Cost effective screening of mine waters using accessible field test kits – Experience with a high school project in the Wonderfonteinspruit Catchment, South Africa

Lindsay Fyffe[1], Henk Coetzee[2], Christian Wolkersdorfer[3, 4]

[1]Brescia House School, Johannesburg, South Africa, Lindsay.Fyffe@bresciahouseschool.co.za

[2]Environmental Geoscience Unit, Council for Geoscience, Pretoria, South Africa henkc@geoscience.org.za

[3]South African Research Chair for Acid Mine Drainage Treatment, Tshwane University of Technology, Pretoria, South Africa, christian@wolkersdorfer.info

[4]Finnish Distinguished Professor for Mine water Management, Lappeenranta University of Technology, Laboratory of Green Chemistry, Mikkeli, Finland

Abstract. In South Africa's Witwatersrand mining area, the issue of acid mine drainage has risen to great public prominence, with community-based activists playing an important role in raising awareness. Conventional water quality monitoring is costly and often requires complex procedures. However simple water quality tests exist for a number of parameters which can be used to identify potential contamination related to mining. These have been applied as part of a high school science project, looking at the environmental impact of gold and uranium mining in the upper Wonderfonteinspruit. The results allow identification and characterisation of water pollution. This demonstrates the ability of volunteer monitoring programmes using simple technologies to complement the work done by regulators, operators and researchers in mining environments.

Introduction

As the environmental awareness of citizens about potential negative impacts of mining activities increases, it becomes more and more important to regularly monitor receiving water courses. In developed countries, mining companies, regulatory bodies and environment agencies usually carry out this monitoring. Developing countries often lack the skilled personnel and other resources to carry out and maintain this monitoring. In remote rural areas of developing as well as developed countries, this monitoring might be impractical or beyond the financial capacity of the responsible government bodies.

In the United States, a large number of volunteer groups are responsible for regularly monitoring of water sheds (Buza et al. 2001, Wolkersdorfer 2008). This procedure has been proven favourable and many members of those groups are well educated in taking water samples and interpreting this data when following given guidelines (United States Environmental Protection Agency 1996). Consequently, the US EPA encourages volunteer water monitoring through its “EPA’s Volunteer Monitoring Program” (http://water.epa.gov/type/rsl/monitoring). A worldwide programme to increase the awareness of volunteer water monitoring is the “World Water Monitoring Day” that has collected volunteer water data since 2003 (Anonymous 2003). As simple and fast on-site monitoring equipment and field kits are available, volunteers are becoming a reliable source for monitoring environmental parameters (Junqua et al. 2009).

This paper describes a South African volunteer school project to monitor mining impacted water courses. It will evaluate if the data collected are reliable enough to be used for reporting purposes or to identify potential action plans in mining impacted water sheds. Reliable data is needed to initiate restoration of water courses or to monitor the development and progress of restoration work (Reutebuch et al. 2008). The paper will also discuss the necessity for such volunteer programmes in South Africa.

The West Rand Gold Field of South Africa has been mined since the late 19th Century (Hocking, 1986). Gold and uranium are extracted from pyritic conglomerates of the Archaean Witwatersrand Supergroup. More than a century of mining has left a large underground void, comprising a number of interconnected mines, accessing a number of orebodies. Waste rock and tailings covers a large portion of the surface.

The West Rand Gold Field straddles a continental watershed, with the northern portion of the area draining into the Tweelopiespruit, a tributary of the Crocodile River which flows north, discharging into the Limpopo River and ultimately to the Indian Ocean and the southern portion draining into the Wonderfonteinspruit, which forms part of the Gariep River system, eventually discharging into the Atlantic Ocean

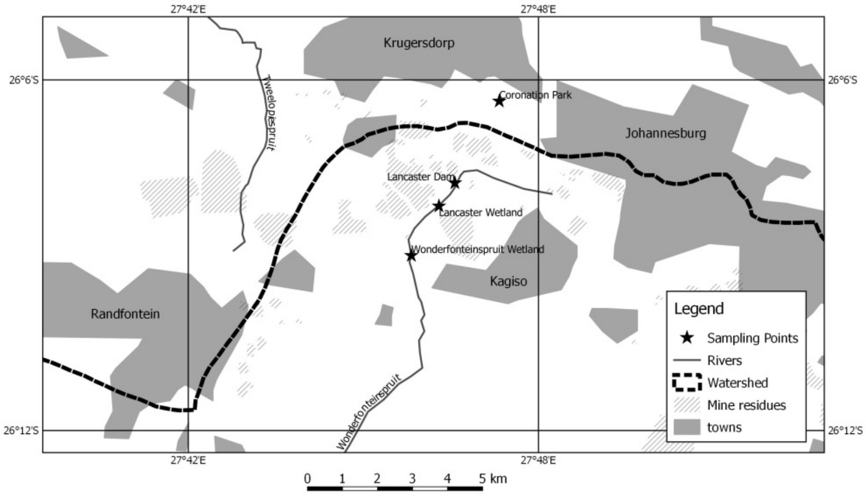

Fig 1. Location of the 4 sampling sites in Krugersdorp, Gauteng, Sputh Africa and the course of the Tweelopiespruit in the West and the Wonderfonteinspruit in the East.

After the cessation of underground mining in 1998, the mine workings were allowed to flood. Water daylighted in 2002 on the northern side of the watershed, leading to contamination of the Tweelopiespruit (Hobbs and Cobbing 2007). South of the watershed, seepage from numerous waste rock and tailings piles enters the Wonderfonteinspruit, where acidification and contamination of water and stream sediments have also been reported (Coetzee et al. 2002; Wade et al. 2002; Coetzee et al. 2006).

Background

The current study was conceived as a high school science project. Acid mine drainage has received a high degree of public and media attention in South Africa in recent years, owing to a number of perceived crises. A common criticism of official efforts to manage the effects of mining is that very little data and information is available to the affected members of the public. The principal author of the study therefore elected to attempt to study an acid mine drainage affected catchment. Initial investigations showed that the type of analyses conventionally utilised were prohibitively expensive and two samples could be collected and submitted to a commercial laboratory for uranium analysis.

Another important application of rapid field analyses is in the screening of large numbers of potentially contaminated sites, for example in the assessment of large numbers of abandoned mines (Coetzee et al. 2008). In many cases, the limiting factor on the number of sites investigated is the cost of laboratory analyses and lead times for analyses. For this reason, a number of approaches have been taken to perform rapid, low-cost analyses in the field, limiting the number of samples to be collected, transported, stored and analysed and providing screening-level data. Examples include the USGS field leach test (Hageman 2007) and the use of simple field test kits (Coetzee 2013).

It was therefore decided to utilise field analytical methods for the testing of samples collected in the Wonderfonteinspruit Catchment with the dual aim of identifying and characterising water pollution and assessing the viability of this approach. Owing to practical considerations, most of the samples were collected in the field and analysed after collection, although some field analyses were also performed.

Sampling and analysis

Water samples were collected at 4 sampling sites:

1. Lancaster Dam, a tailings-filled dam in the Wonderfonteinspruit, receiving seepage from a number of tailings dams and waste rock piles.
2. Lancaster Wetland, a wetland immediately downstream of Lancaster Dam.
3. Wonderfonteinspruit Wetland, a wetland further downstream.
4. Coronation Dam, a background site in an adjacent catchment.

Water samples were collected in plastic soft drink bottles, which were thoroughly cleaned before sampling and then rinsed three times with the water to be sampled. All samples were collected below the water surface and the bottles filled and sealed to minimise headspace. The samples were analysed in the field or transported to the Council for Geoscience Environmental Laboratory for analysis.

Water samples were analysed for a number of parameters using Macherey and Nagel Quantofix (http://www.mn-net.com/tabid/4928/default.aspx) test kits. A number of test kits have been identified which can have relevance to different mine waters. For the purposes of this study, substances which are typically associated with gold mining in the Witwatersrand – pH, SO_4, Fe (total), Al and carbonate hardness – were analysed.

Analytical results

The analytical data are presented on histograms, grouped by sampling site (Figures 2 – 6). Data from Lancaster Dam show a strong acid mine drainage (AMD) signature with low pH as well as SO_4, Fe and Al elevated well above the local background and low alkalinity (measured as carbonate hardness). Other samples collected from the Wonderfonteinspruit show varying degrees of contamination with AMD, with variation appearing to be controlled by rainfall.

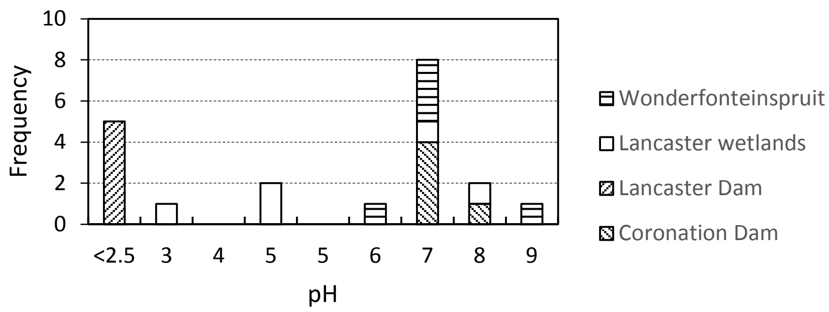

Fig 2. Histogram of pH values measured

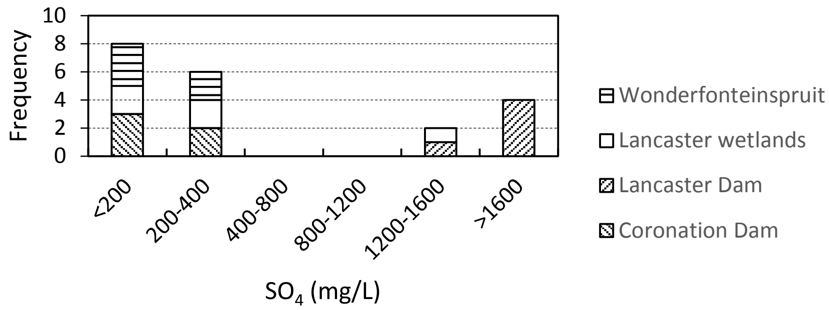

Fig 3. Histogram of SO_4 concentrations measured

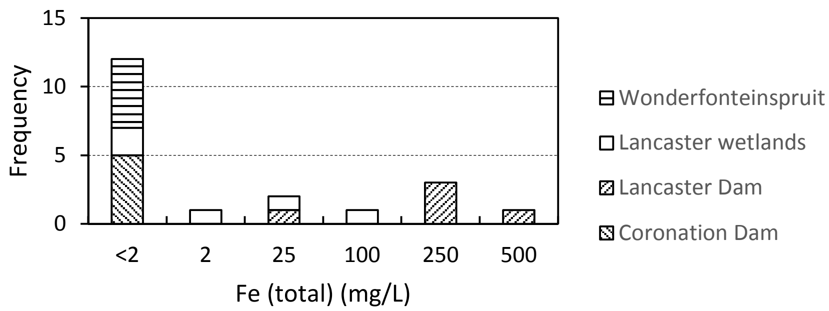

Fig 4. Histogram of Fe concentrations measured

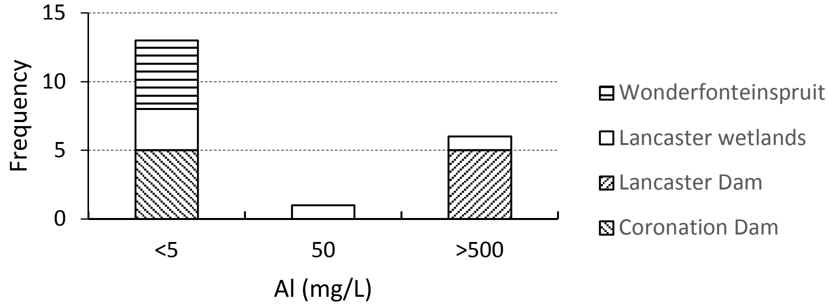

Fig 5. Histogram of Al concentrations measured

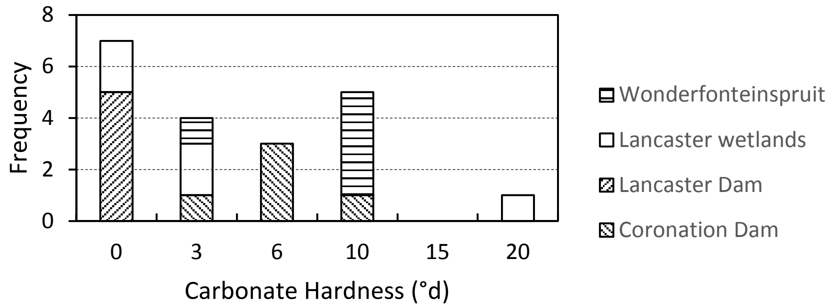

Fig 6. Histogram of carbonate hardness values measured

Conclusions

The data collected confirm previous studies' results in this part of the Wonderfonteinspruit. Interactions between water and mine residues results in low pH and high levels of dissolved sulphate, iron, aluminium and other metals. The methods used provide sufficient resolution to identify polluted sites and detect temporal variations in contaminant levels such as those induced by seasonal rainfall and other factors.

The analytical methods used were able to identify polluted and unpolluted water bodies and to detect temporal variations in water quality. The selected contaminants which are associated with mining in the Witwatersrand were all easily detected, demonstrating that the use of low-cost field tests in mining environments can contribute to water quality monitoring and pollution detection.

The feasibility of rapid field screening tests for the detection and monitoring of pollution from the Witwatersrand has been demonstrated. Additional research is needed on the operational implementation of these methods in mining-affected communities and with interested individuals, to facilitate the monitoring of affected water resources via volunteer monitoring.

As in the US, where volunteer programmes contribute to environmental monitoring, it might be necessary to set up quality assurance guidelines so that citizen's involvement could become part or regular monitoring.

Acknowledgements

We thank the owners of the properties on which the sampling sites are located for providing us access during the course of the programme. LF thanks Mariette Liefferink for creating a mine water awareness that ultimately initiate this programme.

References

Anonymous (2003) World Water Monitoring Day. Mar Pollut Bull 46(10):1217-1217.

Buza M, Dimen L, Pop G, Turnock D (2001) Environmental protection in the Apuseni Mountains: The role of Environmental Non-Governmental Organisations (ENGOs). GeoJournal 54:631–653.

Coetzee, H. (2013). Rapid field based analytical techniques for the environmental screening of abandoned mine sites. Reliable Mine Water Technology (Vol II). A. Brown, L. Figueroa and C. Wolkersdorfer. Denver, Colorado, USA, Publication Printers**:** 943–948.

Coetzee, H., P. W. Wade and F. Winde (2002). Reliance on existing wetlands for pollution control around the Witwatersrand gold/uranium mines of South Africa. Are they sufficient? Uranium in the aquatic environment: Uranium Mining and Hydrogeology III. B. J. Merkel, B. Planer-Friedrich and C. Wolkersdorfer. Freiberg, Springer Verlag**:** 59–66.

Coetzee, H., F. Winde and P. Wade (2006). An assessment of sources, pathways, mechanisms and risks of current and future pollution of water and sediments in the Wonderfonteinspruit Catchment. WRC Report No. 1214/1/06, Pretoria, Water Research Commission**:** 202pp.

Coetzee, H., N. R. Nengobela, C. Vorster, D. Sebake and S. Mudau (2008). South Africa's strategy for the management of derelict and ownerless mines. Mine Closure 2008: Proceedings of the third international seminar on mine closure. A. Fourie, M. Tibbett, I. Weiersbye and P. Dye. Johannesburg, Australian Centre for Geomechanics**:** 113–124.

Hageman, P. L. (2007). U.S. Geological Survey field leach test for assessing water reactivity and leaching potential of mine-wastes, soils, and other geologic and environmental materials, US Geological Survey.

Hobbs, P. J. and J. E. Cobbing (2007). A hydrogeological assessment of acid mine drainage impacts in the West Rand Basin, Gauteng Province. CSIR/NRE/WR/ER/2007/0097/C, Pretoria, CSIR/THRIP**:** 59pp.

Junqua G, Baurès E, Hélias E, Thomas O (2009). Use of Screening Methods in US Water Regulation. In: Gonzalez C, Greenwood R, Quevauviller P (eds) Rapid Chemical and Biological Techniques for Water Monitoring. Water Quality Measurements Series. Wiley, Chichester, p 15–37.

Nadeau, G. (1952). "Gutzeit's Arsenic Test". Can Med Assoc J **66**(5): 489.

Reimann, C. and P. de Caritat (1998). Chemical Elements in the Environment. Berlin, Springer.

Reutebuch E, Deutsch W, Ruiz-Córdova S (2008) Community-Based Water Quality Monitoring – Data Credibility and Applications. In: Auburn University Alabama (ed) Alabama Water Watch. Alabama, p 24.

Wade, P., S. Woodbourne, W. Morris, P. Vos and N. Jarvis (2002). Tier 1 risk assessment of radionuclides in selected sediments of the Mooi River. WRC Report 1095/1/02, Pretoria, Water Research Commission**:** 93pp.

Wolkersdorfer, C (2008). Water Management at Abandoned Flooded Underground Mines – Fundamentals, Tracer Tests, Modelling, Water Treatment. Heidelberg, Springer.

United States Environmental Protection Agency (1996). The Volunteer Monitor's Guide to Quality Assurance Project Plans. vol EPA 841-B-96-003, p 59.