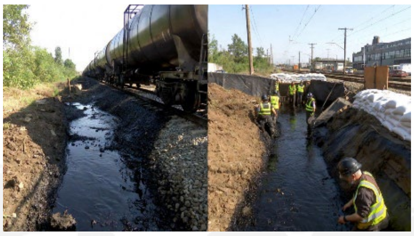
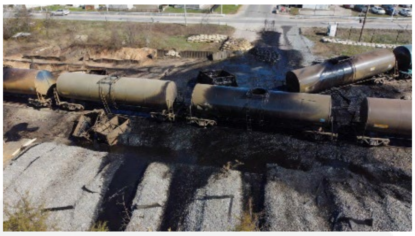
INDUSTRIAL AND LOGISTICS ACCIDENTS – CASE STUDY

STUDY 8/A – NORMAL SYSTEM

1. Starting position and objective of intervention

In the event of a railway oil transport accident, a large amount of oil is spilled, typically from derailed or damaged tankers. The pollution affects the **gravel bed (ballast),** the surrounding soil and the surface areas at the same time. Due to the porous medium of the railway track structure with a large gap volume, the pollution **quickly infiltrates and spreads**, while the site is logistically limited (track closure, access, risk of fire and explosion).

The situation is aggravated by the following factors:

- **Large amount of outflows** (up to 10-100 m³/wagon), which creates an extensive affected zone in a short time;
- **Porous gravel bed**, which promotes capillary and gravitational dispersion of oil (speed up to 0.5-1 m/h in sandy-gravel media);
- **Nearby infrastructure and water bodies** (roads, ditches, streams, rainwater drains) that can trigger secondary migration (runoff, groundwater impact);
- **Environmental sensitivity**, especially in the vicinity of groundwater or surface water, where PAHs and other toxic fractions pose a long-term risk;
- **Fire and explosion** hazards, which limit the possibility of human intervention and machine work.

The main goal is **to localize** the pollution, limit **the spread**, minimize **environmental damage**, and ensure the **safe return of the area** (track restoration, traffic start), in accordance with the relevant regulations (e.g. EU soil and water protection principles, occupational safety regulations, emergency operation protocols). Reference case: the 2013 Lac-Mégantic accident (Canada), where 72 tankers derailed, about 6000 m³ of oil spilled, a fire broke out, and the pollution affected soil, water and air, with long-term recultivation and significant costs.

2. Nature of pollution (normal system)

- **Infiltration into the gravel bed and soil**, with vertical (gravitational) and horizontal (capillary) propagation (0.1–1 m/h, depending on the medium);
- **Formation of a surface oil film** , which can spread rapidly by runoff in the presence of precipitation or extinguishing water;
- **Soil and sediment toxicity**, due to PAHs and hydrocarbons;
- **Secondary pollution to watercourses/stormwater drainage/groundwater**, increasing ecological and human health risks.

The pollutant is typically crude oil or refined product, hydrophobic in nature, but can partially dissolve and fractionate over time. In the long term, it can cause soil toxicity (e.g. death of microorganisms by 20 - 40%, decrease in soil fertility in the order of ~30%), especially when the finer soil layers under the gravel bed are affected.

3. Traditional methods of intervention

3.1 Localization

- Physical barriers (sandbags, temporary barriers);
- Trenching/cutting to stop infiltration and lateral spread.

Limitations:

- Barriers and ditches cannot close **the deeper pores of the gravel bed**, so infiltration can continue (efficiency 50-70%);
- Rain, extinguishing water or soil movement can break through the localization;
- Installation time is 1-2 hours, during which the pollution can increase cumulatively and "settle" in the pavement structure.

3.2 Surface removal

- Mechanical suction, dredging, extraction of contaminated gravel;
- Use of absorbent materials (perlite, zeolite, vermiculite, PP-based).

Limitations:

- In an aqueous medium (precipitation, extinguishing water), the absorbents are saturated → 30-50% decrease in efficiency;
- Dredging will stir up the gravel bed, and the pollution can go deeper;
- A large amount of waste is generated (5-10× weight ratio), which is a dominant factor in transport and disposal costs.

3.3 Surface and structure treatment

- High pressure washing;
- Bioremediation or soil replacement.

Limitations:

- Washing can spread the oil, as well as wash it into channels / trenches;
- Bioremediation is slow (3-6 months) and limited in gravel beds/deeper zones;
- Soil replacement is expensive (50-100 EUR/m³ + logistics), difficult to carry out in a railway environment in a short time.

4. Operational challenges

- The need for immediate intervention (fire hazard + rapid infiltration);
- Official coordination, track closure, dangerous operation;
- Access barriers in the railway area (machinery, utilities, room for manoeuvre);
- High total cost (typically EUR 1-10 million per incident), in which the share of waste and recultivation is decisive.

5. Result (normal system)

- Partial localization (60-80%), but residual infiltration and chronic pollution;
- Significant post-cleaning (for months, with recovery phases);
- High waste disposal cost;
- Long-term soil damage (biodiversity loss of 20-40%).

Summary - Status without exoline:
Conventional systems provide a reactive, partial solution in the event of railway accidents. Their limitation is that they do not deal with the **combined, deep penetrating pollution of the gravel bed + soil** with sufficient efficiency , and due to the wet environment (rainfall/extinguishing water), the performance of the absorbents deteriorates, while the volume of waste is significant.

STUDY 8/B - EXOLINE® OIL STOP

1. Baseline and intervention goal (using Exoline® system) The baseline event is the same as described in Study 8/A. The **aim of Exoline® Oil Stop is not** to replace traditional intervention steps, but **to stabilize and improve them systemically**, especially where traditional solutions are weak: **deep infiltration in gravel** beds, **performance degradation due to wet environment**, **secondary migration**.

The main goals of the intervention with the use of Exoline®:

- Immediate immobilization **of oil** on the surface, in a gravel bed and in soil;
- Prevention **of capillary spread** and secondary migration (runoff, groundwater);

- Creating a controlled, "non-returnable" state in which rescue, extraction and track recovery can be carried out in an organized and safe manner;
- Reducing the risk of fire by stabilizing the mobile oil phase;
- Environmentally safe treatment that does not disperse and does not increase the toxicity of the water column.

2. Nature of pollution with Exoline® (behavioural change)
After applying **Exoline® Oil Stop**, the physical behavior of the oil changes:
2.1 Surface oil film
- **Exoline®** creates a selective hydrophobic bond with the oil phase;
- Oil mobility is reduced, a paste-like/low-fluidity state can be formed;
- The spread slows down and becomes more manageable even in the case of a runoff.

2.2 Gravel bed and soil infiltration
- Fast adsorption stabilization reduces capillary propagation and deeper infiltration;
- Pollution becomes less mobile again (less risk of reflux), which reduces the chronic load.

2.3 Sediment/soil zone stabilisation
- The "keeping in place" of PAH and aromatic fractions may be improved, reducing secondary migration;
- No secondary dispersed contamination phase is created; It supports controlled treatment and aftercare options.

3. Improved intervention methods with the Exoline® Oil Stop system
3.1 Localization and stabilization
- **Exoline®** application in critical zones: tanker environment, sloping areas, catchment points, ditch and runoff directions;
- It can be integrated with traditional methods: trenching, dam, temporary closure;
- It can be used alone or in combination with an improved mineral substrate (e.g. perlite/zeolite granules + **Exoline®**).

Advantages:
- It does not rely solely on physical barriers;
- Rapid stabilization → the "spread window" is shorter;
- In wet environments, the upgraded carrier loses less performance.

Result:
- Faster immobilization of the mobile oil phase;
- Reduced lateral and depth spread;
- Better handling for the extraction phase.

3.2 Surface removal and disposal
- The bound oil is less saturated with water and less draining;
- It can be handled mechanically (collection, pumping, dredging) with minor "smearing".

Result:
- Waste can be reduced (in the range of 30-50%, depending on the location);
- Lower hazardous waste logistics costs;
- Faster site release potential.

3.3 Surface and structure treatment
- Exoline® **stabilization can be applied** before washing and wet procedures;
- Reduce the need and risk of washing (oil dispersion);
- It can be integrated in post-treatment with bioremediation or soil replacement (in a more controlled, smaller zone).

4. Operational impact (with Exoline® system)
- Fast stabilization → more time for decision-making and safe work organization;
- Less human and mechanical risk in the fire hazard zone;
- Simplified logistics: less waste, less repetitive interventions;

- Lower total cost of ownership due to reduced waste and post-treatment components.

5. Result - with Exoline® Oil Stop System
- Fast and stable localization (in critical zones >80%);
- Less post-cleaning and recultivation required;
- Total cost can be reduced by 30-40% (incident and location dependent);
- Reduced long-term ecological risk (biodiversity loss <can be kept below the target value of 20% with appropriate protocols).

Final note - Lesson learned from a railway application (professional closing)
The study presents a subsequent technological comparison. **Exoline® Oil Stop** was not used during the events referred to; the aim is **to demonstrate the material improvement and stabilization potential inherent in the treatment** of gravel bed + soil pollution typical of railway accidents.

It is recommended to launch pilot projects in a real rail environment, with the following measurable endpoints:
- the oil/water content ratio of the material extracted from the gravel bed (risk of back-discharge),
- Soil penetration depth and residual oil content (sampling),
- Waste weight/volume and disposal cost,
- Intervention time and track restoration time (hours/day),
- Environmental compliance and documentation protocol (HSE + soil/water protection principles).

Based on the pilot validation, a standard rail emergency procedure (SOP) can be developed, which sets out the application zones, combined carrier ratios, the collection and waste treatment process, and the restoration criteria.