Water use and trends in emissions to water from EU refineries

Mike Spence

11th CONCAWE Symposium
23rd-24th February 2015
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
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
Soil, Water and Waste Legislative Environment

- IED: Industrial Emission Directive
- E-PRTR: Pollutants Release and Transfer Register
- Chemical analysis and monitoring of water status Directive
- Water Framework Directive
- Pollution by substances Directive (2006/11EC)
- Habitat Directive
- Council Decision on Biodiversity
- Birds Directive
- Groundwater Protection Directive
- Thematic Soil Strategy
- Assessment of Flood Risks Directive
- Sewage Sludge Application Directive
- Environmental Liability Directive
- Waste Framework Directive
- Waste Incineration Directive
- REACH Substances Directive
- Water Framework Directive
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- Water Frame...
Water Policy Implementation Timeline

- Water Framework Directive
- Decision 2455/2001/EC on First list of 33 priority substances
- Flood Risk Directive
- Transpose WFD to National Legislation
- ID River Basin Districts and Authorities
- Characterise River Basins
- Monitoring Network
- Refinery BREF
- Finalize River Basin Management Plans
- Implementation of Programme of Measures & Status Report
- EQS Directive
- Transpose EQS Directive to National Legislation
- Halt loss of biodiversity and ecosystem services in the EU
- EQS Chemical Status
- Transpose Flood Risks Directive to National Legislation
- Flood Risk Management Plans
- EQS Directive
- Transpose QA/QC Directive to National Legislation
- Achieve Good Ecological & EQS Chemical Status
- QA/QC Directive
- Transpose QA/QC Directive to National Legislation
- Finalization of River Basin Management Plans
- Achieve Cessation of first 11 PHS
- Water Pricing Policy
- Transpose QA/QC Directive to National Legislation
- Interim RBMP Status Report
- Final extension date to Achieve Good Ecological & EQS Chemical Status
- Interim RBMP Status Report
- Interim RBMP Status Report
- 3rd RBMP Review/Update
- 2nd RBMP Review/Update
- 1st RBMP Review/Update
- ELV under IED applied in MS
- Refinery BREF Update
- Refinery BREF Update
- Second EQS directive: from 33 to 45 PS
- Transpose EQS Directive to National Legislation

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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
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:
    - REFBRFR BAT-AELs, WFD-PSs, E-PRTR reportable substances
    - Parameters specifically mentioned in operating permits
    - Company policy requirements
Intakes, discharges & freshwater consumption (2010 survey data)

$\Delta = 225 \times 10^6 \text{ m}^3/\text{yr}$
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)

<table>
<thead>
<tr>
<th>Mean fresh water consumption (excluding OTCW)</th>
<th>Mean fresh water usage (including OTCW)</th>
<th>Mean salt &amp; brakish water usage (including OTCW)</th>
<th>Mean total water usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>l/tonne crude</td>
<td>l/tonne crude</td>
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<td>l/tonne crude</td>
</tr>
<tr>
<td>315</td>
<td>994</td>
<td>3,077</td>
<td>4,071</td>
</tr>
</tbody>
</table>
Oil in water/TPH Load (trend since 1969)

- **Oil discharged with aqueous effluents (kt/a)**
- **Oil discharged per reported throughput (g/t)**
- **Total Throughput reported including other feeds (million tonnes/yr)**
- **Number of refineries**

### Key Data:

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

*Reported Throughput (Million tonnes/yr)*

*Number of Reporting Refineries*
## 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

<table>
<thead>
<tr>
<th>C6-C8</th>
<th>normal paraffins</th>
<th>iso paraffins</th>
<th>mono naphthenes</th>
<th>di naphthenes</th>
<th>mono aromatics</th>
<th>naphthenic mono aromatics</th>
<th>di aromatics</th>
<th>naphthenic di aromatics</th>
<th>Poly aromatics</th>
<th>n-CC5 mono naphthenics</th>
<th>n-CC6 mono naphthenics</th>
<th>poly naphthenics</th>
</tr>
</thead>
<tbody>
<tr>
<td>C9-C11</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>C12-C14</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>C15-17</td>
<td>X</td>
<td>X</td>
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<td>C18-20</td>
<td>X</td>
<td>X</td>
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<tr>
<td>C21-23</td>
<td>X</td>
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<tr>
<td>C24-26</td>
<td>X</td>
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<tr>
<td>C27-C29</td>
<td>X</td>
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<tr>
<td>C30-C40</td>
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</tbody>
</table>

- 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
2001- (2013) TPH concentration trend

Concentration in mg/l

- 1st Quartile
- Median
- min
- max
- 3rd Quartile
- upper outliers boundary (UOB)
- Average

Provisional data for 2013
### Total load 2010 vs initial results from 2013

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

*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.
Water use and trends in emissions - EU refineries

Mike Spence

Metals and inorganics (2010)

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

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

* 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)
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
Thank you for your attention