Fate of Hydrocarbon Pollutants in Source and Non Source Control SUDs systems

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OVERVIEW – WHY HYDROCARBONS?

- Runoff ➔ Range of pollutants.

- 50% of pollution in rivers (area dependant) – urban runoff (Designs That Hold Water: Sustainable drainage systems (SUDS) explained, 2010).

- Hydrocarbons (TPH & PAH) serious problem
  - Mutagenic effects
  - Carcinogenic effects (Luch, 2005)

- Behaviour of different compounds
  - Water soluble
  - Attach to solids
SOURCE CONTROL

DEFINITION:
The degradation or retention of a range of pollutants at the source or near to the source of the pollution.

BENEFITS:
- Deal with runoff locally.
- Provision of biological degradation.
- Avoidance of extreme cost.
LITERATURE - HYDROCARBONS/SOURCE CONTROL

- TPHs and PAHs tend to concentrate in the first 10 cm of the soil (Jefferies et al., 2008).

- TPHs and PAHs tend to have higher concentrations in the particulate form (Pitt et al., 1999).

- Volatilization, Photolysis, Biological degradation and Adsorption contribute in the treatment of petroleum hydrocarbons.

- Limited research - accumulations of TPHs and PAHs in SUDS.

- Limited research - source and non-source control systems - treatment efficiency.
AIM OF THIS PROJECT

- Evaluation of the performance of SUDS with source and non-source control, with respect to petroleum hydrocarbons.

- The monitoring focuses on the following types of SUDS:
  - Swales
  - Detention Basins
  - Wet ponds
  - Permeable surfaces

Paired SC - NSC

Motorway detention ponds
Car Parks
Residential Development
CATEGORIES OF HYDROCARBONS

Hydrocarbons

- Cyclic (Benzene) or closed chain compounds
  - Alicyclic
  - Aromatic

- Aliphatic or open chain compounds
  - Saturated Hydrocarbons
  - Unsaturated Hydrocarbons

Saturated Hydrocarbons
- Alkanes CnH_{2n+2} (Single Bond) (e.g., Ethane C_2H_6)

Unsaturated Hydrocarbons
- Alkynes CnH_{2n-2} (Triple Bond) (e.g., Ethyne C_2H_2)
- Alkenes CnH_{2n} (Double Bond) (e.g., Ethene C_2H_4)
TRANSPORT PROPERTIES OF SELECTED ORGANIC CONTAMINANTS

<table>
<thead>
<tr>
<th>Compound</th>
<th>Aqueous Solubility (mg/l)</th>
<th>Vapour pressure (Pa)</th>
<th>$K_{oc}$*</th>
<th>Dominant partition medium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzene</td>
<td>1780</td>
<td>1.3x10$^4$</td>
<td>65</td>
<td>Air</td>
</tr>
<tr>
<td>Phenol</td>
<td>8.2x10$^4$</td>
<td>71</td>
<td>14</td>
<td>Water</td>
</tr>
<tr>
<td>Hexachlorodibenzene- $p$-dioxin</td>
<td>1.3x10$^{-4}$</td>
<td>1.9x10$^{-6}$</td>
<td>2.6x10$^7$</td>
<td>Soil</td>
</tr>
<tr>
<td>Benzo[a]pyrene</td>
<td>3.8x10$^{-3}$</td>
<td>7.3x10$^{-7}$</td>
<td>5.5x10$^6$</td>
<td>Soil</td>
</tr>
</tbody>
</table>

* partitioning coefficient organic carbon-water
TOTAL PETROLEUM HYDROCARBONS

Gasoline Range Organics (GRO)
Carbon Atoms: 
< C10
Acceptable soil contamination: 
0.3 mg/kg

Diesel Range Organics (DRO)
Carbon Atoms: 
C10 – C20
Acceptable soil contamination: 
330 mg/kg

Lubricating Range Organics (LRO)
Carbon Atoms: 
C21 – C40
Acceptable soil contamination: 
580 mg/kg

Water Recovery: 43% - 55%
Soil Recovery: 116% - 122%

(Encia Geoenvironmental Investigations, 2011)
EXPERIMENTAL WORK

LABORATORY TESTS

WATER QUALITY TESTS
- Total Suspended Solids (TSS)
- Volatile Suspended Solids (VSS)
- Chemical Oxygen Demand (COD)
- Biochemical Oxygen Demand (BOD)
- Gas Chromatography-Mass Spectrometry (GC-MS)

SOIL/SEDIMENT QUALITY TESTS
- Accelerated Solvent Extraction (ASE)
- Gas Chromatography-Mass Spectrometry (GC-MS)

IN-SITU TESTS
- Temperature, pH & Water Level
SAMPLING

- Soil samples
- Water samples
CASE STUDY 1 – DETENTION PONDS

❖ A34 Newbury Bypass

- Detention Ponds B & C with Permeable asphalt & Oil interceptors (Source Control)
- Sampling: Every 2 months
- Four water samples: Inlet B&C, Outlet B&C
  - Unfiltered
  - Baseline of data

❖ M27 Itchen Branch

- Detention Pond (Non Source Control)
- Sampling: Every 2 months
  - Two water samples: (Inlet, Outlet)
  - Unfiltered
TPH in road runoff by season and location

TPH (µg/l)

<table>
<thead>
<tr>
<th>SEASON</th>
<th>INLET</th>
<th>OUTLET</th>
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<tbody>
<tr>
<td>Sp</td>
<td></td>
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PLACE

A34

M27
TRUNK ROAD NETWORK SUMMARY

- Water quality - Highly variable in ponds

- Main source of influence of runoff water quality is season

- TPH in road runoff up to 17,000 µg/l; COD to 900 mg/l*; PAH to 50 µg/l

- Large outliers influence data analysis in comparing SC vs NSC – too early to make comparison

* note: in ponds plant debris adds to organic load
CASE STUDY 2 – CAR PARKS

❖ Mount Vernon Treatment Centre, London
Ramboll (Stephen Gibson)

❖ Traffic load of parking lot 1
(porous asphalt): 150 - 200 cars
(Source Control)
  • Sampling: Every 2 months
    • Three soil samples: Basin/Swale/Control
      Layers: 0 – 20, 20 – 40, 40 – 60 mm
    • One water sample: Porous Asphalt
      • Unfiltered

❖ Traffic load of parking lot 2
(standard asphalt): 100 cars
(Non Source Control)
  • Sampling: Every 2 months
    • Two soil samples: Forest Channel/Forest Control
      Layers: 0 – 20, 20 – 40, 40 – 60 mm
    • Two water samples: Standard Asphalt 1&2
      • Unfiltered
MOUNT VERNON TREATMENT CENTRE, LONDON
WATER

- **SUM of PAHS (µg/l)**
  - CarP
  - Bus
  - CarNP

- **COD (mg/l)**
  - CarP
  - Bus
  - CarNP

- **TPH (µg/l)**
  - CarP
  - Bus
  - CarNP

- **BOD (mg/l)**
  - CarP
  - Bus
  - CarNP
SOILS

TPH (mg/g DRY) vs PAHS (ng/g DRY)

Swale, Basin, Control

University of Portsmouth
- Comparison SC AND NSC complicated by NSC discharge to woodland.

- PAH lower in NSC than SC but TPH higher – probably due to HEM is forest soils.

- Further work and analysis is needed

*Note: Future analysis – Correlation PAH runoff vs soil – Possible Source tracking
SUMMARY CAR PARK

- Water quality measured in manholes
- Not accounting for water quantity differences in dilution the porous asphalt car park has **higher** concentrations of:
  - PAHs (median 2.3 vs 1.4 µg/l) but this is not statistically sig (KW, p= 0.45)
  - TPH (median 306 vs 250 µg/l (KW, p= 0.56)

And **lower** concentrations of:
- COD (median 39 vs 71 mg/l) (KW, p=0.88)

- There is a suggestion that the concentration and variety of PAHs from the porous surface is stabilising over time. This may suggest that initial weathering releases PAHs from the higher water\-asphalt interface in porous surfaces. The longer term monitoring will assess this.
CASE STUDY 3 – RESIDENTIAL DEVELOPMENT

- Cambourne, Cambridgeshire
  Steve Wilson (EPG ltd) - EU Demonstrative site

- Treatment Trains (Source Control)
  - Five soil samples:
    Swales 1&2/Basins 1&2/Control
    Layers: 0 – 20, 20 – 40, 40 – 60 mm
    - Sampling: Every 2 months
  - Five water samples:
    Swales 1&2/Basins 1&2/Pond Inlet 1
    - Unfiltered

- Manhole/Drainage (Non Source Control)
  - Two water samples:
    Manhole and Pond Inlet 2
    - Sampling: Every 2 months
    - Unfiltered
WATER

Boxplot of TPH (μg/l)

Chart of Median (SUM OF PAHS)
Soils

Boxplot of TPH (µg/g)

Boxplot of SUM OF PAHS
RESIDENTIAL DEVELOPMENT SUMMARY

- **Lower** concentrations of **PAHs** in the **water of SC** - No clear pattern of TPHs in water.

- In the **SC** system **swales** show **lower** concentrations of **TPHs** in a **particulate** form compared to basins.

- **Higher** concentrations of **BOD, COD** and **TSS** in **SC**.

- Significant **reduction** of **TSS** and gradual reduction of the **COD** concentrations along the **SC** system.
CONCLUSIONS

- Accepted SUDs philosophy is that SC provides the best treatment - Limited comparative studies.
- Variation in runoff quality makes comparison difficult.
- Generally, SC appears to offer benefits and treatment trains show improvements in quality.
- Some SC measures may give short term increases in certain pollutants.
- Analysis of complete data set may give further insights.
OUTCOMES

- Better understanding of the differences between source control and non-source control systems, in terms of treatment efficiency.
- Recommendations for future designs, in terms of optimization of SUDS regarding hydrocarbons treatment.
THANK YOU FOR LISTENING

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