THE ASSESSMENT OF THE BENEFICIAL USES OF GROUNDWATER USING THE PRINCIPLES OF RISK ASSESSMENT AND MONITORED NATURAL ATTENUATION

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INTRODUCTION

Groundwater pollution, if present beneath a site, may potentially preclude one or more beneficial uses of the groundwater resource and it may also preclude the use of the site itself until satisfactory remediation of the groundwater has occurred.

The clean up/ remediation of polluted groundwater initially involves the removal of the primary and secondary sources of the identified pollution followed by the application of an appropriate treatment technology to remove, as far as practicable, any phase separated contamination and dissolved phase contamination that poses a risk to beneficial uses.

Where the initially applied clean up/ remediation measures do not fully restore relevant beneficial uses of the groundwater resource, it may be possible to satisfy regulatory requirements in terms of site suitability for use provided it can be demonstrated that the remaining contamination does not pose an imminent hazard and that natural attenuation processes will reduce pollutant concentrations to acceptable levels over time.

Many regulatory bodies in Australia now consider the effects of natural attenuation when determining the adequacy of contaminant delineation, assessment of risks to receptors and/or determining the need for further remediation.

This paper discusses the use of natural attenuation of groundwater contamination concepts together with the use of health and/or environmental risk assessment with respect to case examples where groundwater pollution has been an issue affecting site and/or groundwater use.

GROUNDWATER

In December 1997 a State Environment Protection Policy (Groundwaters of Victoria)[1] (SEPP) was declared in Victoria. This policy identified the relevant beneficial uses to be protected in terms of the groundwater resources in Victoria. The policy also established relevant groundwater quality indicators and objectives necessary to protect the identified range of beneficial uses. The beneficial uses identified in the policy are as follows:

- Maintenance of ecosystems;
- Potable water supply, desirable,
- Potable water supply, acceptable,
- Potable mineral water supply,
- Agricultural water supply, irrigation
- Agricultural water supply, stock watering
- Industrial water use
- Primary contact recreation
- Building and structures.

In August 1998 the EPA issued a guideline dealing with groundwater issues and contaminated land auditing entitled:-

Groundwater and Contaminated Land Auditing, August 1998 [2].

This latter document provided an explanation of how the EPA saw the policies set out in the 'Groundwater' SEPP were to be interpreted and implemented in the context of contaminated land auditing.

In particular guidance was provided regarding conditions that might be placed upon Statements of Environmental Audit for sites where groundwater is found to be polluted.

The introduction of the 'Groundwater' SEPP in 1997 and the issue of the subsequent guidance document in August 1998 was the first time that guidance became available on what was expected with respect to situations where groundwater pollution was identified beneath a site in terms of its suitability if use for a range of uses, particularly sensitive uses such as standard residential, pre-schools, kindergartens and primary schools.

Other states in Australia (i.e. New South Wales and Western Australia) have formalised systems of potentially contaminated land assessment and auditing. In both of these systems there are clear guidelines that groundwater must be assessed for pollution as part of the site assessment investigation. Where polluted groundwater is identified they require restoration of the environmental values of the groundwater resource. The Victorian policy refers to restoration of beneficial uses which is essentially the same as for the other states. All these systems look at restoration or clean up of environmental values to the extent practicable coupled with ongoing monitoring, management and consideration of natural attenuation processes. The groundwater quality indicators and objectives are set out in such documents as relevant state environment protection policies, Food standards, water quality guidelines and the National Environment Protection (Assessment of Site Contamination) Measure (1999) [3]

LAND

In June 2002 a State Environment Protection Policy (Prevention and Management of Land)[3] was declared. Similar to the Groundwater SEPP, 1997 the "Land" SEPP 2002 identified a number of beneficial uses of land and potential land uses. The beneficial uses to be protected in the context of land include:-

Maintenance of ecosystems

- Natural
- Modified
- Highly modified

- Human Health
- Buildings and Structures
- Aesthetics
- Production of Food and fibre

Identified land uses with the 'Land' SEPP include:-

- Parks and Reserves
- Agriculture
- Sensitive Use
  High density
  Other
- Recreation/ Open Space
- Commercial
- Industrial

The indication and objectives for land are contained in the following documents:-

- National Environment Protection[4] (Assessment of Site Contamination) Measure
- Australia New Zealand Food Authority[5] Food Standards Code

SATISFYING REGULATORY REQUIREMENTS

In Victoria, for cases where sites are subject to an Environmental Audit and groundwater pollution has been present which has impacted on the beneficial uses of the groundwater and land but has been subject to remediation/ clean up it is necessary (since April 2002)[6] for the Auditor to make a detailed submission to the Environment Protection Authority expressing an opinion that clean up to the extent practicable (CUTEP) has been achieved. In most cases when the EPA agrees that CUTEP is achieved, the decision will have been based on a detailed assessment of all relevant information pertaining to individual groundwater pollution and its impact on relevant beneficial uses and an assessment of the time for beneficial uses to be restored.

The outcome of the EPA's consideration, even when it agrees that CUTEP has been achieved, is often a direction that ongoing monitoring must occur until such time that relevant beneficial uses are restored, or will be restored. The ongoing monitoring must be in compliance with a site specific management plan.
The Victorian EPA in determining CUTEP consider natural attenuation evidence and need to be satisfied that there are no unacceptable risks to site users particularly concerning vapour risks from any residual volatile materials (eg. Petroleum hydrocarbons) or any other contaminants in the context of human health or the environment.

In New South Wales similar concepts prevail with the guidelines set out in the following document:-

> "Guidelines for the Assessment and Management of Groundwater Contamination", Department of Environment and Conservation, NSW 2007[7]

In Western Australia the Department of Environment and Conservation has issued guidance[8] in April 2004 on the use of monitored natural attenuation (MNA) for groundwater remediation. In Western Australia the guidance refers to the naturally occurring physical, chemical and biological processes (or combinations of these processes) that reduce the mass of pollutants in groundwater. Dilution of pollution is specifically not considered to be natural attenuation. The guidelines also require that natural attenuation must be occurring at a sufficient rate to ensure that the remedial objectives are achieved in one generation (i.e. about 30 years) to satisfy inter-generational equity considerations.

As mentioned earlier where a regulatory authority agrees that natural attenuation is likely to be occurring, it requires that this be demonstrated by ongoing monitoring to verify that the assumed natural attenuation processes are in fact occurring. Multiple lines of evidence are generally required to firmly establish that natural attenuation is occurring.

The Western Australian Guidlines identifies three levels of evidence as follows:-

- Primary Lines of Evidence – which involve historical concentration data demonstrating reducing contaminant concentrations over time.
- Secondary Lines of Evidence – measured changes in geochemical conditions indicating a loss of contaminant mass and / or data from monitoring bores that show a shrinking or stable contaminant plume. This may include evidence of breakdown products or changes in electron receptor/donor concentrations.
- Tertiary Lines of Evidence – This evidence would require laboratory testing data to show that indigenous bacteria in the aquifer are capable of degrading the contaminants at a reasonable rate. Such data is generally only required where the primary and secondary lines of evidence are inconclusive.

The following sections outline the range of natural attenuation parameters that may be used in assessing whether or not natural attenuation is occurring.

Also discussed is the use of natural attenuation parameters and risk assessment, with respect to three different sites in Victoria, one of which has satisfied CUTEP requirements, whilst the other two are subject to ongoing investigations.

NATURAL ATTENUATION PARAMETERS

A number of parameters are typically used in assessing whether or not natural attenuation of pollutants in groundwater is occurring or likely to occur. Whether or not all parameters are included in a particular study depends upon the specific nature of the contamination, general site conditions, hydrogeology considerations, the prevailing geology beneath the site and the likely controlling attenuation processes.

Conceptualisation of what is happening in a degrading contaminant plume can be aided by preparing horizontal plans of the plume together with a vertical cross section showing well spacing along the plume, depth to groundwater, hydraulic gradient, and relevant geochemical data. In terms of the variation of natural attenuation parameters, and how this can then be used to interpret site conditions, such plans and cross sections can include graphical representations of the recorded values for the various parameters. Ideally, this should include both spatial and temporal variation. In interpreting these variations, what is often of most importance is the patterns of variation, rather than absolute values. The patterns often show relationships that can indicate what is occurring within the plume. These inferred conditions can then be used to qualitatively, or in some cases quantitatively predict future plume behaviour. Such considerations can then be factored into future monitoring and management for sites.

Examples of aids to trend analysis include Piper Plots, Multiparameter Radial Diagrams, Logarithmic Plots and application of the Mann-Kendall tests [8]

The parameters chosen for analysis for any specific site would typically be drawn from the following list:-

Table 1 – Natural Attenuation Parameters

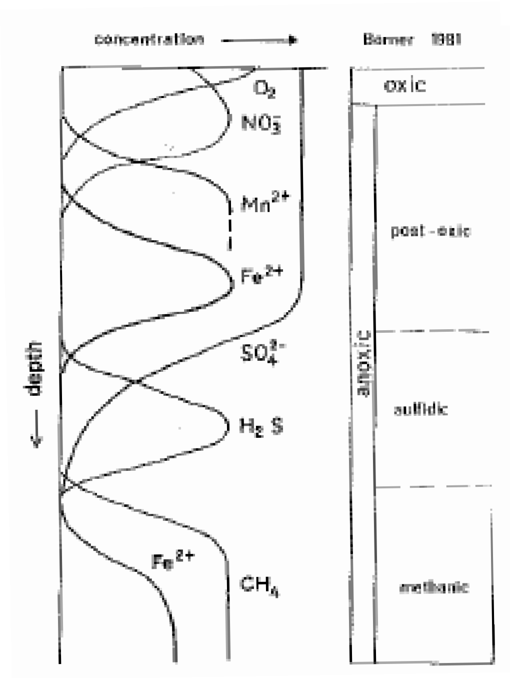
	PARAMETER	PURPOSE FOR INCLUSION
	Former / current site uses	Assists in defining range of likely contaminants.
	Geology	Defines likely plume migration rates and dilution / dispersion potential of contaminants.
	Hydrogeology / depth of water	As above. Plus assists in defining plume extent.
	Contaminant concentrations	Assists in defining likely time period for contaminant reduction to target levels and assessing mass of contaminant.
	Major anions / cations	Used to confirm groundwater chemistry, numbers of aquifers involved and whether other forms of gross pollution are occurring.
	pH	As above
	TDS (EC)	As above
	REDOX Potential	Used to establish whether reducing or oxidizing conditions exists and what type of biological activity is likely to be prevailing (eg anaerobic or aerobic)
Electron Acceptors	Dissolved Oxygen (DO)	DO is the favoured electron acceptor of aerobic microorganisms. Anaerobic organisms prefer DO levels below about 0.5mg/l. They can however use nitrate and sulphate as electron acceptors if available. These conditions are termed ANOXIC. Anaerobic organisms proliferate in environments where there is essentially zero oxygen and no alternative chemical forms of oxygen (eg nitrates).
	Nitrate	Nitrate is used as an electron acceptor when oxygen has been depleted. It is also an essential nutrient for microbial growth.
	Manganese (Mn^{2+})	Manganese oxides are reduced ahead of any iron oxides in the environment. The presence of Mn^{2+} in solution is therefore an early indication of prevailing anaerobic conditions and follows depletion of dissolved oxygen used nitrate.
	Iron (Fe^{2+})	Ferric Iron (Fe^{3+}) is used as an electron acceptor under REDOX conditions intermediate between those of oxygen and nitrate utilisation and sulphate reduction. The presence of ferrous iron (Fe^{2+}) is reflective of anaerobic conditions.
	Nitrate	Nitrate is used as an electron acceptor when oxygen has been depleted. It is also an essential nutrient for microbial growth.
	Sulphate	Sulphate can be used as an electron acceptor when oxygen is depleted and under negative redox conditions. A by product of sulphate reduction is hydrogen sulphide. Sulphur is also an essential nutrient for microbial growth. The presence of sulphate will limit methane production as sulphate reducing bacteria will compete with methanogens for hydrogen.
Electron Donors	Total Organic Carbon (TOC)	TOC is a measure of the presence of soluble carbon containing substrate materials in solution (eg TPH, Carbohydrates etc). TOC materials can act as a source of electrons and can be linked to reductive dechlorination. However, TOC concentrations of less the 20mg/l may not be sufficient to drive reductive dechlorination.
	Specific Organic Compounds (eg carbohydrates)	Various specific organic compounds can act as a source of electrons.
By products	Methane	Methanogenesis only occurs under strongly reducing conditions and usually suggests that all other electron acceptors have been exhausted.
	General Gases (ethane, ethylene, methane, propane and hydrogen)	The general gases are important when considering the stages of reduction reached in a situation where biologically driven anaerobic processes are occurring. Methane is the ultimate product of methanogenesis. Methanogenesis occurs in highly reductive environments where the REDOX potential is of the order of -300mv 300mV and dissolved CO_2 is present. Dissolved hydrogen is indicative of highly reducing conditions. Ethylene and ethane, carbon dioxide and methane are the products of reductive dechlorination reactions.
	Alkalinity	Increasing alkalinity can indicate increasing microbial activity due to the production of CO_2 during the biodegradation of organic carbon.
	Daughter Products	Of particular importance when considering reductive dechlorination of such compounds as PCE and TCE. Their presence is indicative of active dechlorination degradation taking place.
	Chloride	Chloride is released during the reductive dechlorination of such compounds as PCE and TCE. Increasing concentrations can be indicative of active dechlorination taking place.

The above parameters are often recorded in site investigations, but in many cases are not interpreted with regard to the patterns they display that may suggest the nature and occurrence of natural attenuation, or its absence. Interpretation of data using at least the above basic outline of relationships for natural attenuation parameters would enhance many investigations where such parameters are recorded, but not interpreted.

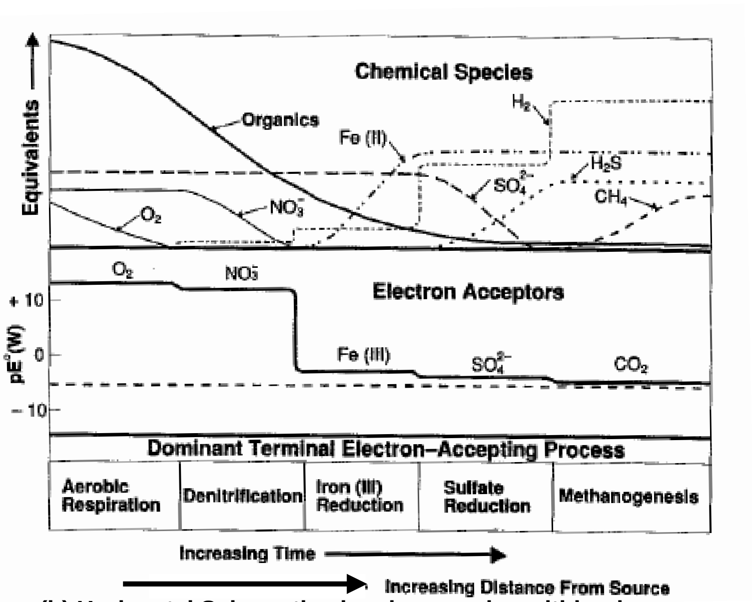
Where evidence of plume extent changes can be presented along with evidence of natural attenuation, and where these arguments are detailed enough, they may be used in combination to predict future plume behaviour to the level of certainty required by regulators and site managers.

SCHEMATIC REPRESENTATION OF PREVAILING CHEMICAL SPECIES DURING DEGRADATION OF PETROLEUM HYDROCARBONS BY MICROORGANISMS IN A HYPOTHETICAL AQUIFER

Figure 1 below illustrates the prevailing species present in a hypothetical aquifer during the biodegradation of a petroleum hydrocarbon fuel spill. The figure is a combination of figures produced by Appelo et al[9] and Wiedemeier et al[10].



(a) Vertical Schematic (Apello[9])



(b) Horizontal Schematic showing species within plume (Wiedemeier[10])

Figure 1. Conceptual sequence of REDOX related species pursuant during different phases of biologically mediated natural attenuation processes.

The above diagrams provide a guide to understanding whether natural attenuation is occurring and what stage it is likely to have reached and whether observed reduction of pollutant concentrations is sustainable.

USE OF SCHEMATIC PLOT TO UNDERSTAND AND DEMONSTRATE PLUME BEHAVIOUR

The Western Australian Department of Environment and Conservation[2] requires that a case for monitored natural attenuation be supported by data from a network of groundwater wells designed to capture information in terms of whether or not natural attenuation is occurring within a contaminant plume/aquifer.

Figure 2 below is an adaptation presented by the Western Australian Department of Environment and Conservation[8] of a schematic presented by Wiedemeier et al[10].

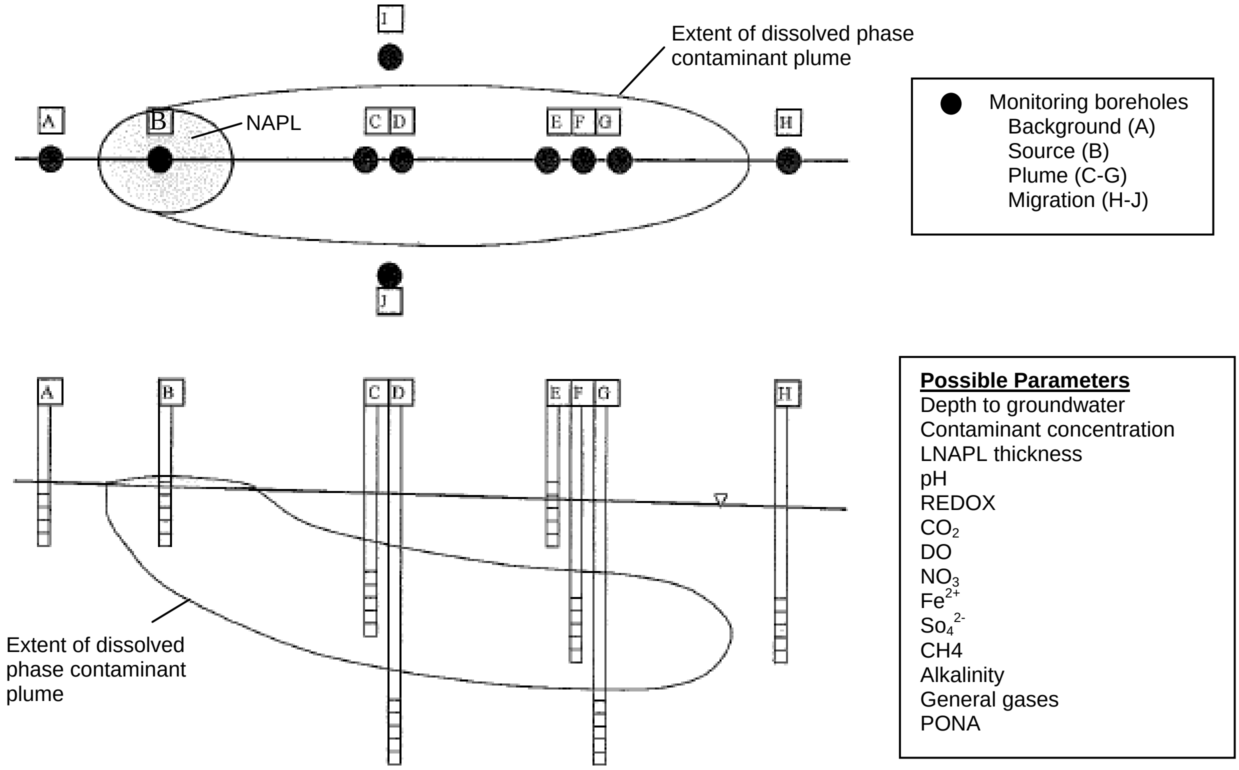


Figure 2. Typical groundwater monitoring well network and natural attenuation parameters for a hydrocarbon plume undergoing bacteriologically mediated reduction.

Diagrams such as Figure 2 are also required to support clean up to extent practical submissions provided to the Victorian EPA.

Coupled with the evaluation of natural attenuation data and contaminant plume extent information should be an assessment of the likely plume migration by using a suitable numerical model (eg BIOSCREEN). Models can be very useful in providing an understanding of the possible extent of migration of a plume to both on site and offsite and whether or not it is likely to persist and/or reach sensitive receptors.

Inputs to such models can include the following:-
Analytical Information

- Analysis for chemical of concern
- Chemical speciation of relevant parameters
- Natural attuentaion parameters
- Groundwater quality indicators, such as major cations and anions, REDOX, pH, TDS and DO

Field Information

- Geology
- Hydrogeology (including depth to groundwater and well concentration details)
- Surface water hydrology
- Prevailing meteorological conditions

ENVIRONMENTAL AND HUMAN HEALTH RISK ASSESSMENT

Coupled with understanding the nature, extent and migration potential of contaminants within a groundwater environment is the need to understand what risks the contaminants may have on the on site/offsite environment and human receptors.

Ecological and human health exposure assessment models are entirely dependant upon the acquisition of information and analytical data about chemicals of concern that may affect human and ecological receptors.

Once it is determined that a site is impacted by chemicals of concern subsequent data collection must be based on soundly established data quality objectives (DQO's). What is essential in collecting soil and water samples is to ensure that the samples taken represent all the contaminants and the soils in all strata present on the site.

Exposure assessments require the identification of sensitive site populations and pathways. The process involves:

- Analysis of contaminant releases
- Identification of exposed populations
- Identification of exposure pathways
- Estimation of exposure concentrations for each pathway
- Estimates of contaminant uptake for various scenarios.

The overall conceptualisation of the site, chemicals/ chemical species, pathways and receptors is critical to the process of risk assessment. The use of screening criteria can be extremely beneficial in terms of time saved in undertaking extensive modelling if contaminant concentrations do not exceed screening values.

Both ecological and health risk assessment require the same level of rigorous analysis of the chemicals of concern, site conditions, pathways and receptors. Models, or a combination of models, can then be chosen on the basis of outcome requirements. Data input into the models should be chosen on the basis of generating best case, worst case and likely case outcomes. This strategy provides a confidence that any decision taken regarding risks, whilst conservative, take account as far as practical, site specific conditions.

It is worthwhile noting that site specific conditions will quite often enable decisions to be made that permit a development to occur which might otherwise be prevented if taken on the basis of genetic non-specific assumptions.

The generally accepted approach to risk assessment is to use a three tiered approach as follows:-

Tier 1 Screening level risk Assessment

This approach usually adopts the human health and ecological assessment levels set out in the NEPM for soil and groundwater for screening purposes. Where contaminant concentrations are below the NEPM concentrations no further action is required provided there are no leaching, odour, volatile releases or erosion issues associated with any identified contaminants.

Tier 2 Initial Risk Assessment

This approach considers contaminants that exceed the adopted criteria in the light of site use scenarios (e.g. high density residential vs standard residential). Normally if concentrations greater than the screening criteria are deemed to be acceptable this decision is most often coupled to a management plan which accounts for management, say, during construction works and ensures that the contamination is not overlooked at some future time.

The management plan may not include ongoing ground water monitoring if the risk to groundwater is judged to be minimal.

Tier 3 Further Risk Assessment

Further risk assessment may involves specialised contaminant fate and transport modelling as well as toxicity assessment of particular contaminants. The detailed assessment makes use of site specific data in reaching conclusions.
Outcomes of detailed risk assessment are likely to include the need to manage the site via a site specific management plan which requires ongoing groundwater quality monitoring, sets trigger levels for specific contaminants and ongoing assessment and reporting of groundwater quality data against trigger levels and other relevant criteria. Monitoring may also include, for example, indoor air quality monitoring where volatile materials remain within groundwater contaminant plumes.

CASE STUDIES

The authors have been involved in a significant number of environmental assessment projects where demonstration has been required that natural attenuation processes are active in the reduction of contamination within various geological settings. The case studies selected below are as follows:

1. A former council works depot in Victoria where the subsurface soils and groundwater had been impacted by a variety of hydrocarbon contaminants including fuels and road making tars. An environmental audit for this project was successfully completed following the submission of a CUTEP opinion by an environmental auditor to the Victorian EPA for their consideration.
2. A former chemical plant where groundwater has been impacted by a variety of organic parameters including chlorinated hydrocarbons. The measurement and reporting of natural attenuation parameters and risk assessment was required by the Victorian EPA.
3. An operating petroleum refinery where natural attenuation parameters are being measured together with an assessment of risks as part of determining a suitable clean up approach/plan.

Table 2 below summarises each of the case schedules in terms of key site features, geology, hydrogeology, contaminant types and the natural attenuation parameters measured together with the range of reported results.

Table 2 – Application of monitored natural attenuation case study summaries

Case Study No	1	2	3
Date of study	**2002-2003**	**2004-ongoing**	**2005-ongoing**
Type of site	Former Council Works Depot	Former Chemical Plant	Operating Refinery
Length of case	1920's to late 1990's	1960's to 1990	1950's to current
Geology	Fine to coarse sands / clay	Basalt	Sandy Silts and Clays
Hydrogeology	Groundwater 2m to 7m within sandy/ clay	Three aquifers to 40m	Groundwater 3m to 8m
Major Soil Contamination • **Before cleanup** • **After clean up**	PAH's up to 6610mg/kg, BAP up to 22mg/kg Naphthalene 180mg/kg Below site specific criteria	Site not fully cleaned up. Chlorinated Hydrocarbon Residual contaminated sludge remains in capped sludge beds	Various hydrocarbons Still being assessed
Major Groundwater Contamination • **Before clean up** • **After clean up**	Benzene up to 14mg/l, BTEX up to 23m/g, TRH up to 33 mg/l, PAHs up to 0.55mg/l, Benzene down to 1 mg/l, BTEX down to 0.5mg/l, TPHs down to 0.5mg/l, PAHs down to 0.42mg/l	Groundwater impacts by chlorinated hydrocarbons, breakdown products and neutralised sulphuric acid waste liquor	PSH and dissolved hydrocarbons and metals. Clean up approach being determined
Natural Attenuation Parameters measured before clean up ✓ (After clean up)			
Depth to groundwater	✓ (stable)	✓ (stable)	✓ (stable)
Plume Extent	✓ (significantly reduced)	✓ (extensive)	✓ (extensive)
Groundwater Containments	✓ (significantly reduced)	✓ (chlorinated hydrocarbons)	✓ (hydrocarbons, metals)
Major anions/ cations	(proposed)	✓ (stable)	✓ (stable)
pH	(proposed)	✓ (6.0-8.4)	✓ (6.5-8.0)
TDS (EC)	✓ (640-1200mg/l)	✓ (variable)	✓ (3000-8000mg/l
DO	(proposed)	✓ (0.1-7.5mg/l)	✓ (inconsistent)
REDOX		✓ (200 to – 280mV)	✓ (100 to -100 mV)
Nitrate		✓ (ND to 3mg/l)	✓ (ND to 14mg/l)
Methane		✓ (ND to 0.07mg/l)	✓ (ND to 0.2mg/l)
TOC		✓ (ND to 74mg/l)	
Mn^{2+}		✓ (ND to 240mg/l)	✓ (ND to 0.2mg/l)
Fe^{2+}		✓ (ND to 18mg/l)	✓ (ND to 35mg/l)
Sulphate		✓ (53 to 300 mg/l)	✓ (ND to 1000mg/l)

*ND – non detect

PROJECT OUTCOME / STATUS

Case Study No 1 – This mid 2003 CUTEP submission was supported by the EPA on the basis that there were no off-site impacts and that on site contaminant concentrations and plume extent had been significantly reduced following source removal and other remedial measures.
Recommendation made by the auditor involves ongoing monitoring of depth to groundwater, plume contaminant concentrations, major anions/ cations, pH, TDS, and DO. Environmental and human health risk were deemed acceptable, provided a passive vapour venting system was included beneath any buildings constructed onsite.

Case Study No 2 – Study demonstrates that groundwater pollution health risks are acceptable and that (reductive dechlorination) is occurring.
However since the aquifers beneath the site remain polluted by chlorinated hydrocarbons it is likely ongoing monitoring and reporting will be required to confirm that natural attenuation of contaminants will sustainably continue to occur into the future.

However since the aquifers beneath the site remain polluted by chlorinated hydrocarbons it is likely ongoing monitoring and reporting will be required to confirm that natural attenuation of contaminants will sustainably continue to occur into the future.

Overall site risks associated with the polluted groundwater were considered to be acceptable on the basis that site is intended to remain unused indefinitely. Risks to offsite human receptors were deemed acceptable but ongoing monitoring would need to verify this situation into the future

Case Study No 3 – Significant correlation between dissolved hydrocarbons and indicators of anaerobic degradation, such as depletion of sulphate and nitrate, and presence of methane. Depletion of DO and consequent reducing conditions associated with elevated naturally occurring metals, which are mobilised in groundwater. Findings allow the occurrence of natural attenuation to be factored into future remediation planning and strategies. Ecological risks are still being assessed.

In all these case studies it was the pattern of variation in parameters, rather than absolute values of the parameters, that supported findings regarding the occurrence and effect of natural attenuation processes. In each case, the natural attenuation characteristics of the site were able to be used in determining an appropriate monitoring and management strategy for the future. Risk assessment in case study No 1 provided an essential element of determining CUTEP. For the other two case studies risk assessment is an essential component of the assessment process

DISCUSSION AND CONCLUSIONS

Natural attenuation is often assumed to be occurring, particularly in cases where groundwater is polluted by hydrocarbon contaminants. However, it is also often the case that the assumption is made without any supporting data and where supporting data is collected, it is, in some cases, not interpreted correctly. Interpretation of the spatial and temporal patterns the various parameters collected, using the basic data for indications associated with parameter variation can often provide a better understanding of attenuation characteristics than is often presented.

Overall it is concluded that the collection and careful assessment of natural attenuation data is highly beneficial to understanding whether or not natural processes are occurring (including dilution, dispersion, absorption and chemical/biological processes) of specific pollutants. In particular, it is clear that the use of natural attenuation monitoring data, to support conclusions that further active remediation of groundwater is not required, has become a corner stone of the Victorian EPA's CUTEP decision making processes in the context of groundwater remediation. It is also apparent that other regulators in Australia have adopted (eg Western Australia and NSW Departments of Environment and Conservation) similar approaches, hence there is a need in Australia for consultants to be aware of this trend and how to use and interpret natural attenuation data.

With respect to environmental and human health risk assessment in the context of groundwater pollution it is clear that the corner stone of undertaking sound risk assessment is the collection of reliable data. The need to undertake a risk assessment, for various reasons, often comes at the end of an assessment project due to the ‘discovery’ of potentially unacceptable levels of contaminants. Often nearing the end of a project, sufficient appropriate data has not been collected to permit a risk assessment to proceed effectively. This results in delays with respect to completing the risk assessment until sufficient, relevant data is collected. This data required includes natural attenuation parameters as well as chemical concentration and possible speciation data.

Overall its is preferable with risk assessments to bear in mind from the outset of a project that the assessment may be required to achieve an acceptable outcome. The need for such assessments can often be judged on the basis of a detailed review of good site history information at the start of the project. Accordingly it is important not to underestimate the site history phase of a project in assisting with managing overall site assessment projects.

It must be emphasised that the use of natural attenuation data, modelling and risk assessment processes whilst useful are not guaranteed to provide desired outcomes.

Finally for the purposes of undertaking the processes involved in building robust, sustainable risk and natural attenuation based arguments the following Western Australian guidelines [8,11] are particularly useful.

REFERENCES

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