Owner Team Consultation

Design, Construct and Operate your Plant with Closure in Mind

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Introduction

Several months ago, my colleague, Cornè Thirion, argued very eloquently that plant operability and maintainability should be considered during the front-end loading phase of any new project (Thirion, 2016). Whilst I support his sentiment fully, I maintain that new operating facilities, and especially chemical plants, should also be designed, constructed and operated with eventual plant closure in mind.

It seems illogical to consider the shutdown of a production facility when a project is still in the front-end loading phase. However, an irresponsible approach towards the environment during the early project phases and during the operations phase will destroy much of the profits from the facility.

In this article, I'll present some realities regarding plant closure and illustrate how bad up-front decisions can destroy wealth. This is followed by a brief introduction to groundwater contamination and the implications thereof. In the following section, actions that can be taken during the design, construction and operation phases to prevent future closure problems are discussed.

Some realities regarding plant closure

Operating facilities, and specifically chemical production plants, are typically designed for a 20-year operating life. This operating lifespan is normally extended by meticulous maintenance and judicious equipment renewal practices. The bottom line is that plant closure is not foreseen, or considered, for a very long time. Certainly both the project manager and the CEO, responsible for establishing the new operating facility, will have moved on to other responsibilities, or have retired, by the time that closure is considered.

The final phase and stage of our OTC Stage-Gate Model is 'Closure'. The verb associated with the closure stage is 'Conclude', meaning to end the prevailing activities at the facility. Over and above the market considerations and human resource implications, this means the shutdown, clean-out and deconstruction of the facilities.

After deconstruction, and depending on the approach towards the environment during the design, construction and operations phases, some level of remediation of soil and groundwater may be required.

The decision to stop production at a facility can be precipitated by a number of factors, including:

- Cost of production;
- Cost of maintenance;
- Competitor's offering;
- Reduced market demand;
- More efficient technologies;
- Catastrophic failure;
- Environmental pressure, and;
- Community health pressure.

To illustrate how accumulated profit from a facility can be destroyed, let us consider a hypothetical case study. Consider a chemical plant, costing 1250 currency units to build (a currency unit can be any amount of money in your preferred currency, e.g. US$100 million) and a construction period of 4 years. The nett annual income and cumulative income for the facility is reflected in Figure 1.

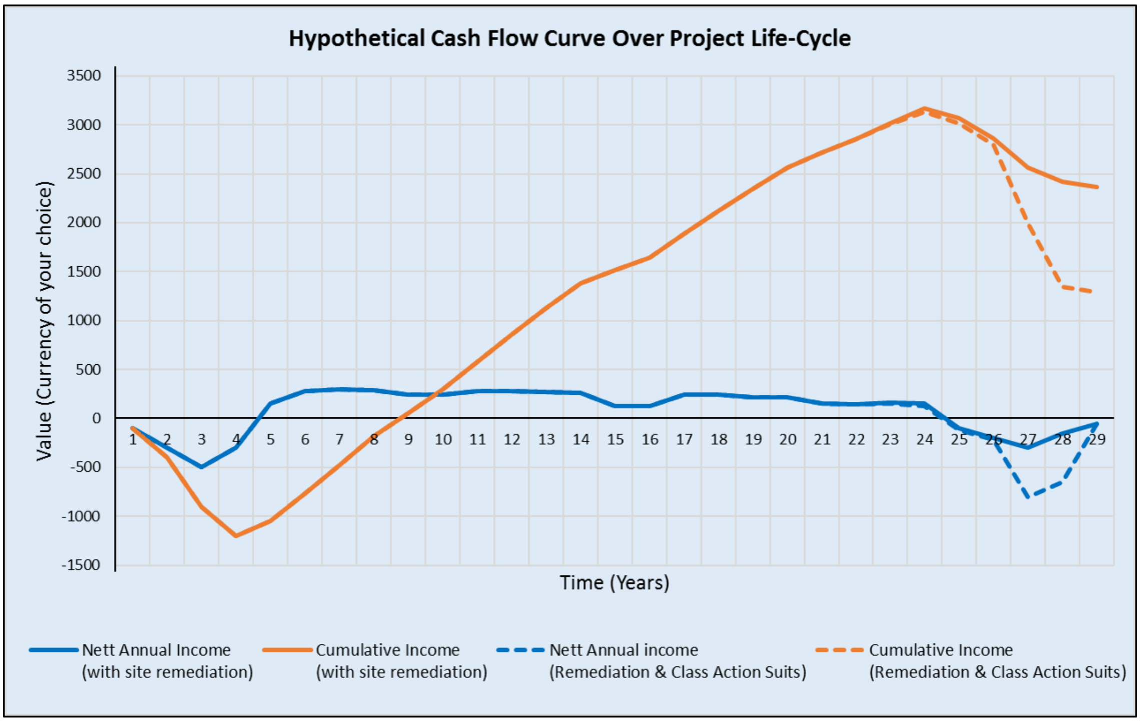

Figure 1: Hypothetical cash flow curve over project life-cycle

A positive nett annual income is achieved from year 5 and the break-even point is reached in year 9 (5 years after completing construction), when the cumulative income reaches zero: see the orange line in Figure 1. Fluctuations in the nett annual income (blue line) is due to market fluctuations and periodic shutdown of the facility for maintenance and/or equipment renewal. Our plant is closed after 20 years of operation. Data from groundwater monitoring wells show a plume of chlorinated hydrocarbons is moving towards a residential area.

A new project now needs to be launched to control the soil and groundwater contamination. This is shown in Figure 1 by the dip in nett annual income from year 24 onward. Two scenarios are shown: in the first case (the solid lines), the problem can be controlled by soil and groundwater remediation actions alone; in the second case (the dashed lines) a class action suit is also brought against the operating company for compensation for medical problems, resulting from the contamination, of plant operators and service providers. In both cases, it can be seen that bad upfront decisions can destroy many years of income. In extreme cases, it can leave the facility with a negative cumulative income.

Ideally, monitoring systems should be in place to identify system failures during operation and hence limit the impact on the environment. Legislation in some countries require a remediation fund from commencement of the project to ensure there are finances at the end, or when problems are identified, to address the impacts.

Introduction to contamination of groundwater

A schematic of groundwater flow and contamination sources is shown in Figure 2.

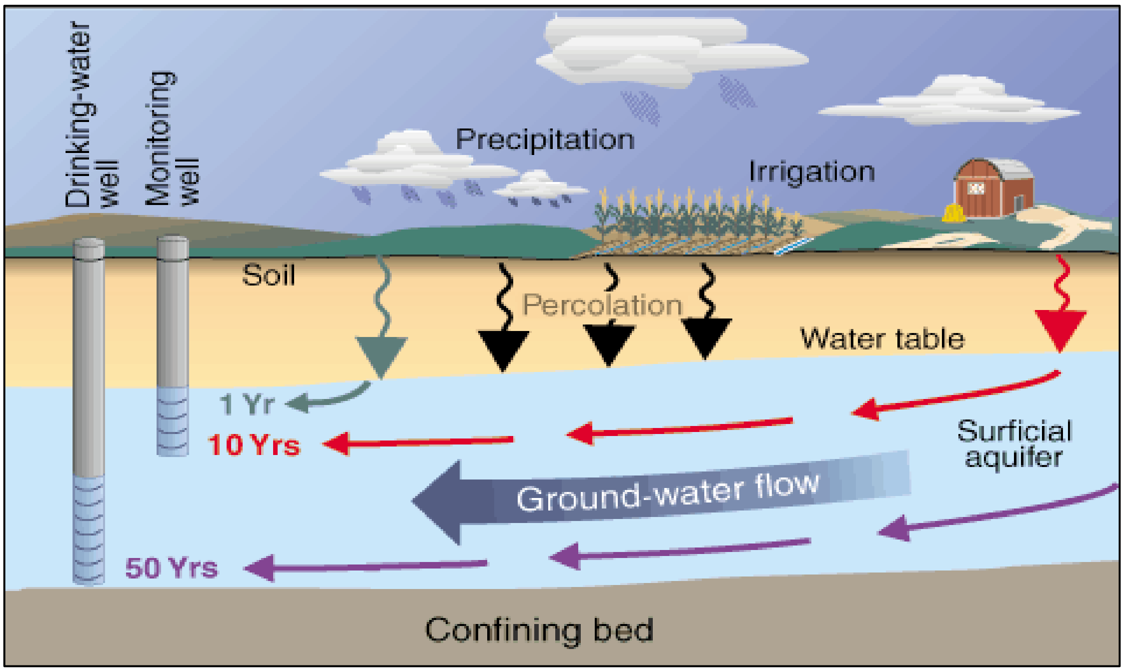

Figure 2: Contamination and flow of groundwater (from USGS, 2015)

The diagram shows contamination from farming activities, but the severity of contamination from industrial processes can be much higher. Specifically, contamination by organic compounds are problematic. Organic contaminants can either totally dissolve in the groundwater or be present as a separate phase, which can be either lighter (LNAPLs or light non-aqueous phase liquids) or heavier than water (DNAPLs or dense non-aqueous phase liquids).

The presence of DNAPLs in soil and groundwater presents unique challenges to site remediation. DNAPLs have a specific gravity greater than water, a relatively low solubility, and a tendency to diffuse into fine-grained materials in an aquifer. These properties make DNAPL masses and residuals difficult to locate and characterise in the subsurface, and they can prolong the process of conventional remedial technologies, such as groundwater pump-and-treat.

Due to their specific gravity, DNAPLs tend to sink in the subsurface. Their migration pathways tend to be complex and hard to predict due to the heterogeneous nature of the underlying soil and fractured bedrock. As a result, a complicated DNAPL fingerprint (shape and size) can develop that is made up of pools, ganglia, and globules in multiple soil layers and bedrock fracture zones. DNAPLs can release dissolved constituents for long periods of time forming large groundwater plumes.

How can we prevent future problems?

Actions during the Design stage

There are many actions that can be taken during the design stage of a project to prevent contamination of the groundwater and costly future remediation thereof. These actions include:

- Site selection: Steer clear of previously contaminated sites… It is essential to know what you are buying in to and, for this reason, a preliminary site assessment is required. Note that soil and groundwater contamination from neighbouring industries can also adversely affect your preferred site.
- Site characterisation: This is required to get an understanding of the geology and hydrogeology of the site and the surrounding areas. Site characterisation also determines the base level contamination of the site and facilitates the planning for future groundwater monitoring wells and remediation measures.
- Technology selection: Some technologies are inherently cleaner than others. This can be in terms of the feed material used, intermediate products or waste products. A technology which is more expensive initially, may turn out to be less expensive in the long run. Base your technology decisions on life-cycle costing.
- Underground storage tanks: Underground storage tanks are typically referred to as ‘leaking’ underground storage tanks by remediation specialists. At some stage in its operating life, an underground tank will leak. If you have to have underground

tanks, use double-walled tanks and ensure that suitable monitoring sensors are placed around it for groundwater contamination and soil-vapour detection. Preferably, don't put tanks underground.

- Minimise volume: Minimising the volume of feed material, intermediate product and final product storage on your site has many benefits, including lowering the risk of soil and groundwater pollution. Remember, what you don't have on site, cannot leak out and pollute something.
- Design for treatment of contaminated streams: Identify the possible sources of contamination up front and design for the capture and treatment of potentially contaminated product and intermediate streams. This will not only prevent closure problems, but enhance the efficiency of the facility.
- Perform the EIA: It almost goes without saying, but perform the environmental impact assessment (EIA) to the best of your abilities. This will help identify potential future problem areas early enough to prevent expensive redesign. Use the result of the EIA to improve your design. Many countries require an environmental management plan as part of the EIA. This should actually be a living document throughout the project life.

Actions during the Construction phase

The construction phase is perhaps not as critical as the design phase, but needs attention nevertheless. Good housekeeping and effective control of fuel depots and pickling liquids will prevent expensive clean-ups. Actions during the construction phase include:

- Follow the EMP to the letter: An environmental management plan (EMP) for the construction and operational phases for the project is a standard deliverable of the EIA process. It also forms the basis of the environmental requirements post approval. Do exactly what is expected from you in terms of the EMP, or your project may be stopped. Implement quality control systems to reduce the risk of unpleasant surprises.
- Install monitoring wells: The preliminary site characterisation study will provide the necessary input for the placement of monitoring wells in the shallow and deep aquifers. The installation of monitoring wells is a task for specialists, since the wells themselves can become pathways for pollutants.
- Emergency spill response: Accidents happen, but be prepared for swift response for spills of pollutants. The sooner appropriate action is taken, the lower the probability of long-term environmental damage. Spill response does not mean covering a spill with fresh soil… This will only exacerbate the situation.
- Don't take chances: Not an action per se, but rather a warning. Taking chances with the contamination of soil and groundwater can have very expensive consequences.

Actions during the Operations phase

Great care should be used during the operations phase to prevent possible contamination of soil and groundwater. Typical actions during this phase include:

- Follow the EMP: Follow the agreed environmental management plan for the operations phase of the project to the letter. Disregarding any of the requirements of the EMP will compromise your licence to operate. Ensure that the required reporting to the responsible authorities is done diligently. Regular auditing and performance assessments are important to ensure compliance.
- Mass balances: Reconcile production figures on a daily basis. Remember that what is put into a processing plant, minus the final product and accumulation in intermediate product, represents loss. This can be to atmosphere (which is bad), to surface water (which is very bad), or to soil and groundwater (which is unthinkable).
- Monitor the wells: Monitor the wells on a prescribed frequency, preferably every six months, depending on the type of contaminants used or produced in the facility. Monitoring systems must include the various aquifer systems; perched, weathered and fractured. It is also important to monitor groundwater levels. Combine with other methods, e.g. soil-vapour sampling, as appropriate, when the first signs of a problem arise. Sampling of the wells and interpreting the results is a task for specialist geohydrologists.
- Implement a GIS based trending system: Results from the groundwater sampling wells very quickly become difficult to maintain and trends may be overlooked. It is essential to be able to access results and depict changes over time. Thus, keep the results from well-monitoring in a dedicated GIS-based data management system. A geographic information system (GIS) can also help with the modelling of contaminant plume movement.
- Emergency spill response: The operations phase covers many years and many start-ups and shutdowns of the production facilities. Cleanouts and maintenance will be done, and equipment will fail. In other words, there will be plenty of opportunities for contamination of soil and groundwater. The sooner appropriate action is taken, the lower the probability of long-term environmental damage.
- Don't take chances: As above, for the construction phase, but with more emphasis...

Closure of a facility

Closing down requires careful planning, long in advance, as it entails exiting from a number of supply and customer contracts and relations built up over a long time. In addition, it normally also requires redeployment or retrenchment of employees, which entails entering into negotiations with labour unions.

Once the decision has been taken to shut down the facility, the fate of the site needs to be decided. The fate is typically one of three options:

- Mothballing of the facility for possible later reuse;
- Deconstruction for a brownfield redevelopment project, and;
- Remediation of site for an alternative use, or sale.

In an ideal world, groundwater quality monitoring on and around the site will have commenced prior to the start of construction and continued throughout the useful life of the facility. In this case, a clear picture will be available of the state of the groundwater in terms of quality and speed and direction of movement. This knowledge will inform the final decision on the fate of the facility and the level of remediation required. For example, a site contaminated with chlorinated hydrocarbons will require more intensive remediation if the future use is to be a new sports complex, compared to reuse as a brownfield site.

Once the facilities have been shut down, cleaned-out and decontaminated, and depending on the fate selected, demolition and site remediation can commence. Remediation of the site is typically handled as a new project.

Concluding remarks

In the case of soil and groundwater, the best approach is to avoid contamination wherever possible by good upfront system design and by the use of impermeable paving and dedicated chemical sewers and oily sewers.

Problem industries, in terms of soil and groundwater pollution, include, but are not limited to, petroleum, petrochemical, gasification, fuel storage, chemical, plastics, paints, pesticides, metallurgical, mechanical where solvents and degreasers are used, electrical where solvents and transformer oils are used, and wood preservation.

Fortunately, financiers, and especially those who are signatories to the Equator Principles, nowadays demand to know the cost of decommissioning and site closure. Doing life-cycle costing of different process options, including decommissioning and closure, can help you make the right decisions in the design stage.

A polluted site, or a history of irresponsible environmental behaviour, can do irreparable damage to your company’s image. Remember also that the directors of a company are jointly and severally liable for any negative impact on the environment, whether advertently or inadvertently caused by the company which they represent, including damage, degradation or pollution.

References

Thirion, C., 2016, *Focus on Operability and Maintainability for Project Success*, Available from http://www.otctoolkits.com/focus-on-operability-and-maintainability-for-project-success/ Accessed on 25 July 2016.

USGS (United States Geological Survey), 2015, *Pesticides in groundwater*. Available from http://water.usgs.gov/edu/pesticidesgw.html Accessed on 8 July 2016.