Shallow anthropogenic aquifers may provide a solution to reduce nitrate in dirty mine water?

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Abstract

High nitrate levels in both surface run-off and groundwater occur in the platinum sector in South Africa and are elevated as a result of the explosives used. The paper discusses the nitrate cycle in the mining environment and conditions that may lead to naturally reduce nitrates. The pilot work was done at Elands Platinum Mine (EPM) located in the north western parts of South Africa. The project was initiated using limited data and required careful monitoring and managed. Raw water is stored in a backfilled mining void (anthropogenic aquifer) and five boreholes are used to extract and supply water to a water treatment plant. Major advantages are cleaner water which requires less filtering, reducing electricity use and water purification costs, while also lessening the carbon footprint. It reduces the risk for the Mine to lose production as a result of water shortages. Long-term monitoring results also show reduction of nitrates as a result of bacteria rich water moving from an aerobic to an anaerobic environment before it is used. Large quantities of excess mine water will be added to the system, but will first undergo pre-treatment by letting it flow through series of artificial wetlands before it enters the anthropogenic aquifer.

Keywords: platinum mines, reduce nitrate, man-made aquifers, artificial wetlands

Introduction

Nitrate pollution is a common occurrence in the platinum sector in South Africa and nitrate levels are elevated at all the platinum mine as a result of the explosives used, which largely consist of an ammonium nitrate emulsion.. Whatever the cause - and there may be an argument to improve management thereof - but as long as platinum mines exist, high nitrate levels will be observed in the water sources. The background values show high "natural" natural levels of nitrates occurring in the groundwater. This may be as a result of farming activities prior to mining - fertilizing with NPK (nitrogen phosphate potassium) or chicken manure mixed with soils to increase their agricultural potential. The result is that higher nitrate levels are often measured in the return waters from the mine and as the water is recycled, the nitrate levels increase. There is limited opportunity for the nitrates to flow from an oxygen-rich to oxygen-poor environment and bacteria and microorganisms are constantly removed with disinfection methods underground. The nitrogen cycle is therefore basically forced in the one direction and de-nitrification cannot occur. The result is a constant increase in nitrate levels - can this be addressed in a sustainable manner?

There are some options mines can consider. The old engineering option is to pump and treat, another option is to mix it with sewerage treatment plant (STP) source effluent and treat it in the STP's, or simply discharge it into the environment and let nature take care of it. The pump-and-treat option is not really viable, because often it is the nitrogen only that needs to be removed. The other concerns, e.g. high levels of suspended solids and hydrocarbons, can both can be effectively handled through proper management of dirty water areas and suspended solids through the use of effective settling facilities. The options to consider are natural remedies to reduce the nitrate to nitrogen gas and get it in the atmosphere, where it is the most abundant gas.

How do we do this? First consider the nitrogen cycle (Figure 1). To get nitrate reduced it needs to be at conditions with a soil pH > 6 and preferable warmer than 5 °C, laboratory results show it best at 40 °C (White, 1997). There needs to be carbon as an energy source and anaerobic conditions with partial pressure of O_2 < 0.004 bar. Finally there needs to be anaerobic bacteria (*Pseudomonas and Bacillus species*). Nitrogen can then be reduced with final products as being predominantly nitrous oxide (N_2O) and dinitrogen gas (N_2).

Now consider the mining conditions where both underground and open cast, nitrogen is produced, oxygen is always available (underground via effective ventilation), water constantly disinfected to kill bacteria and the carbon source removed or simply not available. How do we create conditions to suitable for nitrate reduction? Platinum mines compared with both gold and coal mines generally have groundwater pH values above 7, making it more favorable. One of the most effective natural ways to deal with high nitrates is to create flooded soils or artificial wetlands. Wetlands takes up large surface areas and one of the recent products on the market is enhanced artificial wetlands. This method makes use of synthetic carbon fiber to mimic the biomass surfaces around root systems, thereby making larges surfaces areas available for bacteria to quickly colonize. Results from these enhanced artificial wetlands indicate a quicker reduction of nitrate levels and at higher reduction rates than normal wetlands, making them more effective. They do, however, require constant maintenance and financial sustainability thereof needs to be considered when the mine is closed.

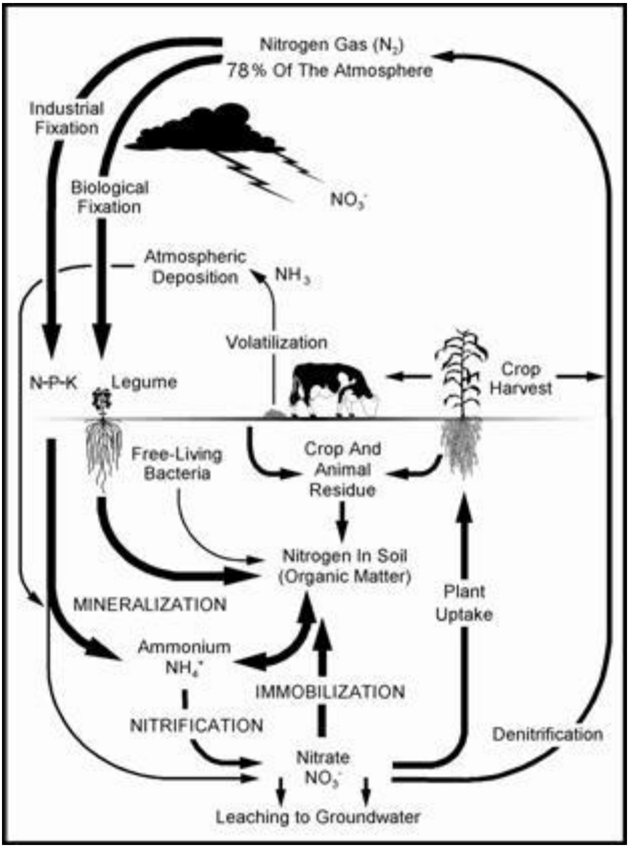


Figure 1 *Nitrogen gas in the atmosphere*

Eland Platinum Mine Case Study

At Eland Platinum Mine (EPM) in the northern parts of South Africa two approaches were considered and implemented: the flooded soil condition with effective wetland-type biomass which is a common approach, as well as reduction of nitrate in old backfill mines. There is an effective monitoring plan at EPM with surface water samples taken every month and groundwater samples every three months (Figure 2). Further to this the potable water supply is tested daily and nitrate identified as a critical salt to be tested daily as a result the reduction of nitrates can be monitoring on a daily basis.

Figure 2 *Monitoring positions at Eland Platinum Mine*

The backfilled open cast is used to store raw water (Botha *et al*, 2011) and reduction of nitrates in the old backfill areas only came by default. The source water nitrate values ranged from 8 to 15 mg/L and the borehole water continued to have nitrate values between 10 and 30 mg/L. The stagnant water in the quarry and the waste rock could have been the source of the higher salt load. In order to remove stagnant water and to flush the system from excess salts, the quarry was dewatered with boreholes drilled through the backfill material to levels below the backfilled area. During both dewatering events the EC and nitrate levels increase significantly and correlated well with periods when no water was pumped into the quarry. After the final dewatering event and once the quarry was filled again, the water quality from the boreholes showed significant improvement with nitrate levels below 10 mg/L and EC values below 60 mS/m. Since early 2011 the quarry was kept at the same level, with salt levels not increasing and since April 2011 the nitrate levels have also become more stable (Figure 3).

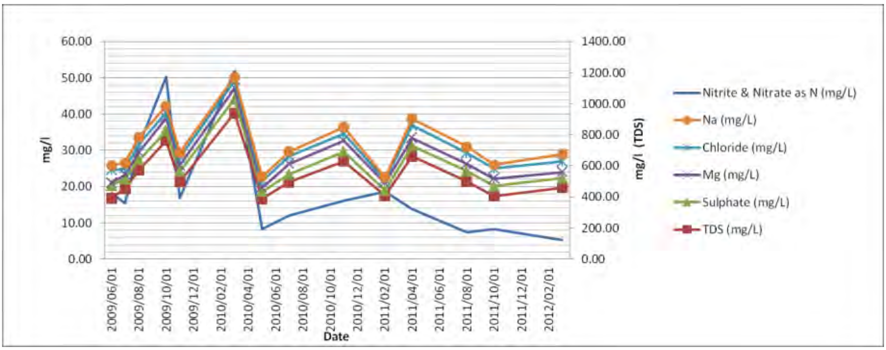
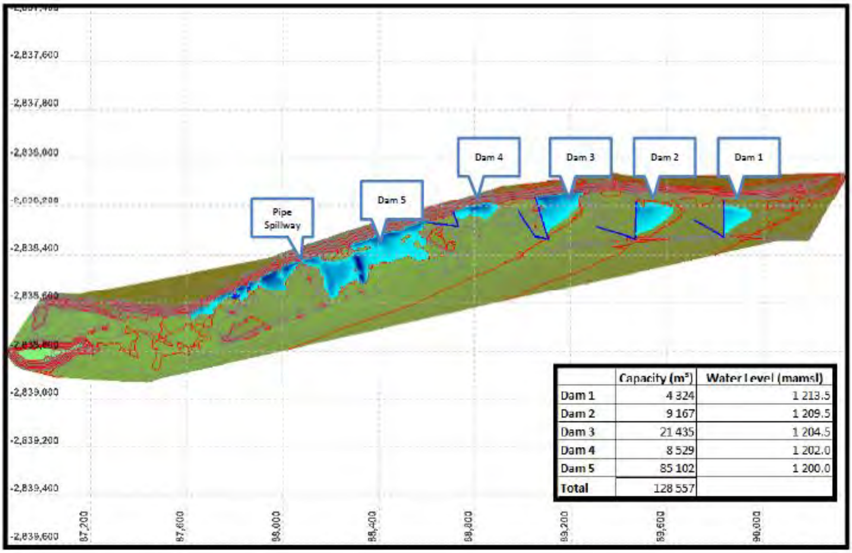


Figure 3 *Shows nitrate to continue to reduce to below 10 mg/L*

At EPM more water with nitrate levels higher than 100 mg/L is extracted from the mining area and most of the water is recycled and used as process water. However, there is an opportunity to reuse this water more effectively if it can be stored in a very large facility. The backfilled open cast area has a total storage capacity of > million m^3 and it is the ideal place to store excess mine water. The high nitrate levels, however, need to be reduced before it is stored, because the anthropogenic aquifer does neither have the biomass nor the warm temperature to effectively reduce high concentrations of nitrates. Artificial wetlands were selected as a pre-treatment and done through a number of small containment facilities to create flooded soils where wetland type biomass can grow to create ideal conditions to reduce nitrates (Figure 4**Figure**). Once it flows tough the flooded soils, it will flow into the backfilled mine, from where it will be used as process water. The old backfill is divided by a massive dyke and will not be mixed with the water used as potable water. The project is almost 90% implemented and will be commissioned at the end of July 2012.



	Capacity (m^3)	Water Level (mamsl)
Dam 1	4 324	1 213.5
Dam 2	9 167	1 209.5
Dam 3	21 435	1 204.5
Dam 4	8 529	1 202.0
Dam 5	85 102	1 200.0
Total	128 557	

Figure 4 *Wetland design for EPM*

Conclusions and recommendations

Nitrate pollution is a major concern within the platinum mining sector in South Africa. Mining conditions tend to create an imbalance in the nitrogen cycle. Sustainable methods to swing the balance need to be considered. The nitrate cycle is complex and most work done is limited to the near surface soils and focus on retaining nitrogen for agricultural purposes. Old backfill mine areas can provide an anaerobic area with enough carbon to create conditions where nitrate can be reduced to N_2 of N_2O, and this was observed at EPM. This can further be enhanced by pre-treatment with development of artificial wetlands. The project however is in the early stages and careful monitoring will indicate if it deemed successful and what additional work may still be required to harvest high nitrate water and effectively treat it using only natural biochemical conditions.

References

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