Monitoring and Control in Mining

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Abstract. Reliable risk management is based on informative decision making. The key to improve decision making is to combine information and create new predictive measurements. Predictive indirect measurements can include open data, process measurements, and modelling. Varying information sources enables viewing the situation from several differing angles and can give the decision maker more time to react. Different data-sources strengthen each other narrowing the uncertainty of predictions. Robust self-monitoring is also needed for the predictive system to be reliable. Mining industry has three major risk sources: water handling in the environmental focus area, condition of machines and process devices, and health and safety of personnel. This article focuses on environmental monitoring in vast mining environment and its surroundings but connects process monitoring and control to subject.

Introduction

Environmental risks are the number one concern of mining companies when it comes to socio-economic relations and maintaining the company image. When dealing with large outdoor areas for water treatment, there is always a great risk of leaks. Leakage detection can take some time and in many cases, the residents detect the leakage from the surrounding lakes and environment. This leads to socio-economic pressure and reductions in company value. Mining companies are very interested in techniques for detecting small amounts of metals in water streams around the mining area [1].

Comprehensive use of varying data sources together with modelling provides great foundations for informed decision-making. The operator needs to be able to maintain the control of its process and assets.

Improvements in this field require advanced process monitoring methods, which include predictive algorithms and new measurement technologies. Working environmental monitoring system and optimal process control can ensure the future acceptance for mining operations among the wider population.

1 Waterflow models

MMEA project introduced the digital surface model (DSM) of Agnico Eagle gold mine area in Kittilä, Finland. The Model was done using photogrammetric processing of airborne image data. DSM can be combined with watershed information for creating a model for watershed management presented in Figure 1. The aerial photography for DSM was done in the MMEA project using a small airplane, which is expensive, compared with modern applications using drones. Tong et al. [2] introduces technique for integrating uav-based photogrammetry with terrestrial laser scanning. They built three 3D models of open-pit mine areas. These new techniques can be used for creating more detailed models for watershed management.

Figure 1: Watershed management. Main watersheds (red) with standard flowpaths (blue).

2 Environmental Monitoring

2.1 Environmental impacts monitoring

Wastewaters are the greatest concern in mining area since they can transport particles and chemicals effectively to wide areas in environment. Wastewater is treated in several stages in settling ponds or tailing dams before released back into surrounding environment. Environmental impacts monitoring focuses mainly on detecting changes in surface waters, groundwater, and air. Commonly measured parameters from process wastewater are the total heavy metal concentrations, pH, sulfate, and nitrogen. It is especially important to monitor and control sulphate discharges as they can form sulfuric acid and hydrogen sulfide that influences strongly water quality [3] [1].

Measurements and watershed models should be combined with open data to form estimates for leakage distributions in environment. These combined models can act as information source for damage control in case of accidents or determining the concentration variations at the different times of year. Variations and error from the expected values indicate the need for closer inspections.

2.2 Environmental measurements

Mining companies depicted in [1] that they are very interested in measuring ppb level amounts of heavy metals in water streams surrounding mining area. Report presented most promising methods for online detection at that time. Technologies for on-line measurements have been developing since that report was made. Technology development has continued since the MMEA project and in Finland, there are several companies focused on these new online measurement methods that can reach ppb level detection accuracies. Meoline has MEO+ heavy metals analyser based on electrochemical analysis. Sensmet µDOES is a multi element analyser for trace metals based in Micro-discharge Optical Emission Spectroscopy. EHP Environment provides very widely used monitoring stations for several different elements including heavy metals in waters.

Another good indicator for detecting changes in surrounding environment is a crowdsourced measurement. The idea is that anyone can take measurements from the environment using a standardized way. Measurements are then gathered into a database where data is treated with outlier detection and stored for the users.

These measurements are not necessarily very accurate but can detect changes when a sufficient number of measurements are reached. Another good thing about the crowdsourcing is that it can act as a rather comprehensive measurement network that is cheap and does not need constant maintenance [3].

3 Process Control

Optimally the working process ensures that there is a minimal amount of emissions. Modern control methods can be used for optimal process control. H2020 Spire project 'Intensified by Design' (IbD) aimed in process intensification and Minesense project that focused on optical measurements for the sustainable mineral beneficiation process provided new information for better process control. Figure 2 illustrates the plan for comprehensive process control that is the ultimate aim of these projects.

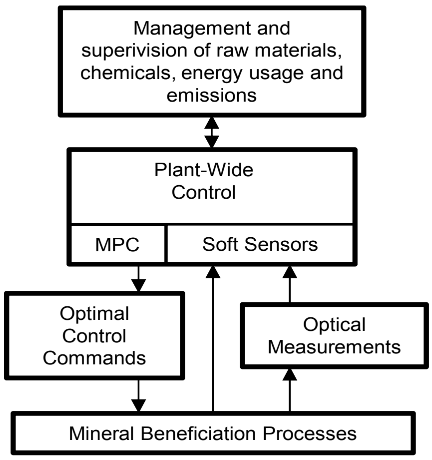

Figure 2: Wide control plan for minerals processing.

IbD focused on grinding process intensification through optimal control actions, coarse flotation, soft sensors, and new measurements. This work was presented in IFAC MMM 2018 conference [4] and it included good results for model adaptation using the differential evolution algorithm.

Modeling is an efficient tool for predicting process operation and generating new soft sensors for advanced control methods. Modelling and simulation for efficient minerals processing is reviewed in [5] and [6] using minipilot scale mineral beneficiation plant as a real life process. Optical sensors can be used in the monitoring of the flotation enrichment process [7]. Optical measurements can enable advanced process control for the typically hard to measure the flotation process.

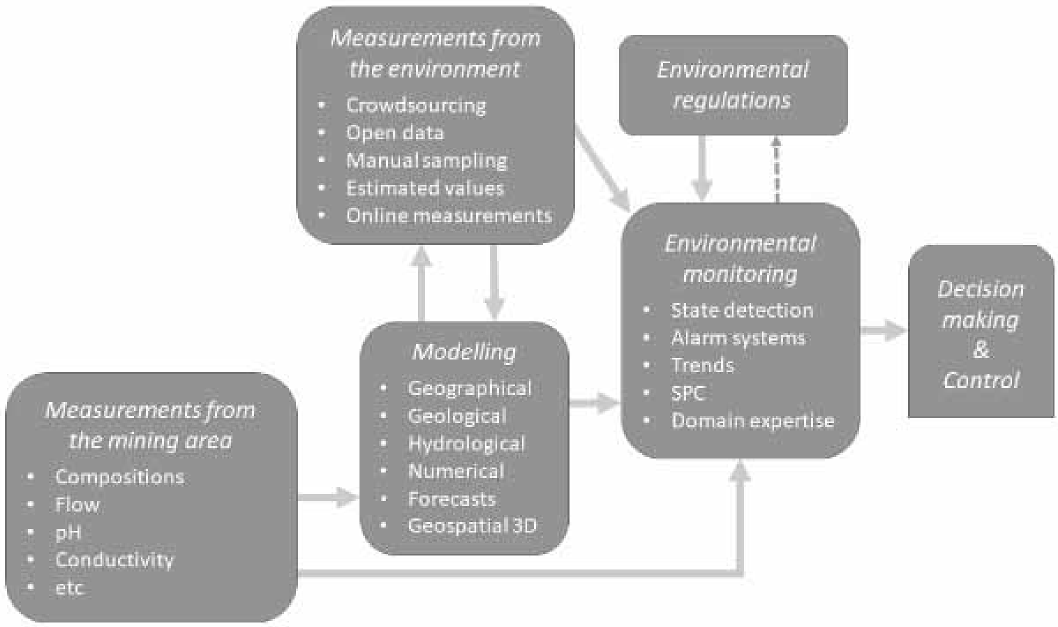

Figure 3: Environmental monitoring concept [3].

3.1 Condition monitoring

Condition monitoring is a vital part of comprehensive process control. We need to know our assets are in good working condition for optimal operation. Advanced methods provide intelligent indicators for monitoring changing condition. Indicators can be scaled to the real-valued interval [-2, 2] [8]. Generalised norms and moments are excellent tools for indicating current condition or change in the current operating state [9]-[11].

Good process control is linked to the environmental risks. By keeping a process running optimally, we can ensure minimal environmental effects. Fluctuations in process operation increases unexpected situations, which are difficult to control. Reduced fluctuations in process operation also ensure better predictions about how the process is going to act in future. This gives more time to react when abnormal operation is detected.

4 Decision Support and Risk Management

Decision-making is based on situation awareness from combining data from several sources with wide domain expertise using intelligent analyzers (Figure 3) [3].

Developments in modeling and increasing accuracy in measurement technologies build a solid base for future decision support systems. Leaps in development are needed to ensure the sustainable mining operations and social acceptance. Survey for environmental decision support tools and general methods are presented in [12] including wide amount of sources for varying methods and software tools.

Online monitoring methods are currently used as a fast response system in case of a leakage. Interest in the environmental measurements is a good sign that the environmental issues are taken seriously and that there is a motivation to prevent any unwanted effluent streams getting into surrounding environment. Correlations between different variables like water stream turbidity and arsenic can be used for indirect monitoring and these soft sensors can trigger actions for more detailed analysis.

The wide use of these methods would require standardization and accepting them as valid proofing methods for the environmental permit. Current legislation only approves scarce laboratory analyses to be used in the validation of the environmental permit. Continuous measurements would include the information on dynamics, which could increase the knowledge about the effects of mining operations to the environment.

5 Conclusions

Work done for better advanced process control and decreased environmental impact is a great basis for pursuing goals in sustainable development. Technological leaps enable the realization of previously outlined innovations. Co-operation between experts in varying fields provide that the expert knowledge develop with the technologies to generate the monitoring systems of the future.

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