Environmental monitoring and management in the downstream oil and gas sector

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Keeping it clean, keeping it green

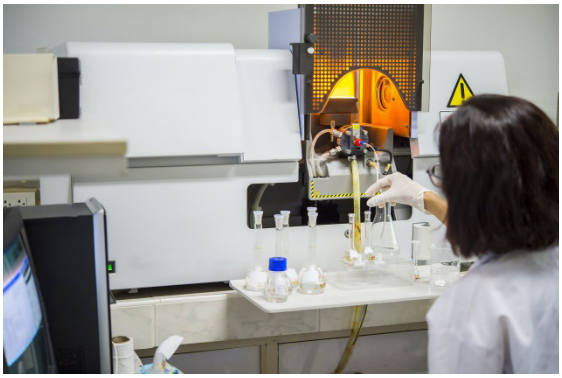
Ground water, rain water run-off and effluent. Contaminated soil replacement in spillage areas, excavated soil disposal during site improvements and end-of-life site remediation. Vapour, flare and smoke stack emissions to air. In the downstream oil & gas sector there's plenty to keep us busy with when it comes to environmental monitoring and protection. In the upstream sector the potential for pollution is significantly more severe, with crude tanker wrecks, such as the Exxon Valdez in 1989, and the BP Deepwater Horizon oil spill in 2010 still painful memories in many peoples' minds. However, refineries, tank farms, oil terminals and the barge, road and rail distribution network all have a significant custodial role to play to protect the land and waterways around which they operate and to maintain ambient air quality.

Environmental monitoring costs are material

Putting the costs of crude oil and other essential chemical inputs to one side, a high proportion of the residual refinery operating costs will be in the areas of labour, utilities, insurance and laboratory expenses. Within the utilities bill, the costs of process waste-water and site rain water run-off management will appear. And, in the laboratory costs there will be product assay in addition to multiple environmental related analysis work to be done. So, putting it all together, the price-tag for environmental management on the refinery can be significant.

In the worst case, if the finger is ever pointed to indicate that regulations have been breached, consent levels exceeded, or laws broken then the costs of litigation can be high. And, the fines, impact on company reputation and share price erosion can be devastating, as we have observed in the recent environmental case of VW in Germany related to diesel vehicle air emissions. The VW share price has somewhat recovered since it lost approximately 30 percent of its value within one month of the scandal coming into the public domain. However, the company now faces a €9.2 billion legal claim involving 1 670 investors who attest that they wrongfully suffered financial losses due to VW malpractice.

Also, in the news as recently as November 2018, has been the case related to Chemours in Fayetteville, North Carolina. Chemours have denied any violation of any regulation, law or permit and have simultaneously offered to settle a pollution case with a $13 million payment to avoid further legal process costs and to address community concerns about the Fayetteville facility. The legal case is still open and relates to emissions of fluorocarbon chemicals to air and in to the Cape Fear river which flows through the city of Wilmington. Whilst these examples are taken from industries outside the refining sector, the lessons are directly transferrable to hydrocarbon processing operations and paint a picture of



the potential negative consequences that can follow from actual, or perceived, poor execution of environmental management policies.

Diversity of monitoring and measurement required

Environmental monitoring on the refinery has implications all around the facility and in all three physical states: air, soil and water. For example, most refineries will have stack emissions from combustion processes which are monitored for regulatory compliance. The most common solution is to use a continuous emissions monitoring system (CEMS) to ensure that the air pollution is controlled within defined emissions limit values (ELV's) for species such as NOx and CO, as laid out in the EU Industrial Emissions Directive. Direct-read Fourier transform infra-red (FTIR) and non-dispersive infra-red (NDIR) instrumentation with a high up-time target are commonly employed for this CEMS application. After the initial capex related to the equipment purchase and installation, the cost of CEMS operation is low because the system is automated and requires only occasional maintenance and calibration, perhaps through a service contract from the instrumentation supplier.

Perimeter ambient air quality monitoring is also regularly undertaken. In this case, it is common to collect air samples intermittently and take them off-site to a highly specialised contract laboratory for analysis using a gas chromatograph with a flame ionisation detector (GC-FID). This device can speculate and detect very low levels of volatile organic compounds (VOC's) which are a typical air-born environmental concern associated with hydrocarbon processing operations. Often, the services of an environmental contractor will be used for this type of environmental monitoring. The samples must be transported in specially designed gas containers that have an extremely inert internal surface treatment to ensure that the collected sample is delivered correctly to the gas analysis instrumentation without any of the pollutant molecules adsorbing to the surface of the gas container.

Water quality monitoring will focus on core issues such as pH and total organic carbon (TOC). pH measurement equipment is one of the most simple and robust types of water quality instrumentation. TOC analysers, on the other hand, are a sophisticated black box that will use an oxidation process (e.g. chemical oxidation with hydroxyl radicals or catalytic combustion) to convert the organic chemicals to carbon dioxide, which is then measured using a gas-phase instrument such as an NDIR sensor. Additionally, for refinery effluent the possibility exists that certain carcinogenic aromatics, such as benzene, may be present in the water. So, additional specific checks for chemicals within the BTEX (Benzene, Toluene, Ethyl-Benzene and Xylene) group may also be undertaken.

Analysis of soil samples can have much in common with water analysis, and it is often the case that soil is mixed with water in the laboratory and the eluate is analysed, in addition to the soil solids. The relationship between soil contamination and groundwater pollution also binds the water and soil environmental issues. When conducting environmental soil analysis, it is therefore common to run similar tests to those conducted on water. Additionally, the scope for soil will generally include a search for trace metals such as lead and mercury and salt ions such as cyanide and sulphates.

For the trace metal species, inductively coupled plasma with various detectors such as mass spectrometry (ICP-MS) or atomic emissions spectroscopy (ICP-AES) is often used. The flame technique known as atomic adsorption spectroscopy (AAS) is an alternative. Various methods will be used for measuring the range of salts. One standard method for total cyanide analysis, as laid out in the US EPA Contract Laboratory Program (CLP) document ILM05.3 - Exhibit D, references a type of liquid phase colorimetry known as UV-VIS spectrophotometry. This CLP document also covers mercury measurement using AAS and gives guidance on the ICP-AES and IC -MS techniques.

On-site laboratory or outsourced contract lab?

With so much measurement to be done, the trade-off between using an on-site laboratory versus outsourcing is extensively debated. The inputs to the decision making generally focus around cost which are driven by the complexity and frequency of the measurement and the capital cost of the instrumentation. For risk mitigation, insurance or legal reasons, it might also be prudent, or required, that an independent accredited third-party laboratory make the analysis.

We have already noted that for CEMS systems with a 100 percent on-line measurement target the instrumentation will exist in situ. The same is not always the case for occasional samples. And, whilst refineries will have a sophisticated production, QC or R&D laboratory on site where some occasional environmental monitoring analysis may be done, smaller downstream operations such as tank farms or terminals will rarely have on-site analytical capability that stretches beyond a few key fuels physical property metrics such as flash point for gasoline and cloud point and pour point for aviation kerosene and diesel. These methods are laid out in the relevant ISO, ASTM or other national standards documents.

The idea that a tank farm would have the sophisticated, expensive instrumentation required to complete a full groundwater analysis or perimeter air quality analysis is unrealistic. The expertise required to conduct the analysis is also highly specialised and with a low frequency of measurement, retaining staff with this level of competence is simply not cost effective. And, even in larger refineries the specialism towards organic analytical chemistry for hydrocarbon analysis would generally mean that they would have neither the inorganic analytical equipment nor expertise to conduct the broad range of soil and water sample analysis that may be required. So, this work is also often outsourced to an environmental contract laboratory by major refineries.

Special requirements - construction and site improvements

Assay on the incoming crude oil and QC work on the refined products is the day-to-day mandate of the production and QC labs on the refinery. Turning samples around quickly on the array of instruments, such as gas chromatographs fitted with thermal conductivity detectors (GC-TCD) might be the priority. Or trouble shooting process issues with a more sensitive GC-FID analyser or a qualitative GC-MS setup might also come onto the reactive agenda.

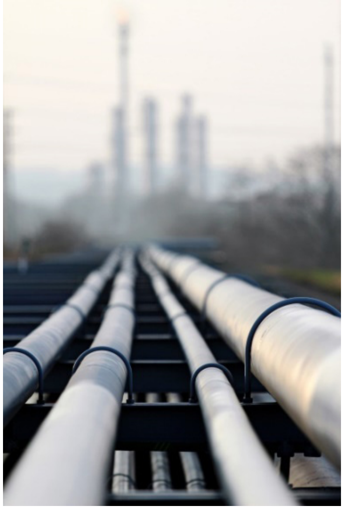
In contrast to this daily core of work another ad-hoc reason that environmental monitoring analysis is undertaken is when modifications and site improvements are taking place on the refinery. In these cases, soil is often excavated to lay new foundations. Perhaps the reason is to install a new piece of de-sulphurisation process equipment or introduce additional storage in the tank farm to keep up with the growing demand for biofuels. Prior to the excavation, there is often the requirement to analyse the soil prior to disposal or re-use. Local regulations will dictate what chemicals must be analysed for, the appropriate measurement technique and various limits that will govern how the soil may be re-used or whether it may be taken for land-fill or must be sent for remediation which can add significant unplanned costs to the construction project.

Pipelines for crude and refined products

Many thousands of kilometres of pipelines exist worldwide for the transportation of crude oil and refined products. As an example, in Europe crude oil flows through the Transalpine Pipeline from Trieste on the Adriatic coast of Italy over the alps to the Bayernoil Refineries in Vohburg and Neustadt, the Gunvor refinery at Ingolstadt, the MiRO Mineraloelraffinerie Oberrhein in Ludwigshafen and on to the OMV refinery at Schwechat, near Vienna in Austria and the Czech Republic. Pipelines inspection regimes can include a multitude of practices that are designed to minimise environmental impact through leakage or damage. Simply walking the pipeline is a common solution, but clearly not the fastest option. Visual observation from a drone or aircraft is also possible and can provide a quick overview of any potential hazards such as building or farming activities encroaching onto areas close to the pipeline that might present a risk.

Road, rail and river – downstream distribution operations

An intermediate, or final, link in the downstream value chain is often distribution of refined products through the regional logistics network. In some countries, such as Sweden, with a vast land mass and where the population is located close to



the coast, small sea-going tankers will be used to move product between terminals. Other, countries that benefit from major arterial waterways, such as the Netherlands and Germany may employ barges to move large quantities of product along rivers such the Weser in Bremen, the Danube in Bavaria and the Rhine which runs through several states in the western part of Germany and joins the river Waal as it flows out into the North Sea just south of Rotterdam.

Two major events in 2018 had an impact on barge operations in Germany. Firstly, the low water level in the Rhine meant that barge movements were significantly curtailed. BASF at Ludwigshafen am Rhein declared force majeure on methyl methacrylate, butyl acrylate and ethyl acrylate from Ludwigshafen in October 2018. Soon after, Evonik declared force majeure on plasticisers supplied from Marl, which is joined to the Rhine by a canal running parallel to the river Lippe. The second event was the final ban on the use of single hulled barges on the European inland waterways. This initiative, which has been a gradual transition for the past decade is designed to protect the environment and minimise the risks of product spillages into the rivers.

Road and rail distribution for refined products, or even crude oil, is also common in many parts of the world. And, in fact, during the recent low water period on the river Rhine in Germany for much of 2018, many of refined products that would normally be moved on barges or inland tankers were switched to the road and rail network.

Making good after accidental spillages

Despite all the technology and good operating practices that refineries, tank farms and fuels distribution operators invest in to avoid leaks, some occasional spillages do, unfortunately occur. There is often a chain of events put into place after such a spillage which is designed to contain and mitigate the environmental impact. Excavation of soil in the immediate area of the spillage will often be required. Analysis of the extent and type of contamination will then determine how the soil may be cleaned up. Perhaps washing may be sufficient, alternatively a biological remediation may be appropriate. Or, it might require combustion of the soil to burn off the hydrocarbon contaminants.

The long-term consequences on the local ground water will also need to be assessed. It might, for example, be necessary to drill a groundwater bore-hole and then extract samples for analysis at regular intervals to ensure that chemicals released during the spillage are not permeating through the soil and sub-strata into local water courses.

Technical due diligence

In recent years, the oil and gas industry has undergone a transformation. The vertical integration between upstream exploration and downstream refining and distribution operations is no longer in vogue. Through several decades of M&A activity many refinery, tank farm and terminal assets have changed ownership. On each occasion, the buyer will want to conduct a thorough investigation of the business that they are investing in. This due-diligence process will generally have a commercial component that focuses on the business model viability and a technical component.

This technical due diligence (TDD) will take an in-depth look into health, safety and environmental aspects of the operation and any related risks which could represent costs for the new investor in the near-term future, or years down the road.

A typical TDD check list will include looking out for recent water analysis reports from any groundwater bore holes that exist on site, site effluent and rain water run-off. Soil samples from recent excavation works or spillages will also come under scrutiny. And air quality samples will be given a thorough review. All of these can be checked against local legal threshold limits and other best-practice benchmarks that exist in the industry for similar operations. In addition to highlighting any specific shortcomings, a picture will soon emerge of the general level of environmental management that has existed on the site in recent years. These inputs will play a critical role in the decision whether to bid for an asset and the price that might ultimately be offered.

End of life – site remediation for brown-field development

It is often the case that oil refineries were built many years ago in locations that were, at that time, close to an important market, but seemingly remote from a major city. As the urbanisation of our landscape has increased, the buffer between the refinery and the expanding housing has often shrunk. In such cases, there may be environmental pressure and a financial incentive for the refinery to simply shut up shop and perhaps import products to a local tank terminal from another location. Re-investment in modern equipment may also reduce operating costs and align better to the fuel mix of the day. In such events, one of the greatest un-knowns in the site decommissioning cost budget will be the soil remediation cost which could, in the case of a large refinery site, stretch to the order of tens of millions of Euros. Understanding the nature

of such risks is one of the most important reasons that buyers of downstream assets are keen to undertake a full technical and environmental due diligence as an integral part of their M&A process.

One example of such a significant land re-use was the closure of Portugal's first refinery, the Cabo Ruivo Refinery on the banks of the river Tagus in Lisbon. The site was subsequently visited by more than ten million people during Expo '98. The tower from the thermoform catalytic cracker (TCC), which was once known in the Lisbon area for its smell and flame, is now a historical landmark and still stands in the Parque das Nações, now a premium residential area that was built on the site of Expo '98. Another example was the clean-up of the old East Greenwich Gas Works that famously delayed the building of the London Dome during the year 2000 millennium preparations and resulted in parliament approving an additional 150 million pounds of costs to the millennium dome construction budget. Like Expo '98, the dome was to become a tourist mecca with more than 6 million visitors in the year 2000 alone.

At the retail end of the downstream operations, there has been an intense consolidation of petrol stations in the past decades. Fewer bigger filling stations with better retail facilities and a wider mix of fuels and AdBlue tanking have been built. The consequence has been the closure of many smaller older stations and the re-use of that land for urban development. If the underground storage tanks and pipework were old and corroded, it has often been the case that the site needed remediation prior to sustainable re-use. As a property developer, it pays to know what you are buying before you take on an aged asset of this kind.

Whether the site is large or small, it is imperative that the soil and groundwater are analysed and, if required, the soil is responsibly cleaned up prior to redevelopment: a task which relies heavily on good science and analytical chemistry to determine firstly what needs to be done and subsequently to confirm when the required levels of soil quality have indeed been achieved.

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