Captain SUBR:IM takes the plunge

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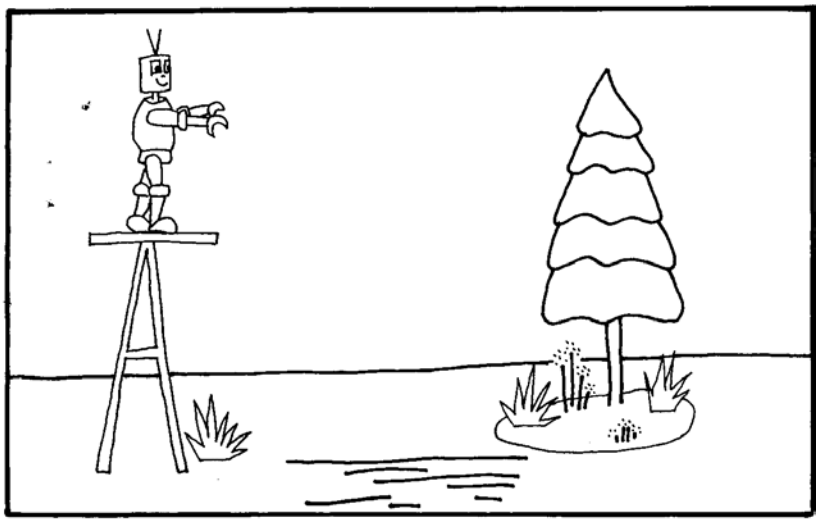
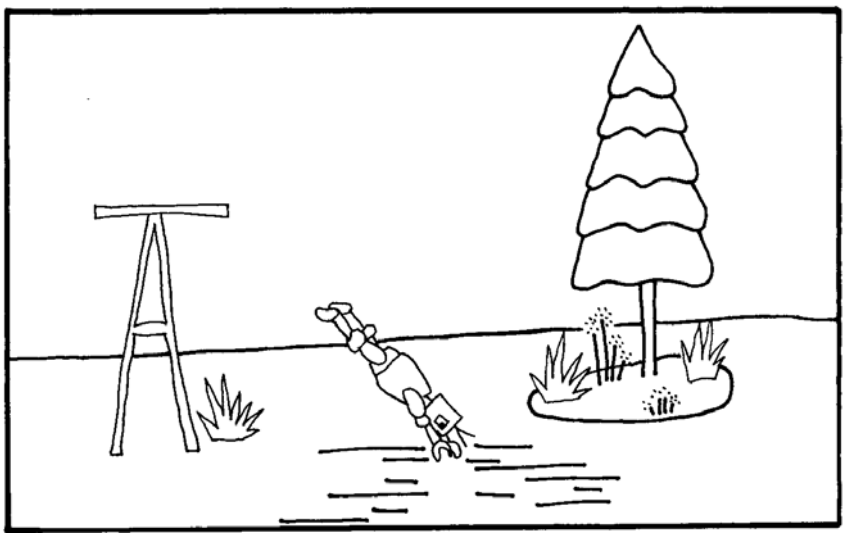


Captain SUBR:IM stood, elegantly poised upon the high dive platform. Below, the deep dark pool seemed so inviting in the summer heat. Launching himself out into mid air, he plummeted towards the water, sun glinting off his metallic body. As he hurtled closer he noticed that the water of that deep dark pool had a brown scum floating on the surface. Too late to turn back, he hit the water. No satisfying splash of a perfectly executed dive could be heard. Instead a small spray of water, and then two legs, extending vertically, slowly sinking downwards. His visual sensors registered black. Chemical readouts indicated a pH <2 and a dense mixture of oils, tars and sulphuric acid - he must have dived into an acid tar lagoon with a deceptive few centimetres of rainwater on the surface! The tar was probably from a benzole refining plant. The sulphuric acid was used to remove impurities from crude benzole (itself a by product of coal carbonisation) allowing the production of purified fraction of benzene, toluene and xylene. The tar was the waste product.



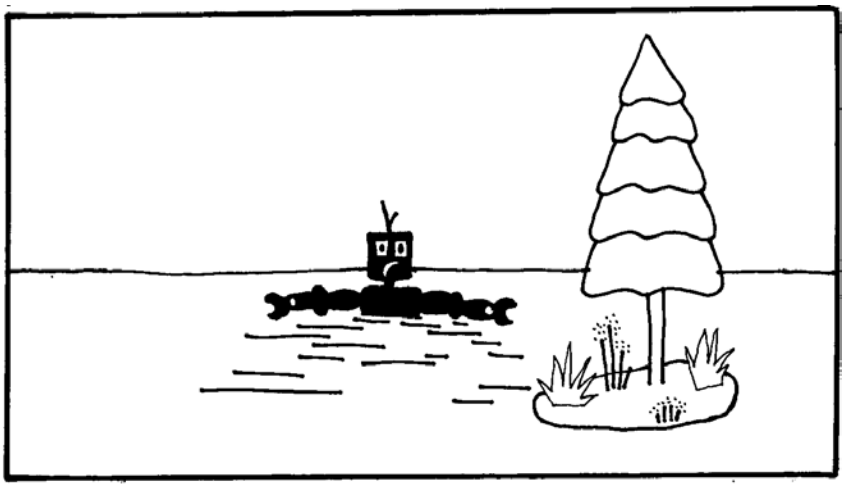
People would float in this stuff; it has a density of ~1.3 times that of water, however Captain SUBR:IM, being largely constructed of steel had a density significantly higher than the tar. Only its high viscosity (similar to treacle) slowed his rate of sinking. Fortunately he didn't need to breathe!

Switching to his built in micro-seismic scanner he could sense distinct density changes several metres below him and to one side - unfortunately he couldn't be more specific as he had nothing to calibrate his sensors on. He resigned himself to sink slowly into the tar feeling out with his hands in front of him, his metal skin slowly dissolving in the acid…

Fortunately this wasn't as bad as being dropped in a bath of sulphuric acid as the acid had to diffuse through the tar to reach his skin - a slow process, whereas in liquid acid, convection currents would replenish the acid in contact with his skin far more rapidly.

Eventually he felt soil beneath him and came to a stop. He righted himself and slowly, *very*, *very* slowly 'walked' towards the nearest identifiable density change to his side. There seemed to be pockets of water in the tar - was he below the ground water table? If so would 'bubbles' of water slowly migrate to the surface of the lagoon? As he was pondering this, he nearly tripped over a lump of concrete and what seemed to be the remains of a steel drum. Obviously people had been dumping other items into the lagoon. He didn't fancy checking what was in the drum - it could be anything. He did feel the surface of the concrete - it was cracked and aggregate could easily be scraped away - obviously an effect of the acid. Eventually he reached the edge of the lagoon and started climbing. Fortunately the slope of the soil/tar boundary was not too steep and he was able to climb up it. However some parts slipped under his feet - it was weird to fall in slow motion - but he could 'pull' himself back through the tar with a swimming action. However he had to be careful with this thixotropic tar - agitating it too much made it more fluid.

As he ascended, his sensors indicated thin strands of tar oozing out of the lagoon. They must have found fissures in the surrounding soil or rock and were being slowly squeezed out under the pressure of the overlying tar.



'The creature from the black lagoon'

His sensors finally indicated he was nearing the surface and safety. Just as he thought he must surely hit the surface his head hit a soft yielding mass. He pushed up through it and after a few minutes struggling broke through and out into the air. Wiping the tar from his visual sensors, he found himself face to face with a small birch tree. He had broken through a 'floating' island of grass and the birch tree sitting atop the tar. Carefully he edged his way onto

'dry' land and surveyed the scene. A small ring of tar extending above the water was all the evidence remaining of his plunge. Despite the acidity life was still able to apparently thrive on the surface of the lagoon; the plants were acid tolerant species. Did their roots penetrate into the tar or steer clear of it? Was there any microbial life in the tar itself? Life is more likely to be found at the interface of lagoon and soil, where groundwater would bring necessary nutrients, and microbes would occupy a niche determined by pH and toxicity of the tar.

Groundwater would leach any of the (relatively) more soluble components of the tar such as phenol, benzene, toluene and xylene and acid from the edges of the tar lagoon potentially forming a plume in the direction of flow. How far would this extend? Would it be subject to significant biodegradation and would it contain compounds in hazardous concentrations?

Would the tar in the fringes of the lagoon be significantly different from the tar in the main body of the lagoon? - how fast would acid and other compounds migrate from the main body of tar in the direction of the interface as concentration gradients are set up? Would less viscous components migrate downwards through fissures , thus increasing the surface area for leaching.

Finally what should be done with the lagoon?
This one clearly needs to be fenced off (and the high dive board removed!). If it is not polluting the groundwater and not oozing far though fissures, could it be left as a potentially interesting extreme habitat for life?! Natural tar ponds have existed for long periods - it is unlikely to vanish in the short term. Of course the surface water on the tar could flow off into streams contaminating them with acid and hydrocarbons. Would this be for months, years or decades? Any tar surface not covered may form a dry crust, break up into (potentially toxic) dust and be blown off to surrounding areas.

If the lagoon is close to a populated area then additional action may be required. Some kind of barrier between the lagoon surface and rest of the environment may be necessary at the least. Unfortunately simply capping the lagoon with soil doesn't work as soil is more dense (~ 1.8x density of water) than the tar. Eventually some instability will occur (most likely on a hot summer's day when the tar is less viscous) and some of the soil will sink as the tar rises and oozes out onto the surface. This churning and mixing may smooth out concentration gradients. If isolation is possible will the local population be content with this? Would an approach of containment and slow treatment/degradation over many years be acceptable/economical or would a more rapid and permanent solution be required?

Other options include removing it (dig and dump), treating it in-situ or ex-situ, or processing it into a commercially useful material. All unfortunately (at present) have significant associated social, environmental and/or economic costs.

After his close encounter with the tar, Captain SUBR:IM awaits developments with interest…

Note by author: most of the above is based on current literature, a few items are educated guesses - the questions asked are some of the issues we feel need addressing and form part of the subject of a brainstorming meeting on January 27th 2004. We have deliberately focused on processes in the lagoon - remediation comes later. Any additional comments, suggestions are very welcome either relating to site characterisation, conceptual model, sampling, remediation, or public perception…You will be pleased to know that Captain SUBR:IM has made a full recovery.

Many thanks to Jenny Chambers for the cartoons.