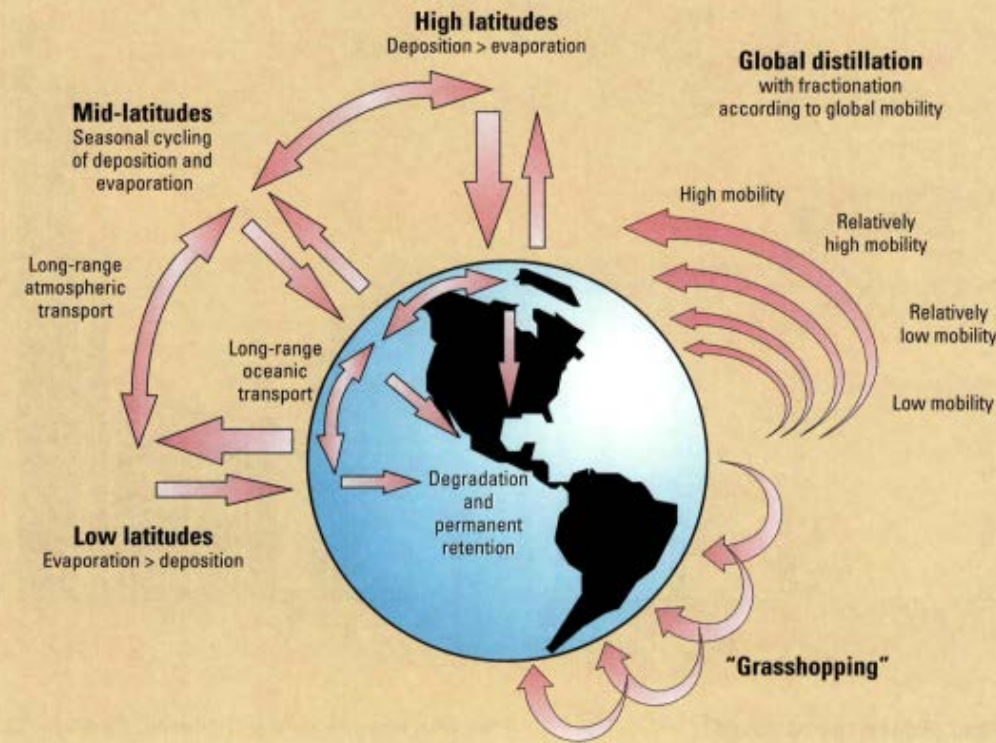
Basic concepts of PTMB chemicals

- Transboundary movement

FIGURE 1

POP migration processes

Global deposition processes become more pronounced than evaporation at high latitudes and lower temperatures.



featured on iFunny.com

Tracking the Distribution of Persistent Organic Pollutants
Wania & Mackay, VOL. 30, NO. 9,
1996 Environmental Science & Technology (News)

Key conventions dealing with PTMB chemicals

Global treaties to protect human health and the environment from chemicals

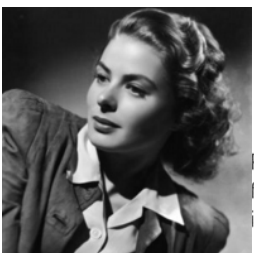
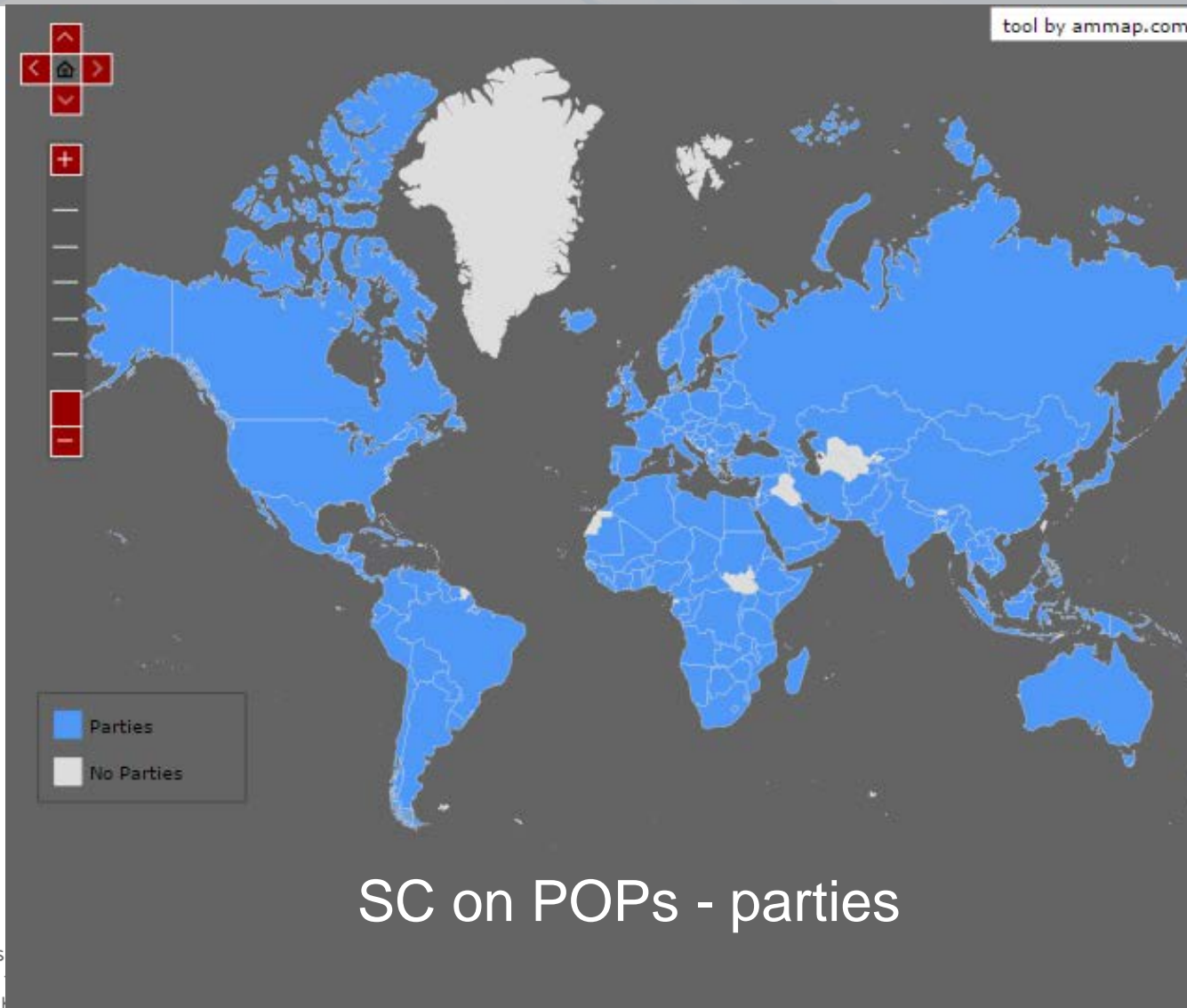
- Stockholm Convention (SC) on Persistent Organic Pollutants (POPs)
 - Reduce exposure by eliminating or reduce use and emissions



- Requires parties to:
 - Restrict, prohibit and/or eliminate the production and use, import and export intentionally or unintentionally produced POPs
 - Promotes the use of best available techniques and best environmental practices for preventing releases of POPs into the environment.
 - Ensure POPs stockpiles and wastes managed safely and in an environmentally sound manner
 - To target additional POPs /list new ones



Key conventions dealing with PTMB chemicals



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Key conventions dealing with PTMB chemicals

- Stockholm Convention (SC) on Persistent Organic Pollutants (POPs)
 - A POP by definition share these properties:
 - highly toxic
 - persistent
 - travel long distances
 - accumulate in fatty tissue

Listing of POPs in the Stockholm Convention

The chemicals targeted by the Stockholm Convention are listed in the annexes of the convention text:

Annex A (Elimination)

Parties must take measures to eliminate the production and use of the chemicals listed under Annex A. Specific exemptions for use or production are listed in the Annex and apply only to Parties that register for them.

Aldrin ●	Chlordane ●	Chlordecone ●
Dieldrin ●	Endrin ●	Heptachlor ●
Hexabromobiphenyl ▲	Hexabromocyclododecane (HBCD) ▲	Hexabromodiphenyl ether and heptabromodiphenyl ether ▲
Hexachlorobenzene (HCB) ● ▲	Alpha hexachlorocyclohexane ●	Beta hexachlorocyclohexane ●
Lindane ●	Mirex ●	Pentachlorobenzene ● ▲
Polychlorinated biphenyls (PCB) ▲	Technical endosulfan and its related isomers ●	Tetrabromodiphenyl ether and pentabromodiphenyl ether ▲
Toxaphene ●		

Annex B (Restriction)

Parties must take measures to restrict the production and use of the chemicals listed under Annex B in light of any applicable acceptable purposes and/or specific exemptions listed in the Annex.

DDT ●	Perfluorooctane sulfonic acid, its salts and perfluorooctane sulfonyl fluoride ▲
-----------------------	--

Annex C (Unintentional production)

Parties must take measures to reduce the unintentional releases of chemicals listed under Annex C with the goal of continuing minimization and, where feasible, ultimate elimination.

Hexachlorobenzene (HCB) ■	Pentachlorobenzene ■	Polychlorinated biphenyls (PCB) ■
Polychlorinated dibenzo-p-dioxins (PCDD) ■	Polychlorinated dibenzofurans (PCDF) ■	

● Pesticide ▲ Industrial chemical ■ Unintentional production



Key conventions dealing with PTMB chemicals

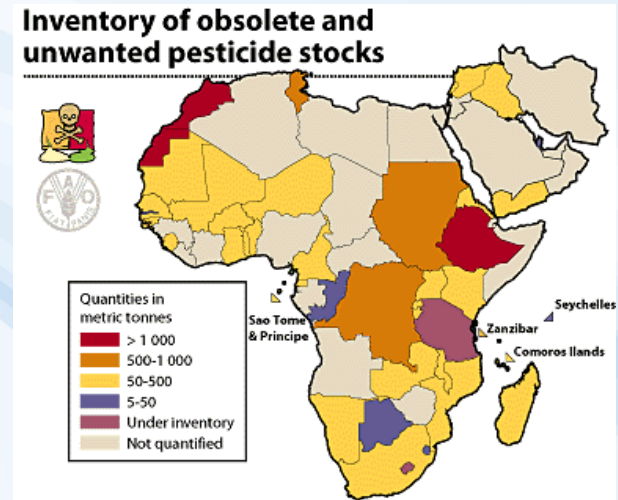


- Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal
 - Under which framework was set up for controlling movement of hazardous wastes across international borders
 - Criteria developed for “environmentally sound management” of hazardous wastes



Key conventions dealing with PTMB chemicals

- Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal
 - *The provisions of the Convention center around the following principal aims:*
 - *the reduction of hazardous waste generation and the promotion of environmentally sound management of hazardous wastes, wherever the place of disposal;*
 - *the restriction of transboundary movements of hazardous wastes except where it is perceived to be in accordance with the principles of environmentally sound management; and*
 - *a regulatory system applying to cases where transboundary movements are permissible.”*
[<http://www.pic.int/>]

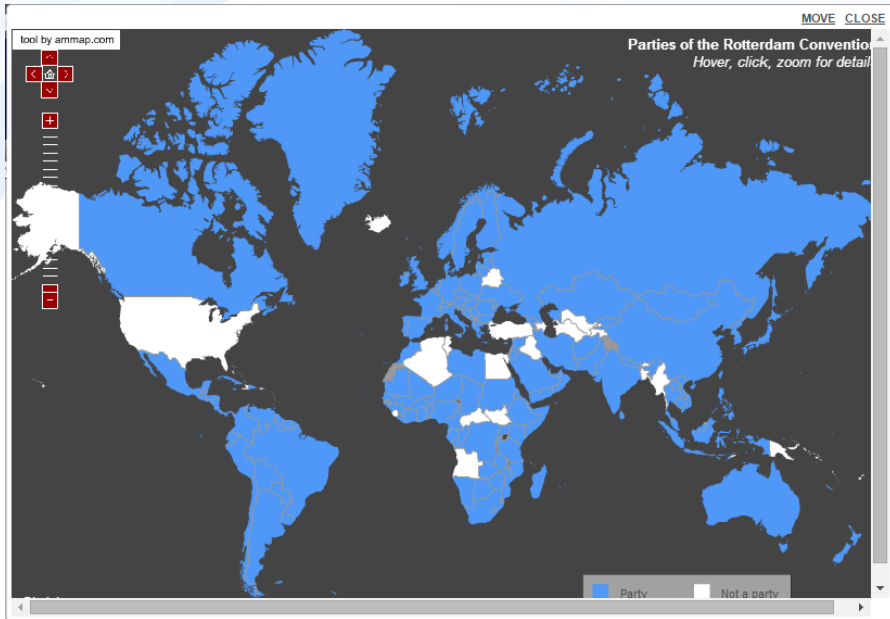


Key conventions dealing with PTMB chemicals

- Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade
 - “Objectives of the convention are:
 - *to promote shared responsibility and cooperative efforts among Parties in the international trade of certain hazardous chemicals in order to protect human health and the environment from potential harm;*
 - *to contribute to the environmentally sound use of those hazardous chemicals, by facilitating information exchange about their characteristics, by providing for a national decision-making process on their import and export and by disseminating these decisions to Parties.”*
[<http://www.pic.int/>]



Key conventions dealing with PTMB chemicals



- Rotterdam Convention
 - “*The Prior Informed Consent (PIC) procedure – The PIC procedure is a mechanism for formally obtaining and disseminating the decisions of importing Parties as to whether they wish to receive future shipments of those chemicals*” listed in the Convention or “*for ensuring compliance with these decisions by exporting Parties.*”
 - “*Information Exchange - The Convention facilitates information exchange.*” Notification required “*when taking a domestic regulatory action to ban or severely restrict a chemical.*”

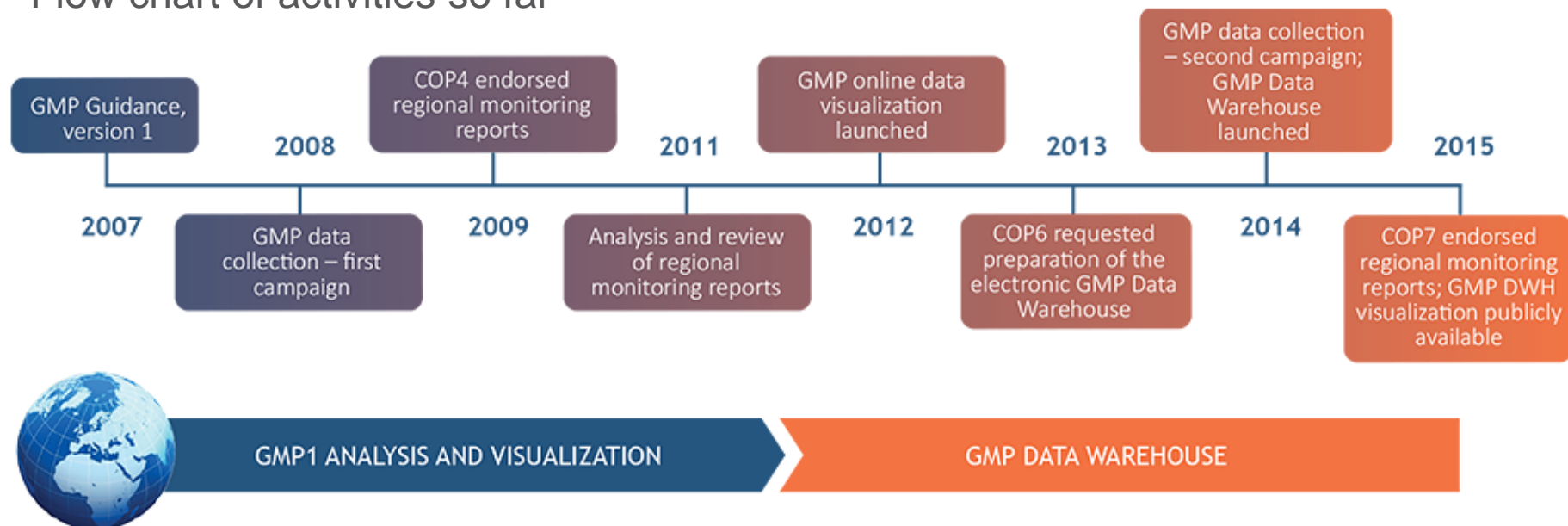


Global monitoring of PTMB chemicals

- Example - The Global Monitoring Plan on Persistent Organic Pollutants (GMP)
 - Article 16 of SC on POPs: requires effectiveness of measures adopted by the Convention regularly evaluated

GMP: aims at collecting comparable, harmonized and reliable information on POP levels in core environmental matrices (air, breast milk/blood and water).

Flow chart of activities so far

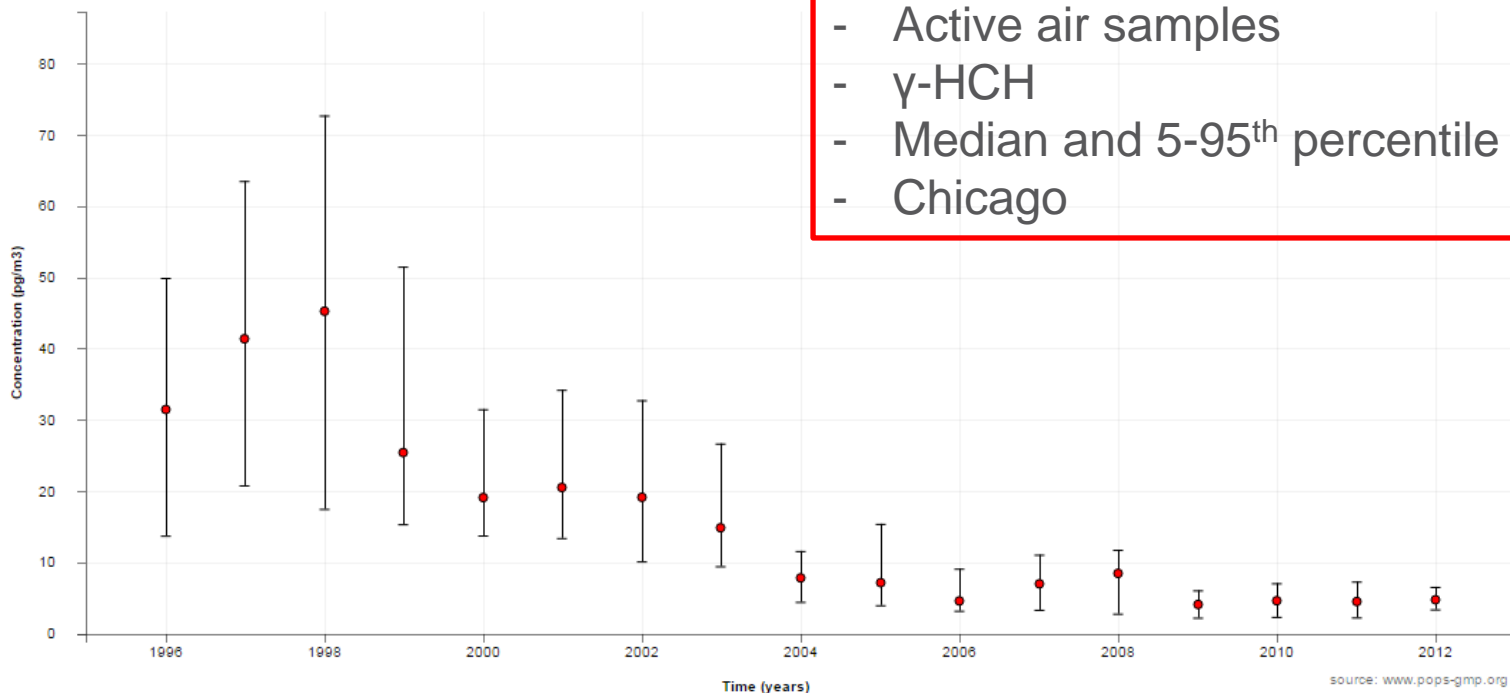


Global monitoring of PTMB chemicals

- Available Global Monitoring Plan (GMP) data

What happens to POPs levels over time? Are measures to eliminate or reduce emissions working?

- Time series analysis
- Active air samples
- γ -HCH
- Median and 5-95th percentile
- Chicago

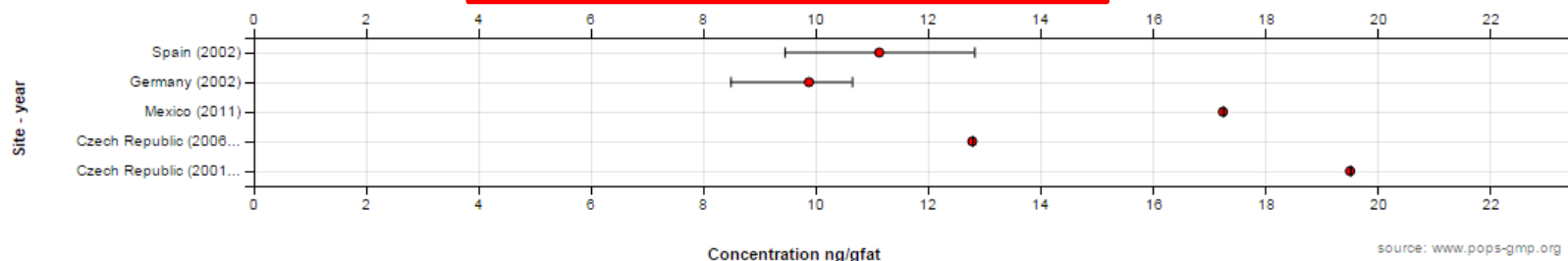


Global monitoring of PTMB chemicals

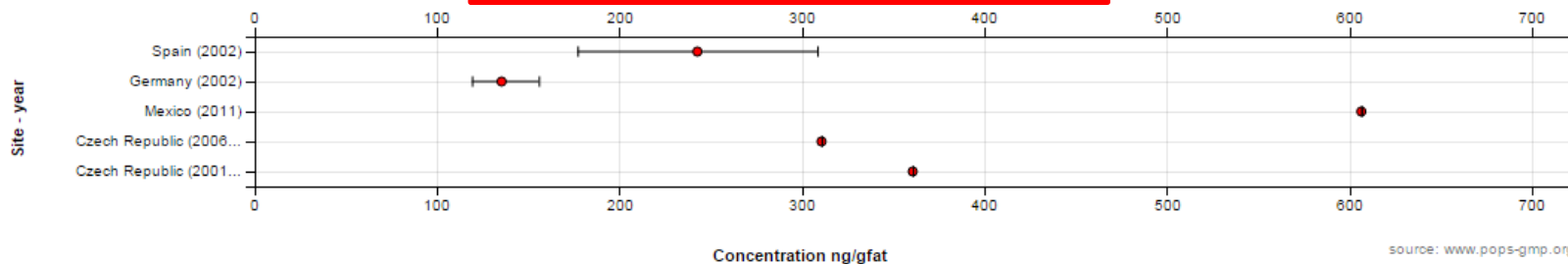
- Available Global Monitoring Plan (GMP) data

Which countries have the highest exposure to POPs? How are people exposed and what are the risks? Do levels decrease over time?

p,p-DDT, pooled breast milk



p,p-DDE, pooled breast milk



Global monitoring of PTMB chemicals

- Available Global Monitoring Plan (GMP) data

Do we know anything about spatial trends? Where are the highest POPs contaminations? Can we figure out why? Are the POPs mobile?

Summary Statistics

Matrix: *
Water

Matrix specification: *
Marine water - open ocean

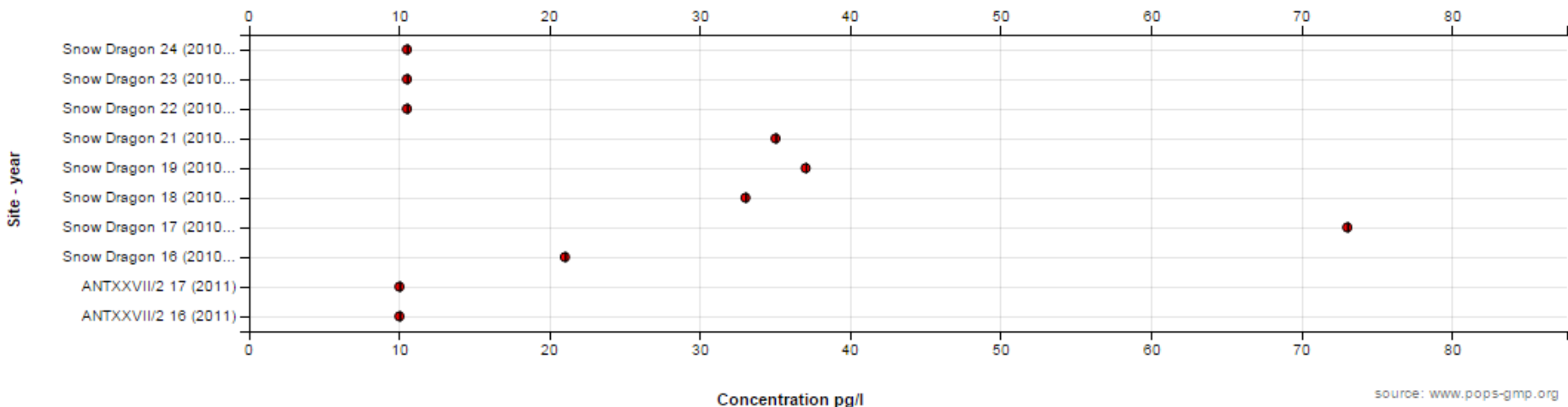
Compound: *
Perfluorooctane sulfonic acid (PFO₄)

Parameter: *
PFOS

Unit: *
pg/l

Site:
-- Choose an option --

Year:



The end.....any questions?

