Systematic Approach in Environmental Geochemistry as Part of a Mining Project Roadmap

Anneli Wichmann[1], Päivi Picken[2], Eeva-Leena Anttila[3], Kirsi-Marja Haanpää[3], Elin Siggberg[2]

[1]*AFRY Finland Oy, Jaakonkatu 3, 01620 Vantaa, Finland, anneli.wichmann@afry.com*

[2]*AFRY Finland Oy, Koskikatu 27B, 96100 Rovaniemi, Finland, paivi.picken@afry.com, elin.siggberg@afry.com*

[3]*AFRY Finland Oy, Elektroniikkatie 13, FI-90590 Oulu, Finland, eeva-leena.anttila@afry.com, kirsi-marja.haanpaa@afry.com*

Abstract

Geochemistry data gaps often result from insufficient consideration of site-specific circumstances or poor conceptualisation. Whoever plans the first mine site soil sampling or analysis of process trial residues, must understand the many future uses of the data. Misconceptions of other data users´ requirements disable future assessments and cause delays in project schedule. A systematic approach in environmental geochemistry enables better assessments and better environmental risk management. The successful project toolkit includes a combination of tools like conceptualisation, repetitive risk assessment, knowledge base management, gap analysis, roadmap, action plan and sampling and analysis plan.

Keywords: Project Roadmap, Conceptualisation, Gap Analysis, Risk assessment, Geochemistry, Sampling and Analysis Plan

Introduction

At the start of a mining feasibility study or an environmental approval procedure, geochemical gap analysis sometimes leads to rewriting the project schedule. Geochemical sampling, analysis, and testing are very time-consuming processes. Wrong choices made at the early sampling and analysis stages may extend the project schedule by months, potentially even years.

Data gaps result often from insufficient consideration of site-specific circumstances or poor initial conceptualisation. Whoever plans the first mine site soil sampling or programs the analysis of process trial residues, must understand the many future uses of the data, as comprehensively as possible. What kind of primary and supporting data is needed for geochemical modelling? What are all the mine site load details that the aquatic ecologist eventually needs to know, to assess the impacts on the watercourse status? What are the information requirements for selection of correct combination of water treatment technologies? As generation of a geochemical data set can require a long time, misconceptions of other data users' requirements are hazardous for project schedule management.

It may seem obvious that environmental geochemistry work should be systematic. In practice, specialist work is often procured in small pieces. Teams work with cases only over a short period. Projects may also go "hibernating" for a while or projects may simply become so fragmented that no team looks beyond the on-going task. This background forces also geochemists to find tools for better and more long-term management of work.

In addition to enhanced project schedule management, a systematic approach in environmental geochemistry enables better geochemical assessments and better environmental risk management. The successful toolkit includes a combination of tools like conceptualisation, repetitive risk assessment, knowledge base management, gap analysis, roadmap, action plan and sampling and analysis plan.

Challenges Related to Multiple Data Requirements

Factors defining geochemical sampling and analysis requirements vary largely between projects. These factors include, for example, soil and bedrock characteristics, catchment area sensitivities, relevant processing alternatives, mining or waste management options, potential backfill techniques, and data requirements set by modelling techniques (fig. 1).

Requirements for extractive waste characterisation vary largely between different data users. One use of the data is the definition of formal extractive waste and waste facility classification. In Europe, these requirements are derived from European Commission decisions in accordance with EU Extractive Waste Directive 2006/21/EC. Information needs for source term modelling or risk management can be much more complex and they vary between cases and modelling approaches (for example Pierce *et al*. 2016, Charles *et al*. 2016). From this perspective, development of any detailed sampling and analysis plan for a sub-project (e.g. process trial sampling and analysis plan) must be considered also from entire project's data requirement perspective. Another example of data user is water treatment engineering: information requirements do not include just the substances to be removed, but also substances impacting or disturbing the potential water treatment.

Data requirements for aquatic ecology impact assessments can be especially challenging to describe at the early project stages. Load estimate is needed for watercourse modelling and aquatic ecology impact assessment. Load estimate, alone, is usually a result of a chain of models, including hydrogeological models, various source term assessments and site wide water and loading balance model. At worst, the first model in the chain may already disable the last phase. From aquatic ecology perspective, generation of geochemistry work plan should, at least, include the following considerations:

- What are the substances or parameters that may impair different aquatic organisms?
- What are the requirements based on regulation? (In Finland, for example, Government Decree 1308/2015 on priority substances)
- What must be known to assess project compliance with formal objectives? (for example, European River Basin Management Plans and objectives set by the EU Water Framework Directive)
- Are there any other site-specific factors to be taken into consideration in risk management and approval procedures?

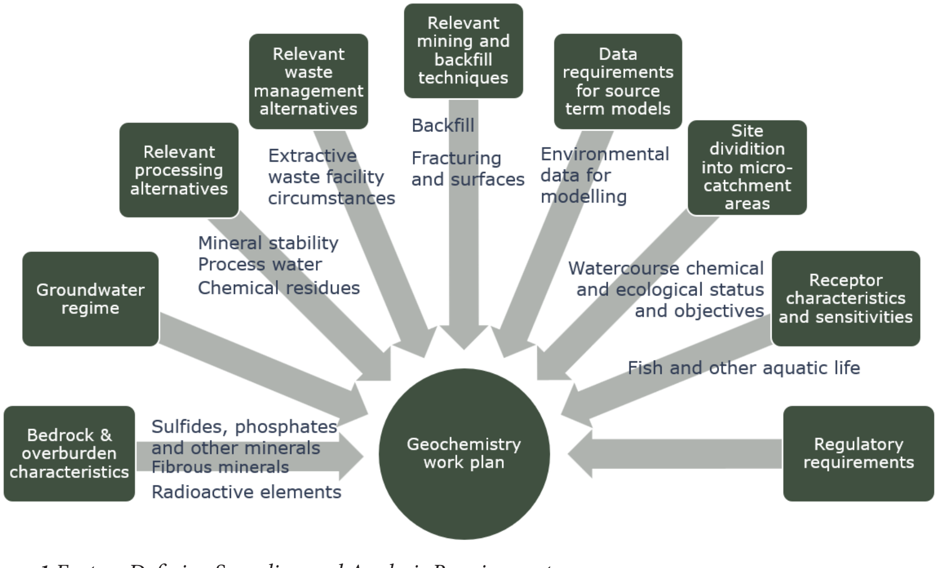

Figure 1 *Factors Defining Sampling and Analysis Requirements.*

In the European Union area, EU Water Framework Directive 2000/60/EC has set a requirement to identify river basin areas and to apply River Basin Management Plans. These plans include watercourse status objectives. Compliance with these status objectives is critical to any mining project and sometimes also one of the most challenging parts of the project. A comprehensive site-specific predictive compliance analysis requires correct choices already at early project stages, like adequate parameter range and detection limits in analytics, or suitable input data coverage over mine construction, operation and closure.

Challenges Related to Data Collection and Timing

Need of data must be recognised well in advance, sometimes years before the data is used. For example, kinetic test-work results that are used as input for source term assessments at feasibility study (FS) phase, must be initiated already during earlier study phases. Sometimes this means that test-work for a technical study should be started before the actual technical study even gets the funding decision.

Number of representing process trials may be few even in a large-scale mining project. Thus, there are not many opportunities to collect and analyse representative process water samples and process trial tailings. In addition, during the actual process trials, the time window for collecting and analysing samples may be narrow. It is important to plan the actual process beneficiation test trials also from water and tailings sample collection perspective, not forgetting sampling of process chemical residues. Persons responsible for project environmental performance and environmental geochemistry should be involved already in trial programming phase. Too narrow parameter range or poor documentation of process trial internal water balance may prevent data usability in necessary future environmental assessments, e.g. tailings water quality source term assessment, site wide loading balance modelling, and both operational phase and post-closure watercourse impact assessments.

Conceptualisation and Risk Assessments as Tools

Conceptual model is an essential basis for numerical modelling work, but it also is a fine tool to support understanding processes inside an individual waste facility (e.g. Lefebvre *et al.* 2001) or site-environment interactions (Enemark *et al.* 2018). First site-wide conceptualisation can be done a lot earlier than in beginning of geochemical or hydrogeological modelling. Early initial conceptualisation helps to identify site-specific data needs, but it also helps to prioritize critical work. While conceptualisation increases understanding on the mine site, also risk assessments are likely to become more comprehensive. Tools applied in risk assessments in mining industry are numerous (Verma and Chaudhari 2016, Tubis *et al.* 2020) and a rather large range of risk identification or risk assessment approaches can help to generate a comprehensive geochemistry work plan. For example, different water risk assessment approaches (Gilsbach *et al.* 2019) can be used in different detail/generalisation levels and in different project phases. Similar approaches can also support planning of geochemistry work. Risk assessment should always be considered as a repetitive process. Each risk assessment round defines and specifies a new or updated risk mitigation plan. Risks deriving from uncertainties in site geochemistry should be assessed as a part of a whole-project risk assessment. For example, extractive waste facility engineering risks cannot be discussed separately from geochemical uncertainties.

Knowledge Base and Gap-Analysis as Tools

Development of site knowledge base (ICMM 2019, 2020) includes a range of aspects from site physical setting and baseline data to operational information, regulation and commitments. Data is collected through all mining project development phases, but also through the years of mine operation and after closure. Site or case knowledge (knowledge base) can be reviewed, for example, before or at start of different study phases. Review also includes identification of gaps and action

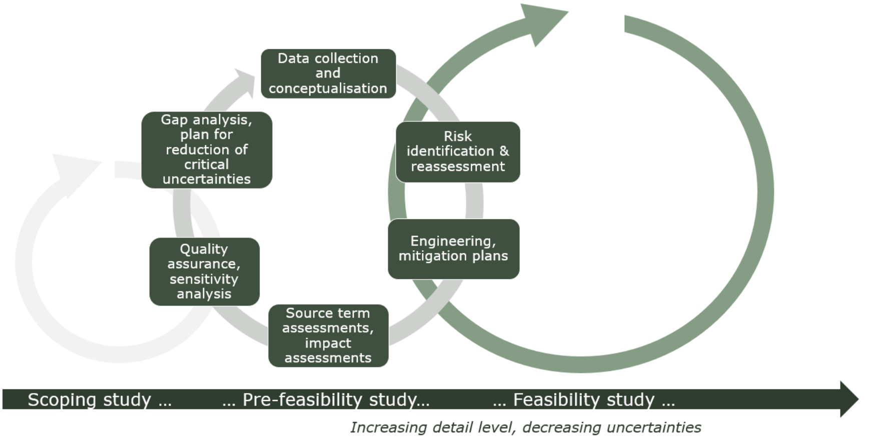

***Figure 2** Illustration of Cyclic Repetitive Work Sequences on a Mining Project Geochemistry Work.*

plan, to fill the critical gaps or to reduce critical uncertainties over the next project phases. At the end of the day, a mining project consists of cyclic repetition of work sequences, reducing uncertainties during every round (fig. 2). These work sequences also include conceptualisation and risk assessments.

According to our experience, data gaps seem to occur even late during the mining project development, especially in situations where environmental impact assessments, permitting, engineering, and economic planning are not genuinely interacting. These processes must be linked to each other at the detail level relevant to the project phase.

Project Roadmap as a Tool

Project roadmap focuses on long-term planning (Albright & Kappel 2016, Phaal *et al.* 2016). It requires defining project goals and understanding project risks. From environmental and social perspective, project roadmap includes identification of site-specific issues and prioritisation of critical issues. Critical issue can be, for example, a sensitive receptor watercourse. In such situation, discharge water quality (or load) can be a major project risk. This means that uncertainties related to water quality and quantity must be reduced as much as possible, as early as possible. This information may be critical even for investment decisions concerning subsequent, more detailed, technical study phases.

Project roadmap organises different study sequences and defines their interdependencies. Scheduling the project requires understanding what inputs each sub-task needs from other sub-tasks. A good roadmap starts from exploration phase and covers a large range of studies and procedures, e.g. different levels of feasibility studies, resource estimates, environmental and social impact assessments, environmental approvals, land-use planning procedures and stakeholder engagement. Roadmap can also be continued over the operational period to closure and post-closure. As the project proceeds and information increases, roadmap must be reviewed and updated time to time.

Integrating geochemistry work plan into the mining project roadmap secures availability of the right information at the right time. Geochemical laboratory testing often takes place between the different technical studies or environmental procedures. From geochemistry perspective, it is always necessary to look beyond the current task. For example, roadmap defines when status of mine planning allows representative waste rock and pit wall sampling. Also, availability of hydrogeological data for geochemical assessments (like pit source term assessments or pit lake models) can be secured by using a roadmap.

Case example: Suhanko PGE-project

Suhanko is a PGE project with a long development history. When a new version of the project plan was on the drawing table, an environmental and social roadmap was developed to link environmental, social, hydrogeological and geochemical work into approvals procedures and engineering work. Roadmap was based on two initial procedures: risk identification and gap-analysis. Over the last few years, site knowledge base has been complemented to support technical-economic studies, approval procedures and environmental and social risk management. Application of the roadmap has, for example, resulted in a systematic sequence of studies and enabled practical scheduling of complementary geochemical test-work between technical study phases.

Conclusions

Specialist work in a mining project is often rather fragmented and misconceptions of other data users' needs are relatively common. Different teams working with the same project need good quality inputs at the right time. Tools are needed for long-term management of geochemical work. The successful project toolkit includes a combination of tools like **conceptualisation, repetitive risk assessment, knowledge base management, gap analysis, roadmap, action plan and sampling and analysis plan.**

Selecting and using a systematic approach for environmental geochemistry requires multidisciplinary teams and looking beyond the current task. Systematic approach enables better management of environmental risks and project risks. It helps to keep the whole mining project on schedule and budget. Decision makers get the right information at the right time and critical issues are adequately prioritized. Financiers get an understanding on the project´s probable long-term geochemistry work requirements.

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