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ENVIRONMENTAL SCIENCE FOR THE EUROPEAN REFINING INDUSTRY

Water use and trends in emissions to water from EU refineries

Mike Spence

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Overview

- EU Environmental protection legislation
- Water use in Refining
- Concawe benchmarking of sector performance
- Overview of sector water usage in 2010
- Review of trends and effluent quality
- Conclusions

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Environmental Protection Legislation

1. Substances allowed on the EU-Market
   - REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals)
   - Classification, Labelling & Packaging
   - Transport of Dangerous Goods (Road, Rail & Inland Water ways)
2. Emissions
   - National emissions ceiling directive (caps per country for air emissions)
   - European Pollutant Release and Transfer Regulation (E-PRTR)
   - Urban Waste Water Treatment Directive
   - Industrial Emissions (IED, 2010)
     - Includes Air & Water targets and obligations to reduce & Soil base line requirements
3. Directives defining Environmental Quality Standards
   - Ambient Air Quality
   - Surface water and Ground Water Standards under WFD and GW daughter Directive

+ 2013 Water Blueprint for Europe- fitness check of EU water policy
   - Quantitative water management based upon the "Ecological flow concept"

+ EU 2020 biodiversity strategy
   - Halting the loss of biodiversity and the degradation of ecosystem services in the EU by 2020, and restoring them in so far as feasible

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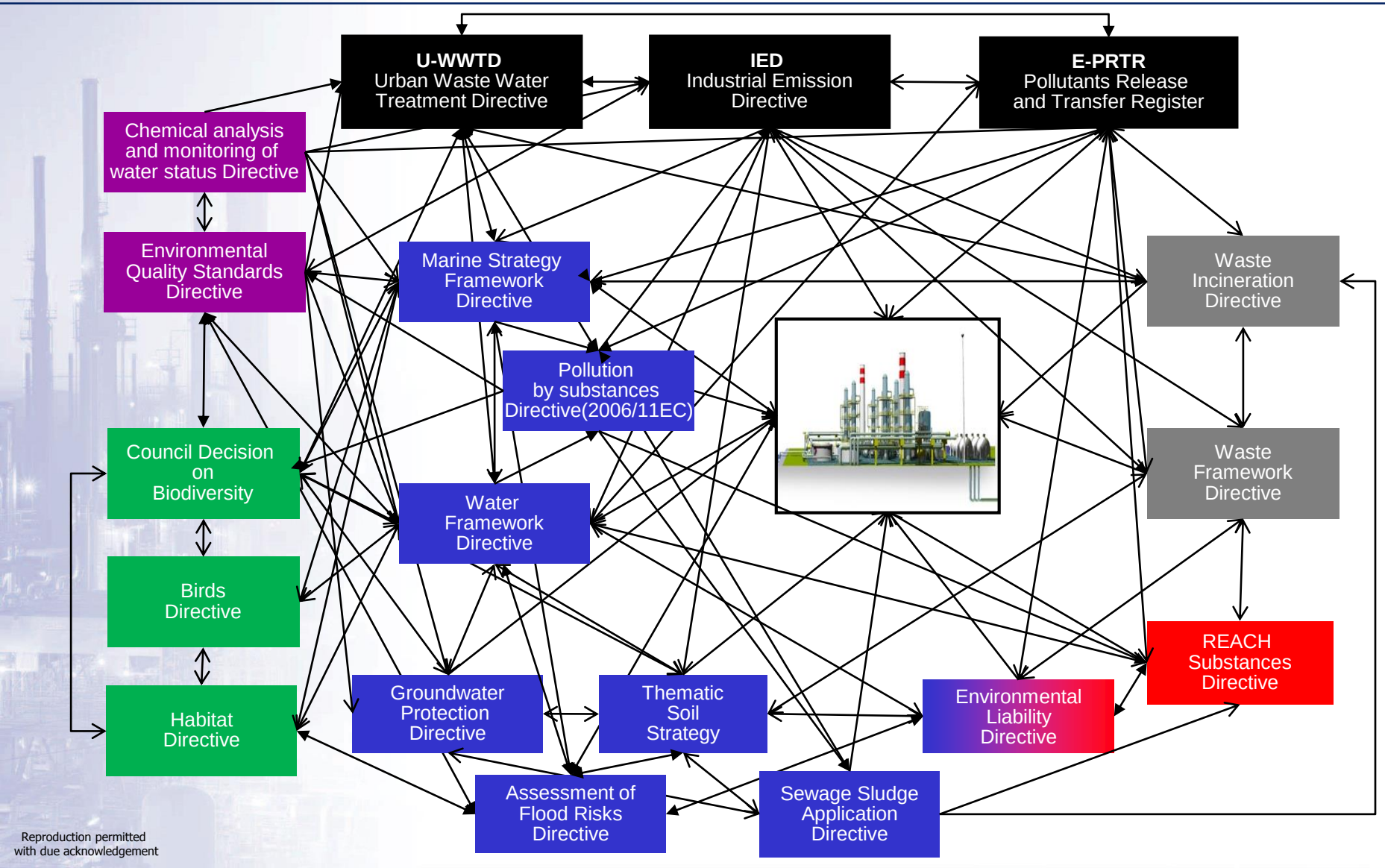
Soil, Water and Waste Legislative Environment



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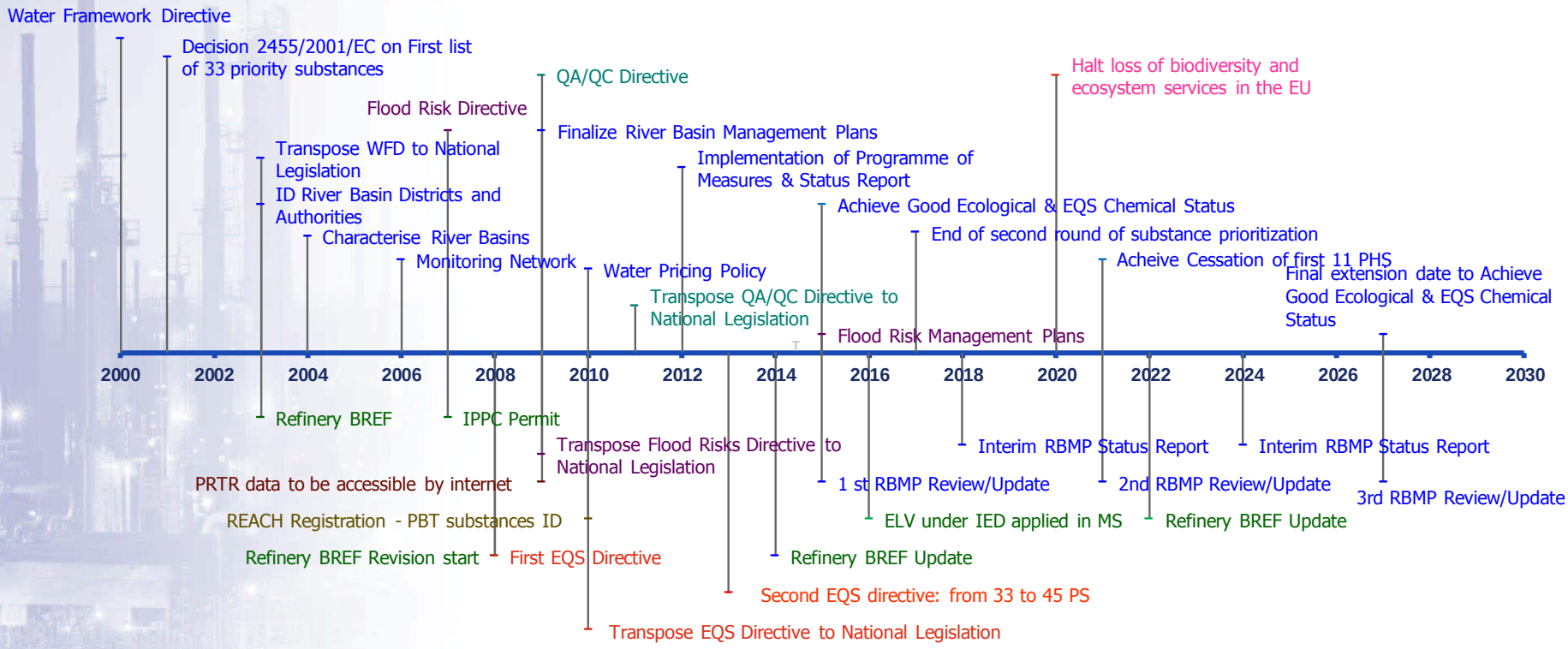
Water Policy Implementation Timeline



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Water use in Refining

- Process water
  - Desalting of crude oil
  - Steam injection
  - Scrubbing for particulate/ gas removal
- Cooling water
  - Once-through- Direct & indirect
  - Other cooling water
    - Recycling
    - Indirect cooling
- Rainwater
- Domestic water- Canteens, showers, toilets
- Other water
  - Site remediation/ control of groundwater levels
  - Cleaning

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Concawe benchmarking of sector performance

- Concawe data allows refining sector to demonstrate continuous improvement in environmental performance
- 1969- 2014 inventories of oil in water/ TPH discharges
- 2013 inventory of refinery non- hazardous and hazardous waste streams (data in process)
- 2010 and 2013 surveys of sector water use and emissions to water:
  - Intake and discharge water flows and recycles
  - 50 effluent quality parameters included in 2010 and 2013 surveys:
    - REFBREF BAT-AELs, WFD-PSs, E-PRTR reportable substances
    - Parameters specifically mentioned in operating permits
    - Company policy requirements

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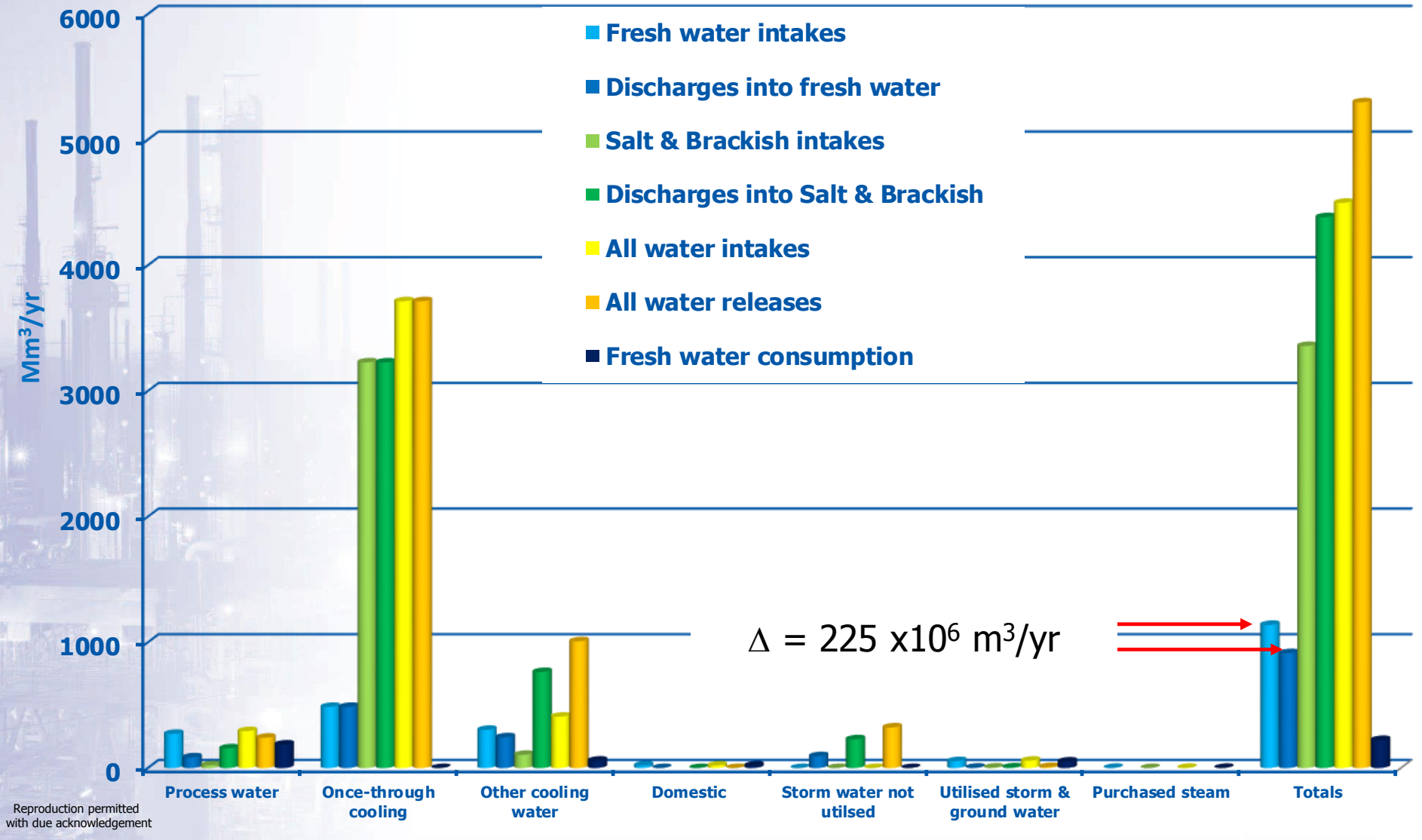
Intakes, discharges & freshwater consumption (2010 survey data)



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Water consumption vs use for cooling

- Using IPIECA sustainability methodology definition of water consumption, i.e.
- Water consumption is equal to the sum of:
  - **Water intake – discharge**, where the intake/ discharge is from aquatic environmental compartments with water of the **same quality** (e.g. Fresh water intakes minus fresh water discharges into fresh water bodies, etc.)
- The values in the table below are calculated based on 2010 production tonnage and water use data for the refining sector
- OTCW = once-through cooling water (water used but not consumed)

Mean fresh water consumption (excluding OTCW)	Mean fresh water usage (including OTCW)	Mean salt & brakish water usage (including OTCW)	Mean total water usage
l/tonne crude	l/tonne crude	l/tonne crude	l/tonne crude
315	994	3,077	4,071

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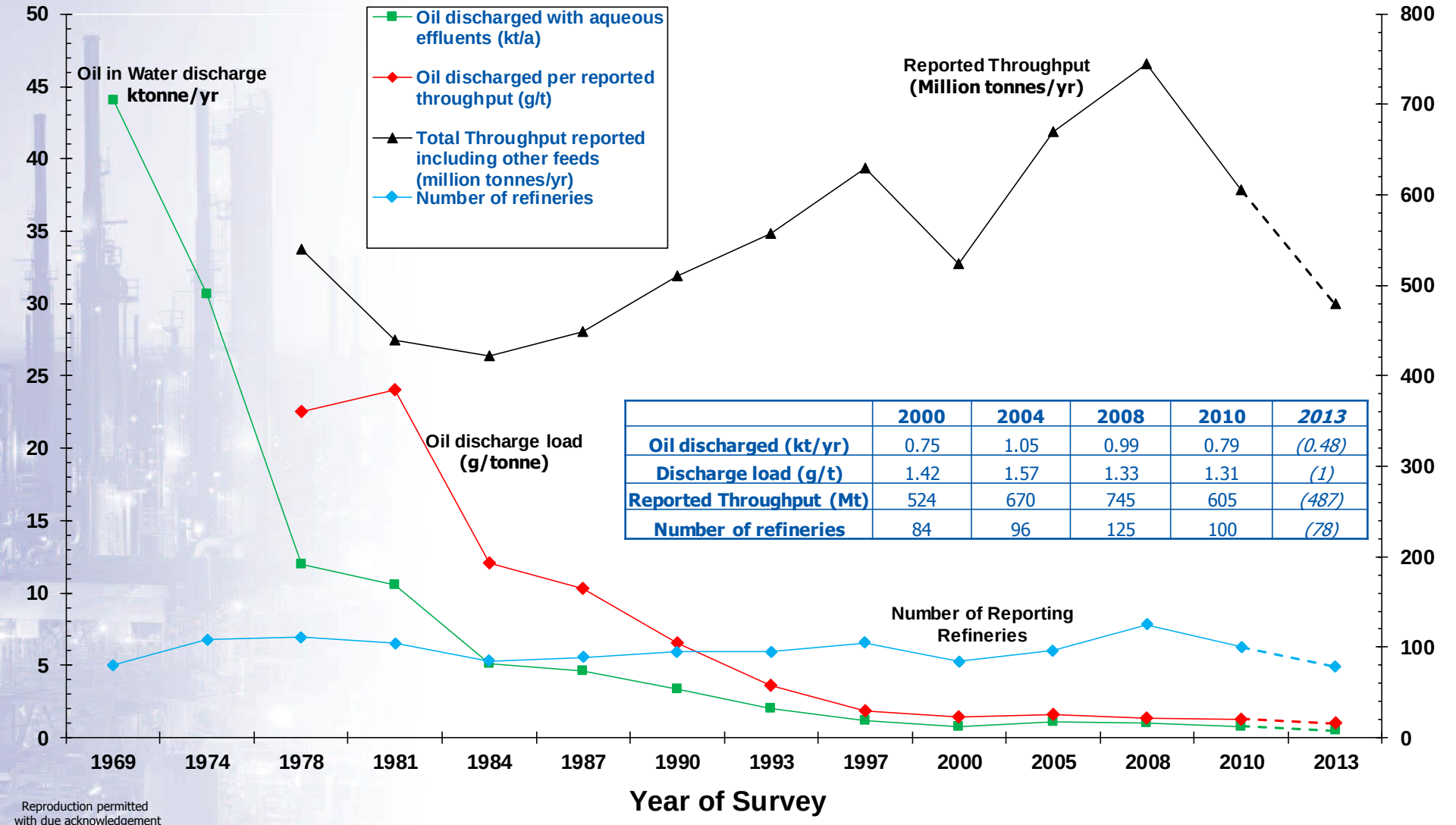
Oil in water/TPH Load (trend since 1969)



	2000	2004	2008	2010	*2013*
Oil discharged (kt/yr)	0.75	1.05	0.99	0.79	*(0.48)*
Discharge load (g/t)	1.42	1.57	1.33	1.31	*(1)*
Reported Throughput (Mt)	524	670	745	605	*(487)*
Number of refineries	84	96	125	100	*(78)*

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I: Total Petroleum Hydrocarbons (TPH)

- C10 to C40 aliphatics, aromatics and naphthenics + PAHs
- TPH fractions that may be present in refinery effluents are indicated in the table below

	normal paraffins	iso paraffins	mono naphthenes	di naphthenes	mono aromatics	naphthenic mono aromatics	di aromatics	naphthenic di aromatics	Poly aromatics	n-CC5 mono naphthenics	n-CC6 mono naphthenics	poly naphthenics
C6 - C8					X							
C9-C11	X	X	X	X	X	X	X		X	X	X	
C12-C14	X	X	X	X	X	X	X	X	X	X	X	
C15-17	X	X	X	X	X	X	X	X	X	X	X	
C18-20	X	X	X	X	X	X			X	X	X	X
C21-23	X	X	X							X	X	X
C24-26	X	X	X							X	X	X
C27-C29	X	X	X							X	X	X
C30-C40	X	X								X	X	X

- Consistent downward trend in Oil in Water/ TPH
- **Discharge load has been consistently below the OSPAR target of 3 g/tonne of crude oil since 1993**

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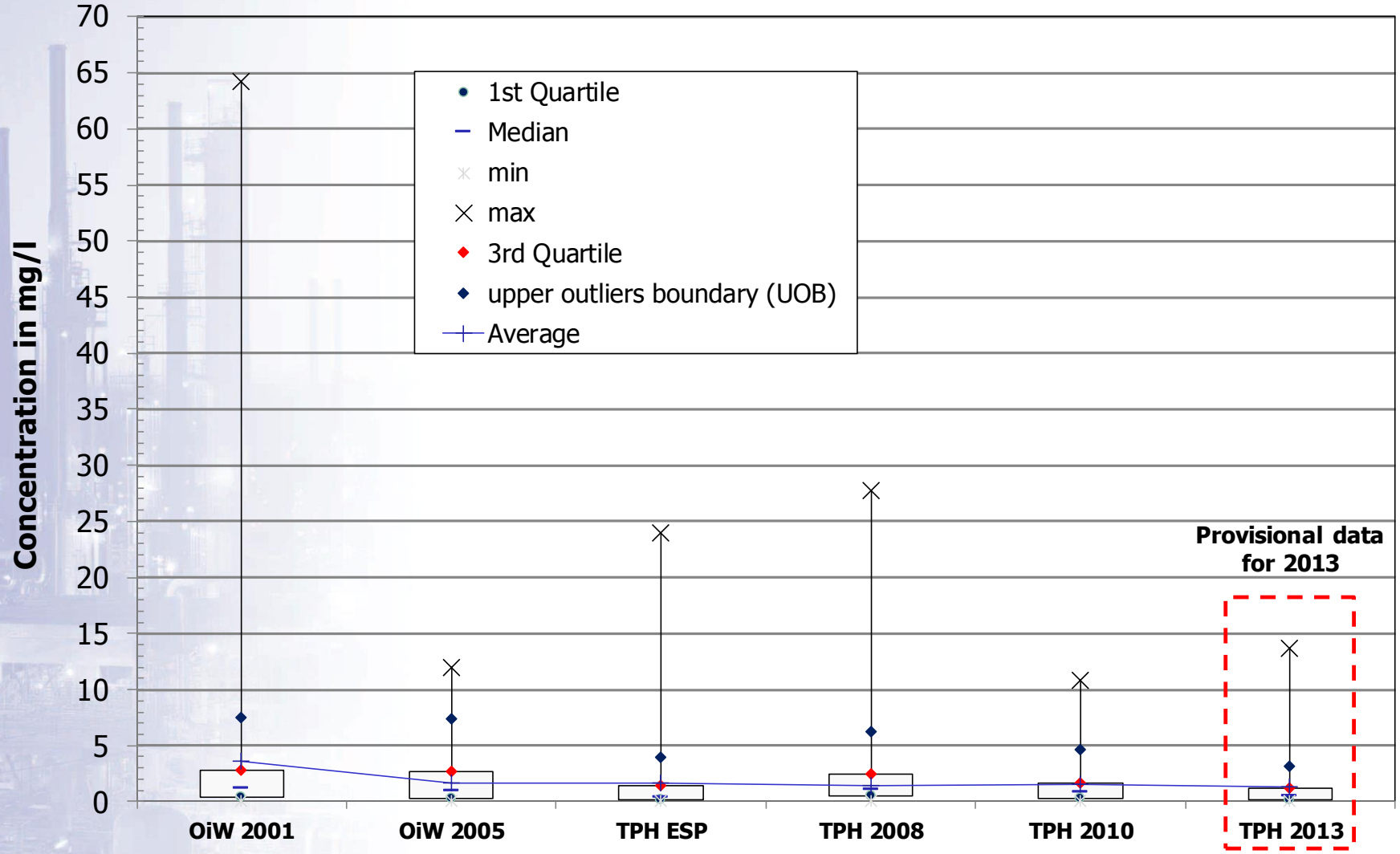
2001- (2013) TPH concentration trend



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Total load 2010 vs initial results from 2013

Parameter	Total Absolute load for the sector (tonne/2010) (100 sites)	Provisional Absolute load for the sector (tonne/2013) (78 sites to date)
Total Petroleum Hydrocarbons (TPH)	773	*441*
Benzene	6.6	*2.6*
Toluene	6.4	*2.6*
Ethylbenzene	3.9	*1.7*
Xylenes	9.3	*3.3*
Phenols	31.8	*16.9*
Sum PAHs	0.18	*0.06*

* Note that for calculation purposes non- detect values have been substituted with 0.5* LOQ

- E.g. 180kg PAH/year is equivalent to approx. 5g PAH per refinery per day
- A typical residential district would, on average, release several times this mass of PAH/ day in the form of smoke from wood fires, BBQs etc.

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Metals and inorganics (2010)

Metals	Total Absolute load for the sector (tonne/2010)*
Arsenic	3.5
Cadmium	0.74
Chromium	2.5
Chromium (VI)	2.4
Cobalt	0.51
Copper	3.4
Iron	150
Lead	3.0
Mercury	0.17
Nickel	8.0
Selenium	4.5
Vanadium	7.2
Zinc	27.7

Inorganics	Total Absolute load for the sector (tonne/2010)*
Ammoniacal Nitrogen	537
Chlorides	275,065
Fluorides	275
Free cyanides	6.2
Kjeldahl Nitrogen	700
Nitrates	1,956
Nitrites	248
Sulphides	26.8
Sulphites	5,493
Total Nitrogen	2307
Total Phosphorus	238

* Note that for calculation purposes non- detect values have been substituted with 0.5* LOQ

- 80% of nitrogen emissions are in an oxidised form, consistent with all refineries using biological treatment (close to 100% reduced nitrogen species before biotreatment)

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Conclusions

- CONCAWE maintains a database of water use and effluent discharge data for the EU refining sector
- The volume of freshwater consumed in refining a tonne of crude oil is low relative to other manufactured products, with the majority of the water intake used for once-through cooling
  - e.g. 0.315m^3/ tonne crude oil vs average green + blue water footprint for cereal crops in Western Europe of 654m^3/ ton (Mekonnen & Hoekstra, 2011)
- Fresh water used and then returned to a fresh water body, respecting the quality standards, is available to other users and therefore, not consumed
- The mass of TPH discharged in refinery effluents per year decreased more than tenfold from 1969 to 2000
- TPH discharge to the environment from the refining sector has been at the levels achievable using Best Available Technologies (BAT) since the year 2000
- Discharges of petroleum substances and other substances in effluents are already highly regulated e.g. by discharge permits and environmental quality standards (EQS).
- It is important that any future measures to reduce water consumption take account of the fact that this could lead to increased solute concentrations in effluents

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Thank you for your attention