Hydrogeobotany in mine water studies

Gareth Digges La Touche[1], Freddy Brookes[2]

[1]*Golder, 20 Eastbourne Terrace, London, W2 6LG, United Kingdom, gdltouche@golder.com*
[2]*Golder, Cavendish House, Bourne End Business Park, Cores End Road, Bourne End, Buckinghamshire, SL8 5AS, United Kingdom*

Abstract

Geobotanical methods and application have a long heritage dating back centuries. Although there were minor peaks in the publishing of geobotanical studies, by Scandinavian and Canadian researchers, in the 1940s and late 1940s to mid 1950s respectively, the use of geobotanical methods only started to grow rapidly in the 1960s. This growth was principally driven by the need of the Soviet Union to establish the mineral resources of the state through a large scale programme of geological mapping (Brooks, 1972). While geobotanical methods became established, although they are far from mainstream, in mineral exploration their application in other geoscience fields has been limited. This paper will explore the application of geobotany to mine water studies.

Geobotany is currently very rarely used in the field of groundwater exploration due to the single discipline approach that is common in current practice. Geobotany, which in this instance may be better referred to as hydrogeobotany or ecohydrogeology, requires a holistic multi-disciplinary approach that draws not only on the disciplines of hydrogeology and hydrology, but also botany, soil science and chemistry. The most useful plants to the hydrogeologist are those whose presence or morphology can provide data about the hydrogeological setting. These indicator plants can be the source of information about the depth to groundwater, fluctuations in groundwater levels and groundwater chemistry.

The application of hydrogeobotany when integrated with conventional hydrogeological approaches has the potential to provide a valuable addition to conventional hydrogeological work flows. This paper will explore some of the concepts and the applications of hydrogeobotany as applied to mine water practice. For example: how it is possible to distinguish between plants that can tolerate high levels of certain metals (metallophyte) and plants that are wholly reliant on the presence of these metals (obligate metallophytes); and how certain plants may be used as indicators of groundwater depth or soil moisture conditions. The paper will conclude with some practical applications that can be readily applied to mine water studies.

Keywords: ecohydrology, geobotany, hydrogeobotany, ecohydrogeology

Introduction

The assessment of the impact of proposed mining operations on groundwater is often constrained by a lack of groundwater information beyond the immediate footprint of the proposed mine. So any information that can help develop a conceptual model of the hydrogeological regime is valuable.

Geobotanical methods have a long pedigree in geological studies, in particular in mineral exploration. Brooks (1972) reports minor peaks in the publishing of geobotanical studies, by Scandinavian and Canadian researchers, in the 1940s and late 1940s to mid 1950s respectively and that the use of geobotanical methods only started to grow rapidly in the 1960s. This later growth was driven principally by large scale mapping programmes in the Soviet Union that were needed to establish the mineral resources of the state (Brooks, 1972). While geobotanical methods became established, although they are far from mainstream, in mineral exploration their application in other geoscience fields has been limited.

In parallel to mineral exploration, or perhaps even preceding, it geobotany has played a role in groundwater studies with the Roman architect Vitruvius reporting on the use of plants to locate water sources (Gwilt, 1826) and the United States Geological Survey (USGS) publishing a water supply paper on the subject in the 1920s (USGS, 1927).

Geobotany in groundwater studies

While geobotany, or more aptly hydrogeobotany, in groundwater studies has clearly been established for some time it is not a commonly applied tool in modern groundwater studies. It has gained more recent prominence in Europe as a direct result of the European Commission Water Framework Directive 2000/60/EC (European Commission, 2000), which presents a requirement for a more holistic consideration of the water environment and impacts on ecological receptors as well as on the chemical quality of the water, however this ecohydrological approach has a focus on understanding groundwater supported ecosystems rather than using geobotanical methods as a tool for understanding groundwater.

Ecohydrological methods can however be equally be applied to determining the nature of the hydrogeological regime through application of the hydrogeobotanical method. The aim is to use plants to provide information regarding the groundwater regime in terms of depth to groundwater and or groundwater quality. What indicators are useful will vary depending on the environment, thought the common theme should be for the hydrogeologist to observe the environment in a holistic manner recording and taking note of floral assemblages as much as they record information relating to the geology or water features.

At the simplest level vegetation growth in arid regions can often indicate groundwater discharge zones as springs and oases (fig. 1 and 2), whereas in temperate regions the density of vegetation may indicate the depth to groundwater and the range of groundwater level fluctuation (fig. 3)

More subtly in tropical and subtropical regions the absence of trees and bushes may indicate the presence of calcrete horizons (fig. 4) indicative of differing soil conditions and vadose zone processes.

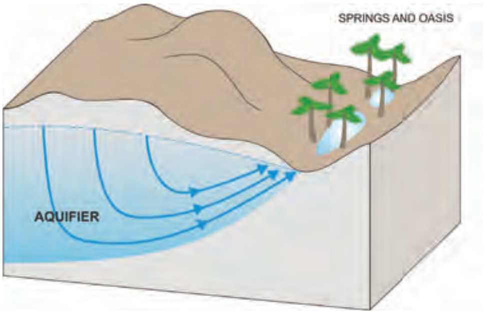

Figure 1 *Vegetation around springs and oasis as indicators of groundwater discharge in arid regions (after International Association of Hydrogeologists, 2016).*

Figure 2 *Vegetation supported by perineal spring flow from a fracture conduit.*

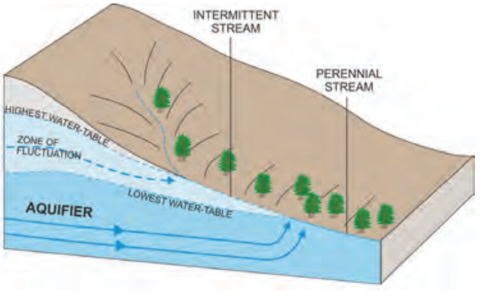

Figure 3 *Vegetation density variation around a perineal stream in an area of fluctuating groundwater levels (after International Association of Hydrogeologists, 2016)*

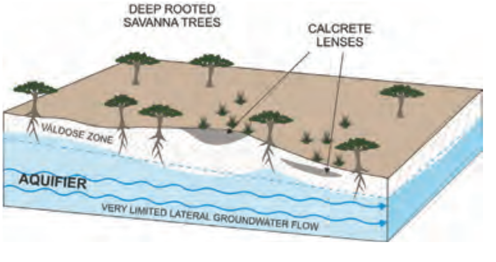

Figure 4 *Tree growth controlled by the presence of calcrete lenses (after International Association of Hydrogeologists, 2016)*

Direct indicators

Some plants are very direct indicators of particular geochemical conditions in the soil, for example the Alpine Pink (*Viscaria Alpina*) is an indicator of the prescence of copper (Brooks, 1972), hence the Viscaria Copper Mine in Sweden, and Milk Vetch (*Astragalus spp*) can be an indicator of selenium and uranium (Brooks, 1972), whereas others such as Couch Grass (*Agropyron repens*) typically indicate shallow groundwater and Marsh Marigolds (*Caltha palustris*) in wetland areas can be good indicator of a groundwater discharge into a surface water body (Rosenberry et al, 2000).

In more arid areas, such as for example the Sinai Desert, the height of a plant may also provide information regarding the groundwater regime. For example it is reported that the Manna tree grows to a mature height of approximately 1 m when groundwater is between 2 m and 5 m below ground level, but only to around 0.5 m tall when groundwater levels are deeper than about 8 m (Lewis, 2012). Similar controls on tree height are seen in eucalyptus (Bot, 2014) where maximum heights of greater than 25 m were recorded where groundwater depths were less than 5 m, but for example height was restricted to approximately 16 m where groundwater depths were greater than approximately 10 m (Zolfaghar *et al*, 2014).

An understanding of the types of tree present can also provide a constraint on the depth to groundwater as part of the development of a conceptual hydrogeological model. A number of studies have been published with regard to rooting depth (e.g. Stone and Kalisz, 1991) and while rooting depth does not necessarily indicate the depth to groundwater few trees develop well established root systems below the groundwater table. One reliable indicator of shallow groundwater is the presence of Mesquite (*Prosopis* spp) (Verma *et al*, 2015), native to the southern United States and northeastern Mexico but introduced and considered an invasive species in parts of Africa, Asia, and Australia. Another example is the Willow (*Salix* spp) which does not grow where groundwater depths are greater than approximately 3 m (Lewis, 2012).

Application

As outlined above the key is to establish what are the indicators present in the area of study. This may most readily be achieved through liaison and ideally working with biologists and ecologists familiar with the area and establishing the key indicators. The acquisition of hydrogeobotanical data should then be incorporated as part of reconnaissance and groundwater mapping studies. The benefit of such an approach was recognised by Tóth (1966) who recommended the inclusion of vegetation mapping as part of a groundwater mapping study commenting that it was, for a regional study, likely more cost effective than drilling a small number of boreholes.

The following general workflow is advocated:

- Establish indicator species and or assemblages for the area of interest;
- Incorporate vegetation mapping as part of the hydrogeological mapping or reconnaissance study;
- Formulate initial conceptual hydrogeological model constrained by the collated data;
- Acquire additional data as required (e.g. boreholes, spring surveys);
- Refine conceptual model and test using available geobotanical data and results of ecological surveys undertaken as part of environmental and social impacts assessment (ESIA) studies.

Conclusions

The application of hydrogeobotanical methods to groundwater investigations for mine impact assessments in areas with limited or no existing data has the potential to provide a valuable addition to conventional hydrogeological approaches. The use of hydrogeobotanical methods can facilitate the development of better constrained hydrogeological conceptual models at an earlier stage of study in the absence of conventional hydrogeological data acquired from drilling boreholes and monitoring groundwater levels and quality. In addition it may allow additional refinement when combined with conventional hydrogeological data, or at least constrain our conceptualisation of a groundwater system.

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