Acid Rock Drainage in the Indigo Shores Housing Development, McCabe Lake, Halifax Regional Municipality, Nova Scotia

C. J. Hirtle[1] and C. E. White

Introduction

Acid rock drainage (ARD) is produced when sulphide-bearing material is exposed to oxygen and water. This can cause long-term impairment to waterways and biodiversity. Acid rock drainage may contain large quantities of toxic substances, which have serious human health and ecological implications. Acid rock drainage has been an ongoing environmental problem in the Halifax Regional Municipality (HRM), and several studies have been completed regarding the bedrock geology in HRM and its association with the production of acidic waters (e.g. Fox et al., 1997; White and Goodwin, 2011; Trudell and White, 2013a, b).

This report is the fourth in a series of senior student research projects studying ARD risks in HRM (e.g. White et al., 2014a; Farmer and White, 2015; Tarr and White, 2016) and is the result of collaboration between the Environmental Engineering Technology-Water Resources Program at the Nova Scotia Community College, Waterfront Campus, Dartmouth, and the Nova Scotia Department of Natural Resources (NSDNR). This report focuses on the new Indigo Shores housing development at McCabe Lake off Highway 101 near Middle Sackville in HRM (Fig. 1).

The recent development around McCabe Lake and the associated watershed area has exposed new sulphide-bearing bedrock of the Cunard Formation (Halifax Group), which may contribute to lowering the pH levels of the local surface-water bodies (e.g., McCabe Lake). In addition, one of the effects of acid rock drainage is the production of H_2S gas, which is commonly dissolved in groundwater. Not only will the water have a distinctive odour and taste, it can cause corrosion of plumbing metals such as iron, steel, copper and brass, all of which are common in water-using appliances. Hydrogen sulphide can also interfere with the effectiveness of water softeners and filter systems and has the potential to require more costly and difficult treatment processes in order to make the water potable. This is not an issue with the urban development in HRM, but the Indigo Shores housing development is in an area outside of municipal services, so all the residential houses have on-site drilled wells and septic systems.

Local Bedrock Geology

The bedrock geology in HRM consists of the Cambrian to Ordovician metasandstone-dominated Goldenville Group and the overlying slate-dominated Halifax Group, both intruded by granitic plutons of the South Mountain Batholith (White et al., 2008; Horne et al., 2009a, b; White 2010). In the McCabe Lake area, the Goldenville Group is divided into the older Taylors Head and younger Beaverbank formations (Fig. 1). The Taylors Head Formation consists of grey, thickly bedded and weakly cleaved metasandstone interbedded with metasiltstone, and rare black to rusty-brown slate. The conformably overlying Beaverbank Formation consists of grey to black, cleaved Mn-rich metasiltstone and slate. The younger Halifax Group is divided into the older Cunard and younger Glen Brook formations (Fig. 1; Horne et al., 2009a, b; White 2010). The Cunard Formation consists of black to rusty-brown graphitic slate and metasiltstone interbedded with thick, cross-laminated,

[1]Environmental Engineering Technology, Nova Scotia Community College, Dartmouth, Nova Scotia B2W 2R7

Hirtle, C. J. and White, C. E. 2017: *in* Geoscience and Mines Branch, Report of Activities 2016-17; Nova Scotia Department of Natural Resources, Report ME 2017-001, p. 85-88.

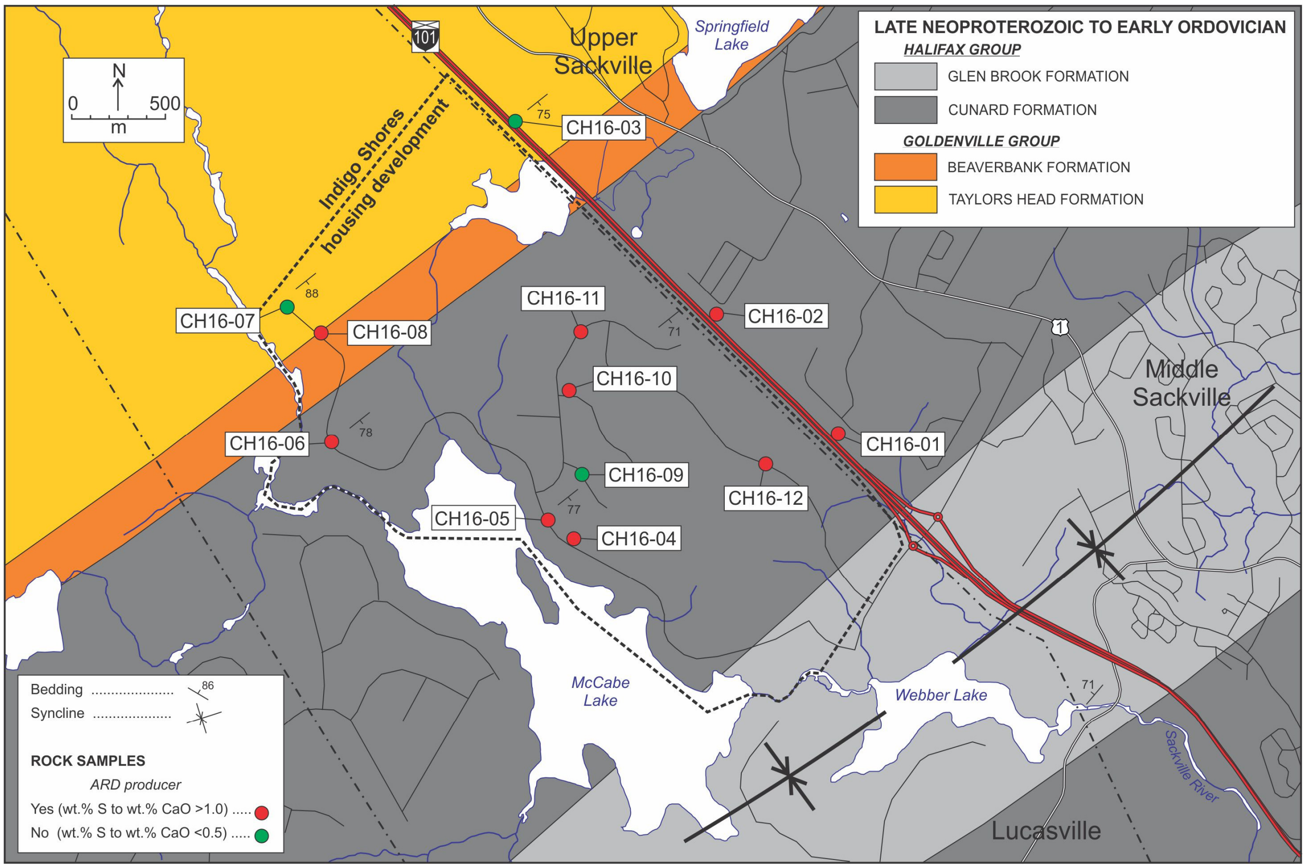

Figure 1. Simplified geological map of the Indigo Shores housing development area (modified after Horne et al., 2009a, b).

fine-grained metasandstone. Typically this formation contains abundant pyrite and pyrrhotite and lesser amounts of arsenopyrite (White and Goodwin, 2011; White et al., 2014b). The overlying Glen Brook Formation consists of green-grey laminated metasiltstone and minor slate and metasandstone. About 95% of the current housing development is located on the Cunard Formation of the Halifax Group (Fig. 1).

Methods

On April 7, 2016, bedrock samples and structural and magnetic data were collected from twelve sites in the study area (Fig. 1). Nine samples are from the Cunard Formation, two from the Taylors Head Formation, and one from the Beaverbank Formation. Additionally, the pH of water (ditch or stream) at each site was measured in situ using a handheld pH meter (Hach HQ11D Portable pH Meter), and additional water samples were collected using 1 L polyethylene water bottles for later pH analysis. The bedrock samples were slabbed and multiple spots on each slab were analyzed and averaged for total sulphur, calcium and a suite of other elements using the NSDNR portable X-5000 X-ray fluorescence (pXRF) machine manufactured by Innov-X.

To test their acid-producing potential, half of each rock sample was crushed and pulverized, and 50 g of this powder were added to 100 mL of de-ionized distilled water. In addition, 25 g of powder from each of the four most sulphur-rich samples, based on the pXRF analyses, were added to 100 mL of distilled water together with 25 g of calcium carbonate (powdered limestone). The water-rock mixtures were then left for two days, and on April 27, 2016, the pH was again measured using the handheld pH meter. The mixtures were then left for another four days and on May 1, 2016, the pH values were again measured.

Results and Discussion

White and Goodwin (2011) showed that total sulphur (wt.%) versus CaO (wt.%) can be used as a first approximation to determine if a rock is acid producing. When the ratio is greater than 1:1, the rocks can be classified as 'acid producers,' whereas below a ratio of 1:2, the rocks are assumed to be 'acid consumers.' When the acid to base ratio falls between 1:1 and 1:2, it is uncertain if the rock is an acid producer or not.

Based on the above criteria, most of the samples from the study area are acid producers (Fig. 1). The S/CaO ratios average around 1.5 in the Beaverbank Formation but range from 3 to 7500 in sulphide-rich slates of the Cunard Formation. One grey slate sample from the Cunard Formation (CH-16-09) had relatively high sulphur, but it did not produce acid because it also had high CaO content, likely due to the presence of carbonate cement, which resulted in a S/CaO ratio of 0.22. Similarly, the other two non-acid producing rocks — metasandstone from the Taylors Head Formation — also have low ratios due to both lower sulphur and the presence of abundant carbonate cement.

The water pH measurements made in the field on April 7, 2016; measurements made later in the laboratory yielded values of 6.80 to 7.00. Based on previous studies (e.g. White et al., 2014a; Farmer and White, 2015; Tarr and White, 2016), these values were considered too high for the sampled rock-types, likely due to dilution from the previous two days of rain and melting snow. To correct for this discrepancy, we monitored the pH values over time from the mixtures of powdered rock samples and distilled water (starting pH of ~7). The results show that after two days, most of the samples from the Cunard Formation had pH values of 3.60 to 4.91, and after an additional 4 days the pH values for the same samples further decreased to 3.18 to 4.27 (Fig. 2). In the four high-sulphur samples to which powdered limestone ($CaCO_3$) had been added, the pH values were consistently above 7 (Fig. 2). Although these experiments are not highly controlled, they indicate how rapidly ARD can affect water pH. They also show that limestone can buffer the pH of acid-producing rocks, at least in the short term.

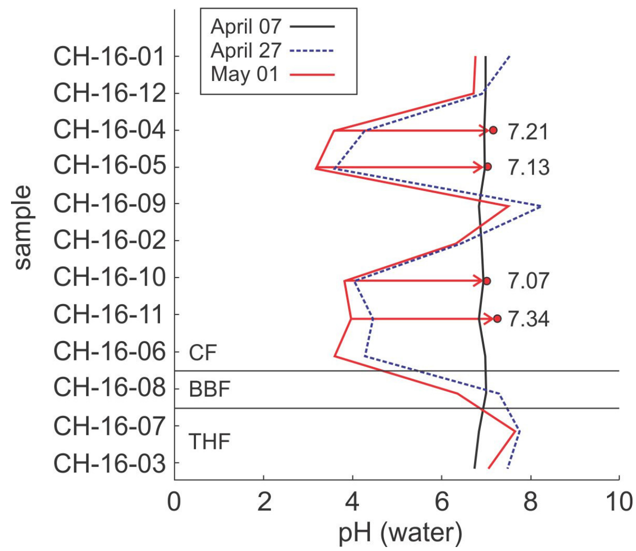

Figure 2. Plot of stratigraphy versus pH water data. April 07 are data collected in the field. April 27 and May 01 are data collected from laboratory experiment. Arrows indicate the duplicate limestone-laced samples and numbers are pH values. Abbreviations: THF = Taylors Head Formation, BBF = Beaverbank Formation, CF = Cunard Formation.

Conclusions

Slate and metasandstone in the Cunard and Beaverbank formations show the greatest acid-producing potential in the Indigo Shores housing development. As shown elsewhere in the Cunard Formation (e.g. White et al., 2014a; Farmer and White, 2015; Tarr and White, 2016), the presence of abundant sulphide-bearing minerals, such as pyrite and pyrrhotite, coupled with lack of Ca to neutralize the acid is a major problem in the Cunard Formation. In contrast, the relative high Ca and low S contents in metasandstone of the Taylor Head Formation shows that this unit has little risk of producing acid. Based on the pH water-monitoring experiment, the values obtained also reflect these acid- and non-acid-producing conditions.

Ideally, to avoid potential ARD issues, development projects should avoid areas underlain by the Cunard Formation, but this is not a viable solution in HRM. One relatively economical solution would be adding crushed limestone to ditches in the housing project to buffer the pH of the water. However, the pH would have to be monitored on a regular basis because limestone rapidly becomes coated with iron, calcium sulphate and biological growth, which can inhibit interaction with acid-rich water.

Acknowledgments

Thanks are extended to the teachers of the Environmental Engineering Technology-Water Resources Program at the Nova Scotia Community College for providing C. Hirtle with the background knowledge, resources and encouragement required to undertake this project. Special thanks to T. Lenfesty and J. Brenton for their continued help in the departmental library. Comments on an earlier version of the report by S. Barr led to substantial improvements.

References

Farmer, B. and White, C. E., 2015. Acid rock drainage (ARD) in the Lucasville area, Halifax Regional Municipality, Nova Scotia; *in* Geoscience and Mines Branch, Report of Activities 2014, (ed.) E.W. MacDonald and D.R. MacDonald; Nova Scotia Department of Natural Resources, Report ME 2015-001, p. 11–25.

Fox, D., Robinson, C., and Zentilli, M., 1997. Pyrrhotite and associated sulphides and their relationship to acid rock drainage in the Halifax Formation; Atlantic Geology, v. 33, p. 87–103.

Horne, R. J., Ryan, R. J., Corey, M. C., and Fox, D. L., 2009a. Bedrock geology map of the Waverley area, part of NTS Sheet 11D/13 (sheet 1 of 4), Halifax County, Nova Scotia; Nova Scotia Department of Natural Resources, Open File Map ME 2009-2, scale 1:25 000.

Horne, R. J., Ryan, R. J., Corey, M. C., and Fox, D. L., 2009b. Bedrock geology map of the Pockwock Lake area, part of NTS sheet 11D/13 (sheet 2 of 4), Halifax and Hants counties, Nova Scotia; Nova Scotia Department of Natural Resources, Open File Map ME 2009-3, scale 1:25 000.

Tarr, C. and White, C. E., 2016. Acid rock drainage in the Chain Lakes Watershed, Halifax Regional Municipality, Nova Scotia; *in* Geoscience and Mines Branch, Report of Activities 2015, (ed.) E.W. MacDonald and D.R. MacDonald; Nova Scotia Department of Natural Resources, Report ME 2016-001, p. 109–119.

Trudell, L. L. and White, C. E., 2013a. Acid rock drainage in southwest Nova Scotia; Nova Scotia Department of Natural Resources, Information Circular ME 067, 2 p.

Trudell, L. L. and White, C. E., 2013b. Overview map showing locations of bedrock acid rock drainage potential maps for the southwestern area of Nova Scotia; Nova Scotia Department of Natural Resources, Minerals Resource Branch, Open File Map ME 2013-2, scale 1:250 000.

White, C. E., 2010. Stratigraphy of the Lower Paleozoic Goldenville and Halifax groups in the western part of southern Nova Scotia; Atlantic Geology, v. 46, p. 136–154.

White, C. E., Bell, J. A., McLeish, D. F., MacDonald, M. A., Goodwin, T. A., and MacNeil, J. D., 2008. Geology of the Halifax Regional Municipality, central Nova Scotia; *in* Mineral Resources Branch, Report of Activities 2007, (ed.) D. R. MacDonald; Nova Scotia Department of Natural Resources, Report ME 2008-1, p. 125–139.

White, C. E. and Goodwin, T. A., 2011. Lithogeochemistry, petrology, and the acid-generation potential of the Goldenville and Halifax groups and associated granitoids rocks in the metropolitan Halifax Regional Municipality, Nova Scotia, Canada; Atlantic Geology, v. 47, p. 158–184.

White, C. E., MacDonald, M. A., and Horne, R. J., 2014a. Bedrock geology map of the Halifax area, NTS 11D/12, Halifax County, Nova Scotia; Nova Scotia Department of Natural Resources, Minerals Resource Branch, Open File Map ME 2014-10, scale 1:50 000.

White, C. E., Trudell, L., and Vander Toorn, R., 2014b. An update on the acid-generating potential of rocks in southwestern Nova Scotia with emphasis on the metropolitan Halifax Regional Municipality; *in* Mineral Resources Branch, Report of Activities 2013, (ed.) D. R. MacDonald and E. W. MacDonald; Nova Scotia Department of Natural Resources, Report ME 2014-001, p. 67–80.