

## Surface Remediation for Contaminated Rail Ballast

**Miles Martin**

Senior Engineer

Soil Mechanics (Environmental Scientifics Group)

**Peter Nicholas**

Operations Director

Waste Management Total Solutions (WMTS) Limited

# Contamination of Ballast

## The Problem

There is a widespread problem throughout the rail network of contamination of railway ballast. Types of contamination include:

- Metals
- Herbicides
- Ethylene Glycol (antifreeze)
- Sewage
- **Hydrocarbons (fuel oils, polychlorinated biphenyls (PCB), polycyclic aromatic hydrocarbons (PAH) and lubricating oils)**

# Contaminative Processes

The main sources of hydrocarbon contamination in ballast are:

- Leaks of diesel from the fuel tanks of locomotives, multiple units and on-track machinery.
- Lubricating oil and grease from engines and wheel assemblies.
- Spillage of fuel at fuelling points.



# Distribution of Hydrocarbons

Distribution of contamination is irregular, concentrated in:

- Areas where trains are stabled (sidings).
- Areas where trains stand temporarily (stations / signals).
- Refuelling areas.
- Maintenance areas (Depots).
- Train washing facilities (although generally controlled environments)



# Associated Hazards and Problems

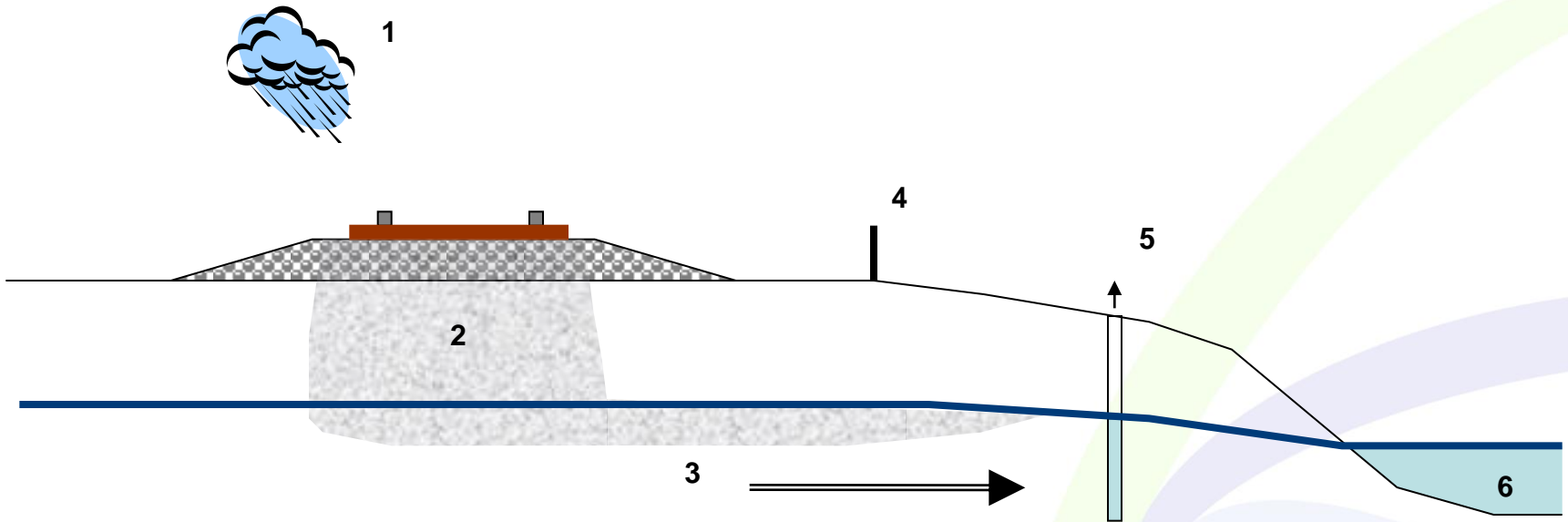
- On the surface, this hydrocarbon contamination, which typically includes potentially carcinogenic substances, represents a significant health hazard to railway station, track workers and depot staff.
- It also has a negative impact aesthetically, and substantially increases the likely disposal costs of the ballast.
- Furthermore, as described in the Department of Environment Industry Profile on Railway Land (DE, 1995), these organic contaminants are highly mobile and pose a threat to groundwater which may become contaminated through the downward seepage of liquids under gravity, and the movement of vapours in unsaturated soils. Less soluble compounds, which become adsorbed onto clay or organic matter, can also pose a longer term threat to groundwater.

# Potential Receptors at Risk

Possible receptors are both human and environmental:

- Human Receptors (Potential direct contact):
  - Track and signalling maintenance teams
  - Depot personnel (train maintenance workers, train cleaning staff etc).
- Environmental Receptors:
  - Ground (the soils underlying the site)
  - Landfill (disposal of contaminated ballast)
  - Groundwater (including possible threat to drinking water)
  - Controlled water bodies (nearby rivers / streams / lakes)

# Conceptual Model



1. Rainfall
2. Leachate migration (mobilised by percolation of rainfall) down to groundwater
3. Lateral movement of contamination due to groundwater flow
4. Potential migration of contamination beyond railway land boundaries
5. Possible influence on groundwater abstraction points
6. Possible contamination of other controlled water bodies such as rivers and lakes

# Control Measures - New Contamination

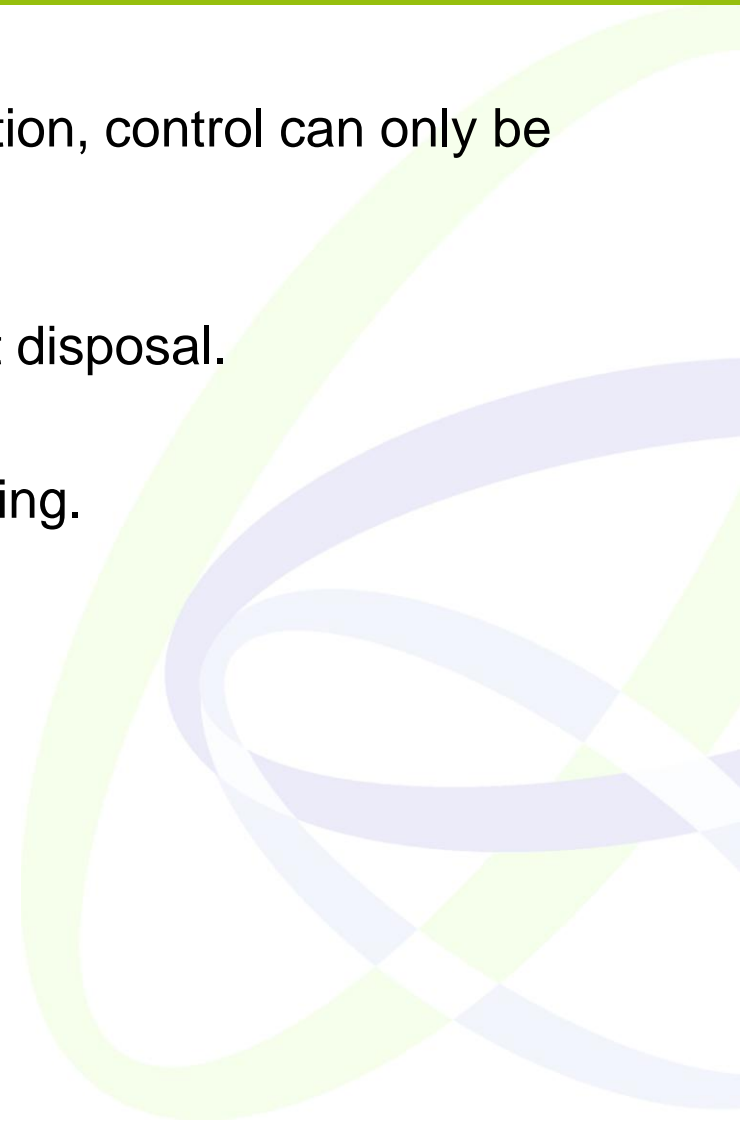
- Total prevention of contamination source (Leak-proof trains).  
Unfeasible at present time?  
(High cost may prevent development?)
- Interception of contamination between train and ground.  
Drip trays / concrete bases / absorbent track mats (Disposal costs?)
- Remediation of contamination within the ballast.  
Removal of contaminated ballast.  
(Disposal costs?)  
  
Removal and washing of ballast.  
  
**Reduction of hydrocarbons by in situ treatment.**

# Control Measures - Existing Contamination

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For existing areas of hydrocarbon contamination, control can only be through remediation:

- Removal of contaminated ballast for direct disposal.
- Removal of contaminated ballast for washing.
- Remediation of ballast in situ.



# Proposed In Situ Bio-Remediation

- An in situ bio-remediation technique is proposed, using a liquid hydrocarbon digester.
- Application by hand, using a backpack type sprayer, or smaller hand-held garden type sprayer, in order to target specific areas of contamination.
- A fine spray applies a thin coating of the bio-remediation product over the surface of both the coarse ballast fragments and the finer matrix materials.
- Aim to combat the ongoing accumulation of hydrocarbons, and also decrease the degree of contamination already present in the ballast.
- The objective would be to intercept the problem at a high level, to control the contamination at and just below the ballast surface, before the hydrocarbons are able to migrate to greater depths where remediation becomes more difficult and costly.
- Depending on the extent of contamination, and the sensitivity of the location, validation testing of the ballast and monitoring of the groundwater chemistry should be undertaken during the period of remediation.
- The application would be repeated at a rate of three times per week. Once a suitable improvement has been confirmed, the rate of application would be reduced appropriately (i.e. remediation followed by longer term maintenance).

# Liquid Hydrocarbon Digester

The proprietary liquid bacteria bio-remediation product applied by WMTS Limited combines:

- Micro-organisms, selected to perform under aerobic and anaerobic conditions.
- High potency biological nutrients and stimulants.
- Surfactants, to allow penetration of hardened hydrocarbon deposits.

Applied at a rate of one litre of the product, diluted with water at a ratio of 20:1 (water:product), per 25 m<sup>2</sup> of contaminated ballast.

Product designed to degrade a range of hydrocarbons, including diesel, crude oil, petrol, benzene, toluene, ethyl benzene and xylene.

An alternative version of the product, without surfactants, has also been developed.

# Trial at St Phillip's Marsh, Bristol

A trial of the product and proposed procedure undertaken during 2009 – 2010 included:

- The testing of remediation effects under controlled laboratory conditions.
- Full scale in situ site trial at St Phillip's Marsh Maintenance Depot (courtesy of First Great Western).

Main objectives of the trial were to:

- Confirm that hydrocarbon concentrations are reduced by the proposed bio-remediation process.
- Determine whether the groundwater beneath the site is adversely affected by the remediation process.

# Reduction of Hydrocarbons in Ballast: In Situ Trial

- Ballast sprayed with standard bio-remediation product for three months.
- One area left untreated for comparison.
- Spraying at rate of three applications per week.
- Visual improvements observed within approximately three weeks (colour change, from black to grey, and texture change, from glossy to matt).



# In Situ Trial – TPH and PAH Results (1 month)

- Samples recovered from treated and untreated areas of ballast after one month of spraying.
- Laboratory analyses undertaken for TPH, PAH and moisture content.
- Results indicate that the effects of remediation are a significant reduction of TPH and PAH, together with an increase in moisture content.

<b>Sample:</b>	<b>Moisture Content (%)</b>	<b>TPH (mg/kg)</b>	<b>Total (USEPA 16) PAH (mg/kg)</b>
Control Panel (Untreated) – sampled after one month of trial	7.1	249,000	< 60 and < 290
Test Panel (Treated) – sampled after one month of trial	11.5	111,000	< 40 and < 98

# In Situ Trial – TPH and PAH Results (3 months)

- Additional samples recovered from treated and untreated areas of ballast after three months of spraying.
- Again, significantly lower TPH and PAH values were present in the treated ballast sample.
- Much higher values, particularly in the untreated ballast, demonstrate the ongoing process of contamination in the trial area.

<b>Sample:</b>	<b>Moisture Content (%)</b>	<b>TPH (mg/kg)</b>	<b>Total (USEPA 16) PAH (mg/kg)</b>
Control Panel (Untreated) – sampled after three months of trial	12.9	574,000	632
Test Panel (Treated) – sampled after three months of trial	23.1	170,000	< 100

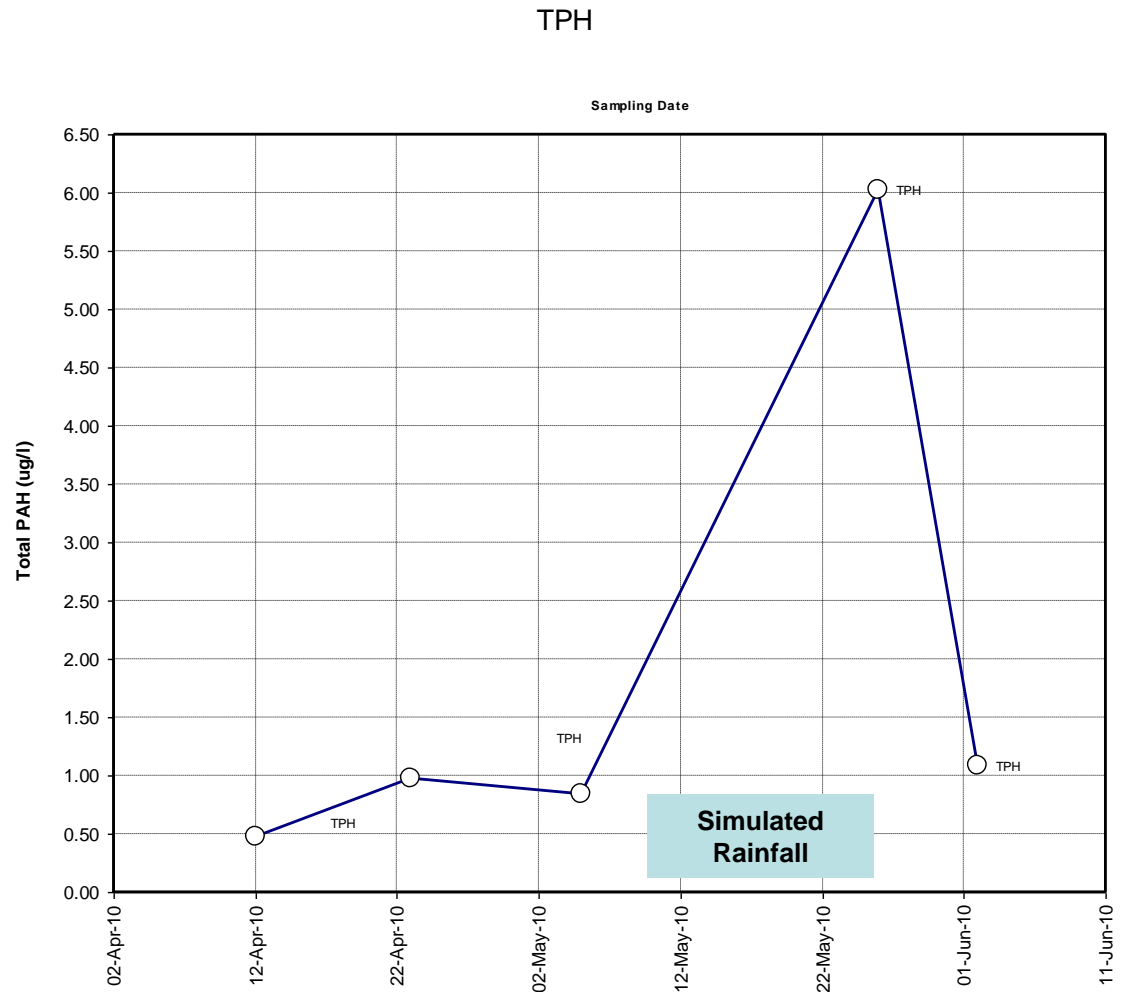
# Reduction of Hydrocarbons in Ballast: Laboratory Assessment

- In a laboratory experiment contaminated ballast specimens were treated with the standard bio-remediation product, the alternative non-surfactant based product, and distilled water (a control specimen, representing the existing conditions for contaminated ballast left untreated).
- Test results indicate lower TPH concentrations and generally lower PAH concentrations in the treated specimens after two months.

<b>Sample:</b>	<b>TPH (mg/kg)</b>	<b>Total (USEPA 16) PAH (mg/kg)</b>
Ballast Sample from Lab-based Apparatus (Untreated specimen)	392,000 and 404,000	<299 and <319
Ballast Sample from Lab-based Apparatus (Specimen treated with standard surfactant-based product)	364,000 and 377,000	<92 and <241
Ballast Sample from Lab-based Apparatus (Specimen treated with alternative non-surfactant based product)	303,000 and 371,000	<277 and <366

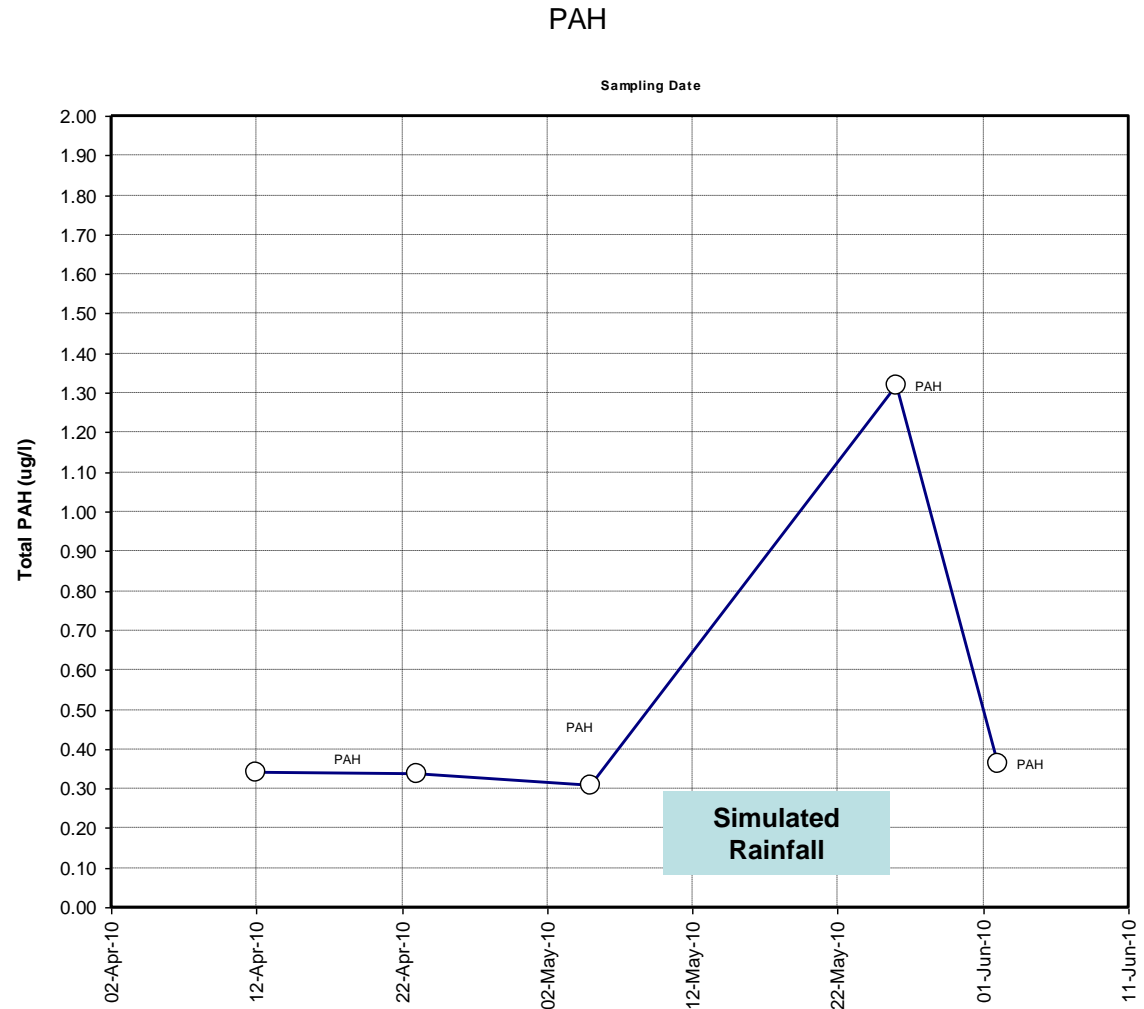
# Leachate from the Untreated Ballast Specimen (TPH)

- In the laboratory experiment the ballast samples were initially sprayed at a rate equivalent to that used in remediation.
- A period of rainfall was then simulated by spraying with an increased volume of water (for two weeks).
- Leachate from the untreated ballast specimen (sprayed with distilled water) showed a significant increase in TPH after the rainfall.



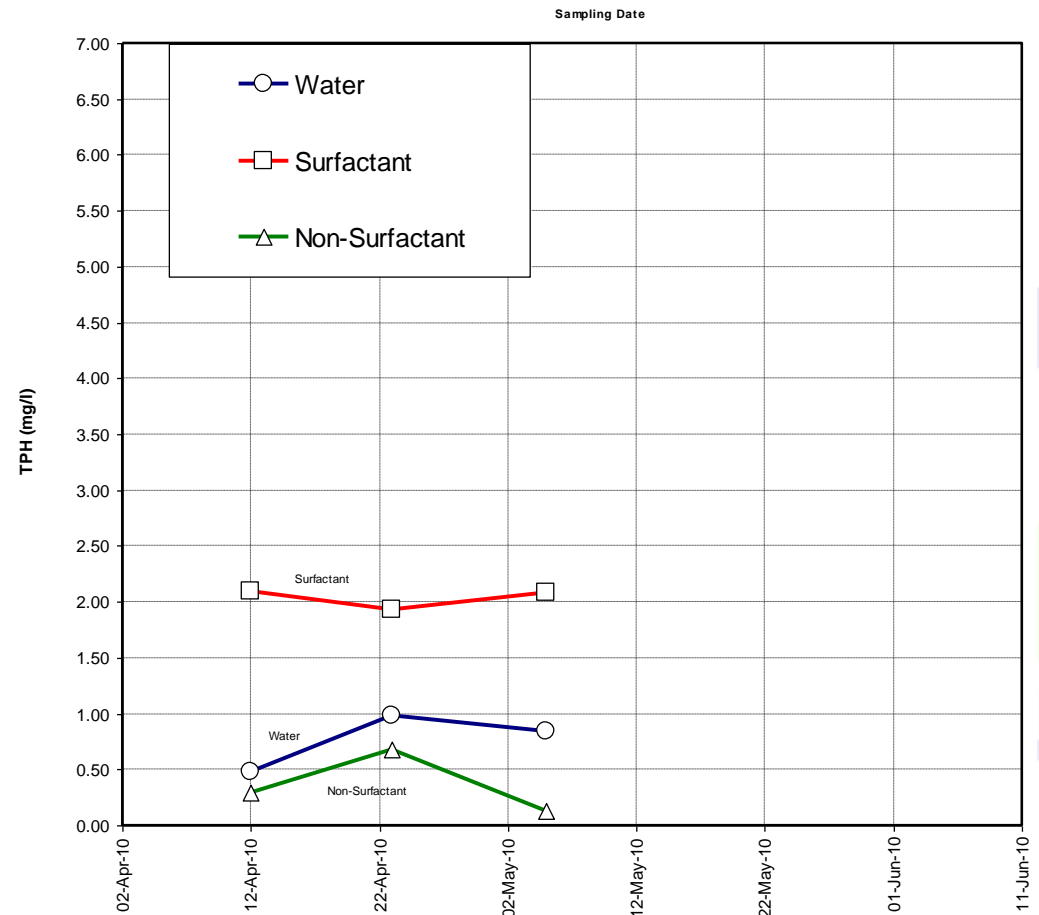
# Leachate from the Untreated Ballast Specimen (PAH)

- Leachate from the untreated ballast specimen also showed a significant increase in PAH after the rainfall.
- As with the TPH, the concentration of PAH then returned to similar levels as recorded before the rainfall.



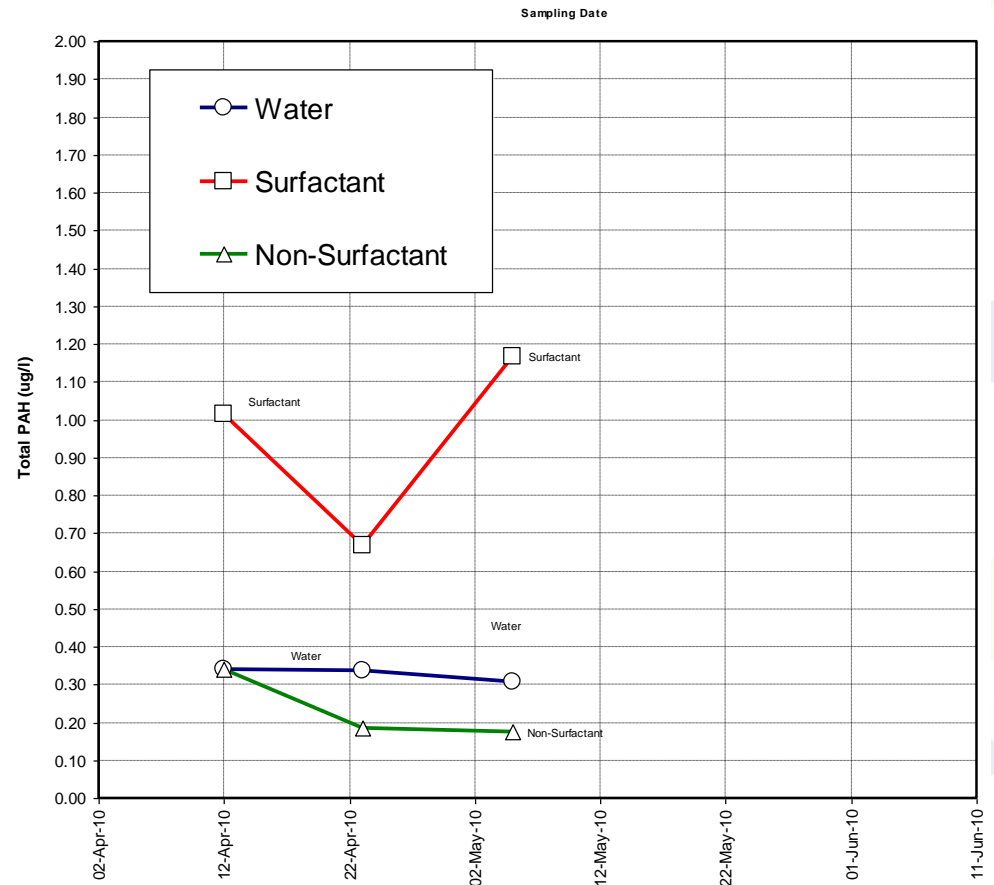
# Comparison of Leachate from Treated and Untreated Ballast Specimens (TPH)

- During relatively dry conditions (prior to period of simulated rainfall) the TPH values for the untreated and treated specimens remained generally consistent.
- Values of TPH for the specimen being treated with the standard surfactant based product were higher than those for the untreated specimen, but in the leachate from the specimen treated with the non-surfactant product the values were lower.



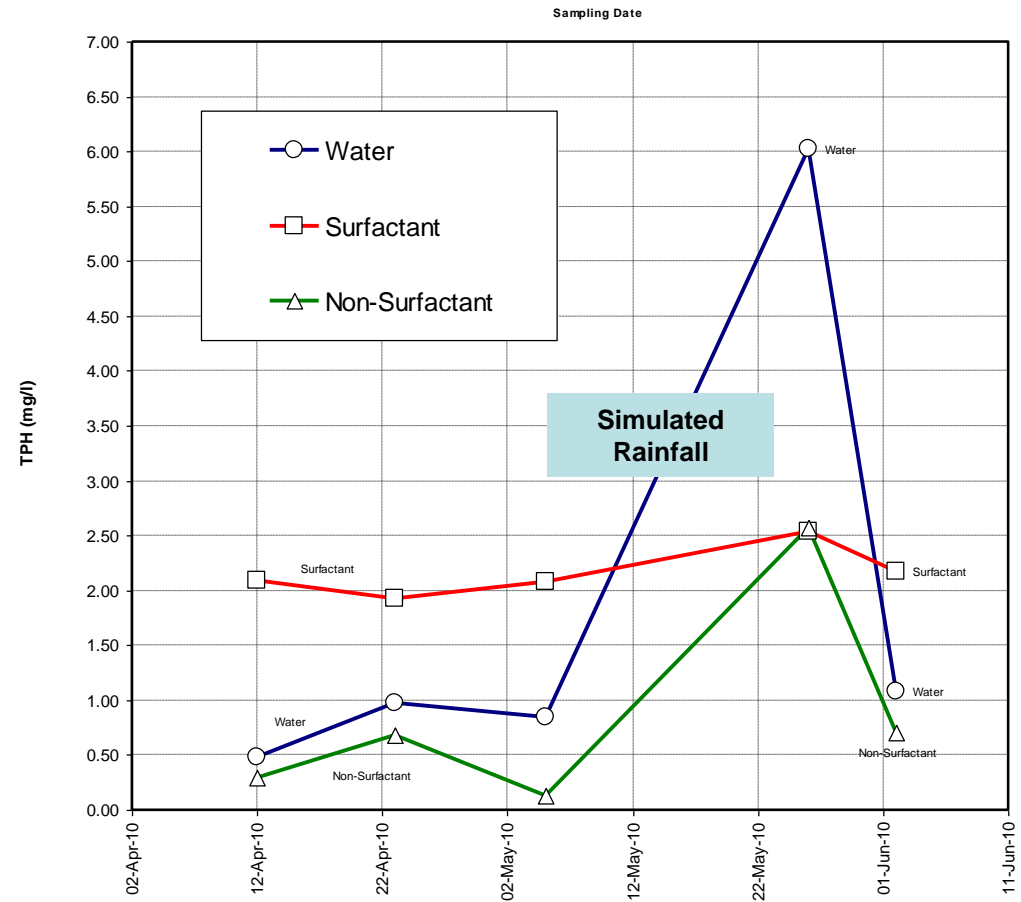
# Comparison of Leachate from Treated and Untreated Ballast Specimens (PAH)

- A similar relationship was recorded by the PAH analyses (although a the results from the specimen being treated with the standard product were more variable over time).



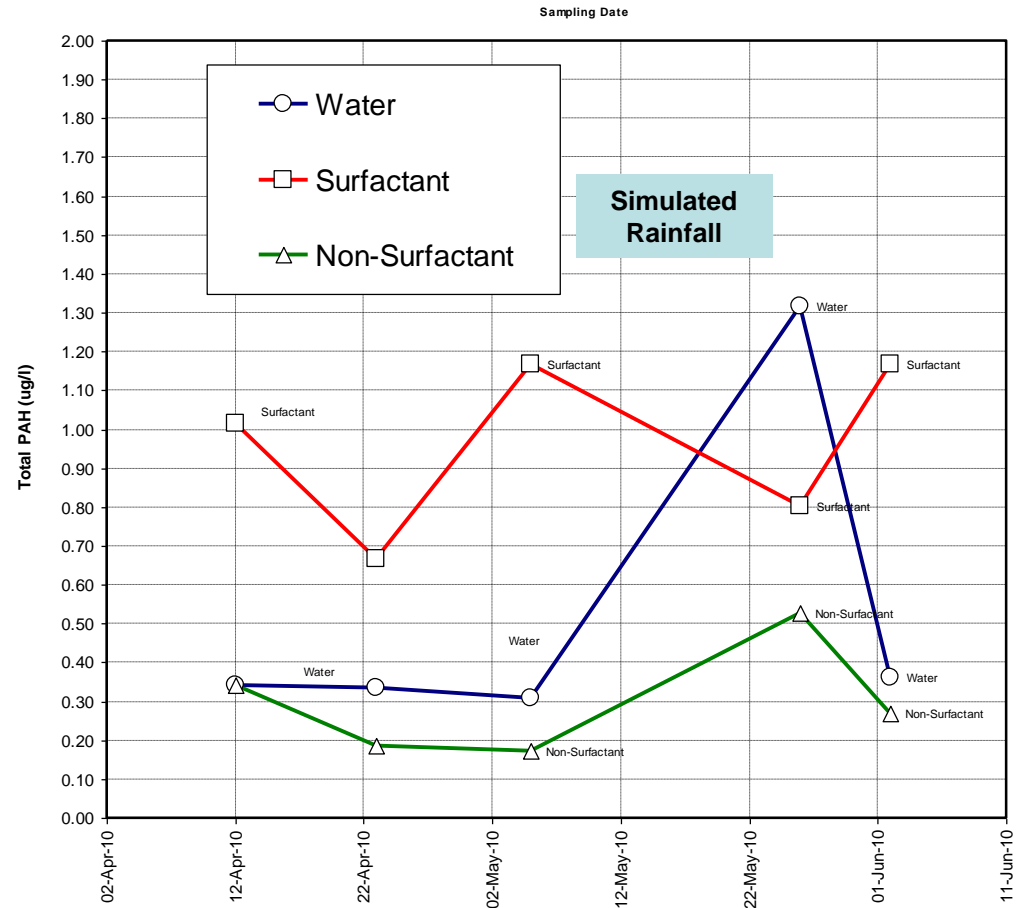
# Comparison of Leachate from Treated and Untreated Ballast Specimens (TPH)

- As with the untreated ballast, the specimens of treated ballast also showed an increase in TPH in the leachate collected during the simulated rainfall, compared to before and after.
- However, values were much lower than that measured in the leachate from the untreated specimen (< 50%).



# Comparison of Leachate from Treated and Untreated Ballast Specimens (PAH)

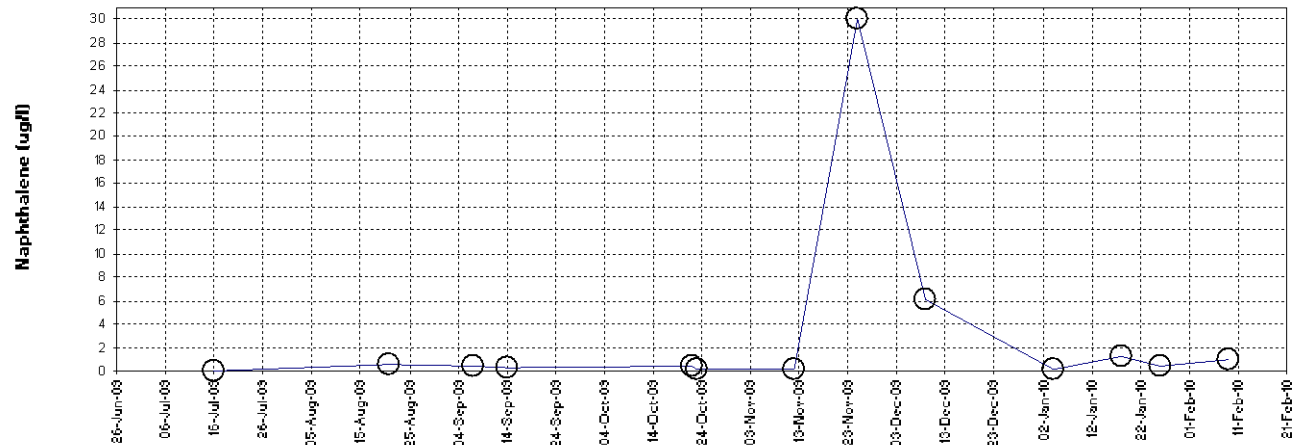
- The PAH concentrations in the leachate from the treated ballast was also much lower than in the leachate from the untreated sample.
- This was particularly evident for the specimen treated with the non-surfactant based product (the results from the surfactant-based product remaining variable and less conclusive).



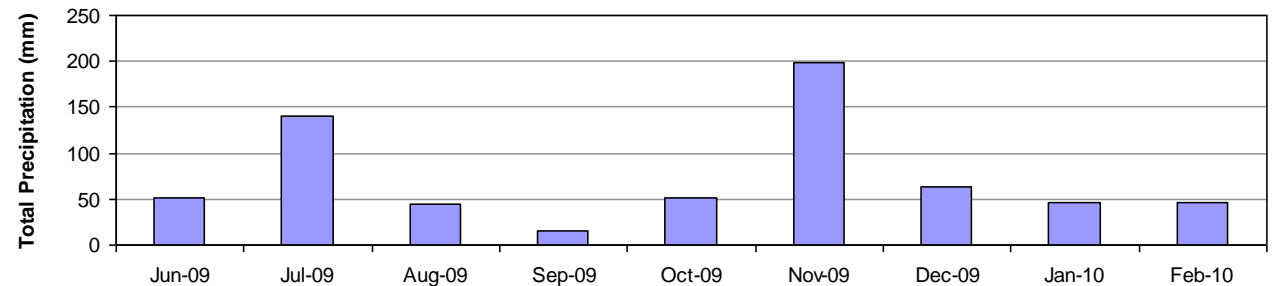
# Analysis of Groundwater During Site Trial

- Groundwater sampling and analysis was undertaken during the site trial.
- It confirmed a close relationship between hydrocarbon concentrations in the groundwater and rainfall (as observed in the laboratory based experiment).

Water Sample Analysis Results



Total Monthly Precipitation (mm)\*



# Conclusions

- Localised contamination of railway ballast by hydrocarbons is present in many areas of the network, particularly in stations and maintenance depots.
- Hydrocarbon contamination represents a potential risk to railway workers who could come into contact with it, and also a risk to the environment.
- Left untreated, hydrocarbons can be mobilised by rainwater, potentially allowing contaminated leachate to migrate to groundwater, rivers and lakes.
- Current methods of contamination control (using track matting to intercept leaks, for example), or remediation (typically the physical removal of contaminated ballast), are expensive.
- A potential cost effective alternative of using a bio-remediation technique to remediate the contaminated ballast in situ has been examined.
- Tests indicate that a standard surfactant based bio-remediation product, and a non-surfactant based alternative product, are both effective at reducing TPH and PAH concentrations in contaminated ballast samples.
- The tests also indicate that rainfall on ballast that has undergone remediation yields leachate with significantly lower concentrations of TPH and PAH than from untreated ballast.