# The Use of Mass Flux as a Risk Management Metric – Implementation at a DNAPL Site

Reynolds, David[1]; Kirchner, Rachel[2] and Stuart Rhodes[2]

**Resumo**

Investigações no local contaminado normalmente incidem sobre as concentrações químicas e processos de fluxo de subsuperfície em locais discretos, e em seguida a análise dos conjuntos de dados em larga medida independentes uns dos outros. Quando ambos os tipos de dados são considerados, é na maioria das vezes para a interpretação da dinâmica da pluma. Uma tendência crescente é a combinação destes conjuntos de dados em uma única medida quantitativa do fluxo de massa de contaminantes através de um plano de controle. Fluxo de massa tem sido freqüentemente usado por praticantes para categorizar um site ou como uma métrica para avaliar diferentes técnicas de remediação da zona de origem. Fluxo de massa também pode ser usado para estimar os impactos sobre os receptores, quer em conjunto com, ou como uma alternativa ao ponto de concentração. Em 1998, a EPA dos EUA Atenuação Natural Monitorada Seminário constatou que "as estimativas de fluxo através da fronteira para um receptor são a melhor estimativa de carga a um receptor."

Fluxo de massa está sendo usada como uma gestão de métricas em um site de DNAPL na Austrália Ocidental, de propriedade da Argyle Diamonds. Fluxo de massa entre dois planos de controle foi medido utilizando um número de diferentes métodos antes e depois da correção. Um site que usa o plano de gestão do fluxo de massa medida na região de origem como a medida pela qual a saúde humana e os valores ambientais são protegidos (por oposição a pontos de concentração em poços de monitoramento) é considerados pela entidade reguladora. Esta apresentação descreve a metodologia e oferece detalhes sobre os principais aspectos que constituem as partes interessadas a confiança na gestão de risco neste local incomparável.

**Abstract**

Contaminated site investigations typically focus on chemical concentrations and subsurface flow processes at discrete locations, and then analysis of the data sets largely independent of each other. When both data types are considered, it is most often for the



1 – Geosyntec Consultants, 427 Princess St, Suite 429, Kingston, Ontario, Canada. DReynolds@geosyntec.com

2 – Rio Tinto, 120 Collins St., Melbourne, Australia

interpretation of plume dynamics. A growing trend is the combination of these data sets into a single quantitative measure of contaminant mass flux across a control plane. Mass flux has most often been used by practitioners to categorize a site when assessing source zone remediation techniques. Mass flux can also be used to estimate impacts on receptors, either in conjunction with, or as an alternative to point concentrations. The 1998 US EPA Monitored Natural Attenuation Seminar found that *"flux estimates across the boundary to a receptor are the best estimate of loading to a receptor."*

Mass flux is being used as a risk management metric at a DNAPL site in Western Australia owned by Argyle Diamonds. Mass flux across two control planes was measured using a number of methods before and after remediation. A Site Management Plan which uses the mass flux measured at the source zone as the metric by which human health and environmental values are protected (as opposed to point concentrations in monitoring wells) is under consideration by the regulatory body. This presentation outlines the methodology, and details key aspects which provide stakeholders confidence in the risk management at this unique site.

**Key Words:** Mass Flux, Management Metrics, Regulatory Acceptance

## 1 – INTRODUCTION

Argyle Diamonds, a subsidiary of Rio Tinto, acquired a former diamond ore sample processing facility in 2000. Subsequent investigations of soil and groundwater confirmed a release of tetrabromoethane (PBA), a dense non-aqueous phase liquid (DNAPL), had occurred from the facility drainage system, which acted as a long term source of groundwater contamination at the site. A number of other brominated compounds have been detected in groundwater down-gradient from the source, including the degradation products tribromoethene (TBE), 1,2-dibromoethene (DBE), and vinyl bromide (VB).

Site investigations have shown the contaminant plume in groundwater extends westward from the site and discharges to a local engineered surface drain, which is located approximated 200 m away from the source zone. Groundwater is used locally for irrigation of parks and gardens, and concentrations of one or more of the contaminants exceed risk based criteria for irrigation within the groundwater plume.

Remedial actions at the site have included soil vapour extraction and a groundwater extraction and treatment system. A series of focused management goals have been developed for the site, including protection of surface water ecological receptors,

protecting occupants of commercial buildings on and off site, and restoring beneficial use of groundwater, with priority given to off-site impacted properties. A key facet of the management approach is to use the mass flux of contaminants in groundwater downgradient of the source zone as the regulatory compliance metric, as opposed to concentrations in individual monitoring wells.

## 2 - ACHIEVING GOALS THROUGH A FLUX-BASED METRIC

Mass flux is defined as the total dissolved mass of a contaminant in groundwater that passes through a defined "window" within an aquifer per unit time. This concept is well suited to evaluating the risk to down gradient receptors from a well defined contaminant source, such as discharge to surface water or from an irrigation supply well. If the groundwater flow system is well understood, and can be satisfactorily quantified (through the use of analytical or numerical models), average down gradient concentrations at points in space and time can be related to a mass flux measured immediately downgradient of the source zone.

A hypothetical pumping well on downgradient properties was considered as the pathway for exposure. Predictive modelling was used to determine the source zone mass flux for TBE (10 - 40g/day) which would result in groundwater from this well having TBE concentrations less than the risk-based criteria for irrigation use (TBE is the dominant dissolved brominated compound in groundwater). Mass flux measurements immediately downgradient of the source zone taken in late 2007 using Passive Flux Meter (PFM) technology determined a TBE mass flux of 106 g/day. Pumping from the source zone since 2007 removed an estimated 200kg PBA and TBE. Mass flux estimates (derived from monitoring well concentrations) in August 2010 indicated that TBE mass flux from the source zone was in the order of 15 g/day. A second PFM deployment in March 2011 confirmed that the mass flux is now in the target range.

## 3 – DEVELOPMENT OF A MANAGEMENT PLAN

More than 150 individual monitoring points have been installed at the site over the course of investigation and monitoring. Many of these points are located on properties not owned by Argyle, and could present challenges for long term monitoring. The management plan includes the following steps:

1) Quarterly monitoring of mass flux (for a limited period);

2) Quarterly monitoring of point concentrations along the centerline of the plume (for a limited period);
3) Demonstration of compliance with remediation criteria for the irrigation well; and
4) Long term monitoring of mass flux at the source zone control plane to provide assurance of future downgradient compliance.

This approach has been designed to validate the model predictions as the plume redevelops after the cessation of source mass removal actions (steps 1 and 2). If monitoring does provide validation, then step 3 is intended to provide stakeholders with confidence that the remediation goals will continue to be achieved. Success will result in on-going management requirements being limited to annual monitoring of the source control plane wells, without direct monitoring of compliance points on off-site properties.

## 4 – CONCLUSIONS

An innovative management approach for achieving off-site regulatory compliance without long term off-site measurements has been developed for a DNAPL site located in Western Australia. The use of mass flux from the source zone, as opposed to concentrations at discrete compliance points reduces long term monitoring costs, eliminates the need for negotiating access to off-site properties, and provides a more effective approach to risk management for sites with low level cross-boundary impacts.