The use of radon and complementary hydrochemistry tracers for the identification of groundwater – surface water interaction in New Zealand

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Heather Martindale

A thesis presented in partial fulfilment of the requirements for the degree of

Master of Environmental Management

At
the Institute of Agriculture and Environment

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

Palmerston North, New Zealand

Heather Martindale

2015

Abstract

Understanding how surface waters and groundwaters interact is an integral component of managing the influence of nutrient inputs to water quality. Knowledge of the potential nutrient loads from discharging groundwater is essential for meeting the bottom line nutrient concentrations in surface waters. Radon-222 is an emerging tracer for measuring groundwater-surface water interaction which has been underexploited in New Zealand. The aim of this research was to establish the potential of using radon for measuring groundwater and river water interaction in the New Zealand environment.

Low and high resolution radon surveys were carried out in two gravel-bed rivers, the Hutt and Mangatainoka Rivers, in lower North Island of New Zealand. To provide accurate measurements of radon concentrations in surface waters containing very little radon, the development of a cost and time effective, simple and reproducible high sensitivity radon measurement method was investigated. Furthermore, the study aimed to assess the potential of using radon measurements in combination with concurrent stream flow gauging and other hydrochemistry data for providing more detailed information on groundwater and river water interaction processes.

Radon measurements were found very helpful to identify groundwater discharge and recharge locations in both the Hutt and Mangatainoka Rivers. Furthermore, a high sensitivity radon analysis method was developed with a lower limit of detection of 0.006 BqL^{-1}, a vast improvement on the direct count method, and offering practical advancements over previously published methods. This high sensitivity method was used to establish radon concentration thresholds to identify locations of groundwater discharge, potential groundwater recharge and hyporheic exchange in NZ gravel-bed rivers.

In both studied rivers the groundwater discharge and potential recharge patterns identified by radon were not always matched by the concurrent flow gauging surveys, highlighting the ambiguity surrounding the use of concurrent flow gauging in gravel-bed rivers for mapping river gains and losses. In some sections of the studied rivers the concurrent flow gauging data indicated areas of groundwater recharge or discharge where the radon data showed the opposite process to be occurring. This has led to the conclusion that underflow beneath the gravels and other parafluvial exchange processes can cause the interpretation of concurrent flow gauging results to be misleading. Flow gauging combined with radon sampling gives a more conclusive picture of the groundwater and river water interaction processes in the gravel-bed rivers.

Acknowledgements

I would like to express my thanks to my supervisor, colleague and manager, Dr. Uwe Morgenstern for having faith in, and providing me with, the opportunity to undertake my Masters study while working full time. Dr. Morgenstern not only introduced me to the topic for my thesis, but also proactively found funding to support my study. His knowledge and guidance have been invaluable and I am grateful.

I also wish to express my sincere gratitude to my supervisor Dr. Ranvir Singh. His experience, guidance and feedback have been essential for the completion of this thesis.

Thank you also to Dr. Bob Stewart for your guidance during this thesis. Your practical advice in managing workflow, workload and field work planning around health and safety issues is greatly appreciated.

I would also like to thank my fellow work colleagues, Kurt McBeth, Vanessa Trompetter and Rob van der Raaij, in the Water Dating Lab at GNS Science. Thank you for providing moral support throughout this process, for carrying the extra work load when I was on leave and to Rob, for answering all of my questions about working with dissolved gasses.

I would like to thank Abby Matthews and Horizons Regional Council for providing the funding for this study. Thank you also to the Horizons field team, particularly Darren Bentley-Hewitt, for familiarising me with the local area and providing invaluable local knowledge.

For his (hopefully) superb editing skills, I would like to thank my Father. I will be forever grateful for both his and my Mother’s support, encouragement and advice throughout all of my studies.

Lastly, I would like to thank Mitchell Davis for his unrelenting support and encouragement. Unwittingly, Mitchell also found himself partaking in a Masters, spending many of his weekends trudging through rivers, providing expert kayaking support and being a sounding board for all of my ideas. Thank you.

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$$C = C_{0s} \frac{n_g - n_b}{n_s - n_b} \frac{1}{Z} \ell^{-\lambda t_0}$$ EQUATION 1 33

$$\frac{\sigma(C)}{C} = \sqrt{\left[\frac{\sigma(n)}{n}\right]^2 + \left[\frac{\sigma(n_s)}{n_s}\right]^2 + \left[\frac{\sigma(Z)}{Z}\right]^2 + \left[\frac{\sigma(P)}{P}\right]^2}$$ EQUATION 2 33

$$\sigma(n) = \sqrt{\frac{n + n_b}{t_s} + \frac{n_b}{t_b}}$$ EQUATION 3 33

$$Z = \frac{n_{enr}}{n_{dir}}$$ EQUATION 4 34

$$Z = \frac{n_{enr}}{n_{dir}} = \frac{V_s}{10mL} \times \eta_{TTE}$$ EQUATION 5 34

$$\eta_{TTE} = \eta_{TSW} \times \eta_{TEC}$$ EQUATION 6 35

$$\eta_{TEC} = \frac{V_{(Scint)}}{V_{Tot(Scint)}}$$ EQUATION 7 35

$$\eta_{QC} = \frac{cpm}{dpm}$$ EQUATION 8 35

$$F_c = \frac{K}{\left[K + (V_s / V_c) + (V_v / V_c)H\right]}$$ EQUATION 9 45

$$F_v = \frac{H}{\left[H + (V_s / V_v) + (V_c / V_v)K\right]}$$ EQUATION 10 45

$$P = \left(\frac{\sigma_{Scint}}{Mean_{Scint}} + \frac{\sigma_{Water}}{Mean_{Water}}\right) \times 100$$ EQUATION 11 52