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Source control of manganese (Mn) in a drinking-water supply reservoir: the importance of including geology in watershed management

Dr Lee D. Bryant1,2, Mahan Amani3, Niamh Brockbahnk1, Jack Waterhouse1, Robert Luckwell2, Matt Postlethwaite1, Dr Neil Macdonald2, Dr Thomas R. Kjeldsen1
1 Department of Architecture & Civil Engineering, University of Bath, Bath, UK, 2 Bristol Water, Bristol, UK, 3 University of Liverpool, Liverpool, UK; *contact: l.bryant@bath.ac.uk

1. Introduction
- Manganese (Mn) is a common and abundant trace metal in rocks and sediment which is currently costing drinking-water utilities (e.g., in the US and UK) millions of USD/year due to customer complaints, aesthetic issues regarding taste, colour and odour, and distribution problems related to Mn-driven pipe blockages.1
- Removal of Mn for meeting the US and UK drinking-water limit (50 μg/L) is feasible but often difficult and costly due to conventional water treatment processes.2
- Water utilities are actively using in-reservoir, engineered aeration and watershed-focused management in attempt to improve water quality and reduce treatment costs resulting from sub-optimal conditions and subsequent release of soluble chemicals (e.g., Mn) from lake and reservoir sediment.3
- Despite these efforts, significant Mn-related water supply issues often persist which may be attributed to the predominant agricultural (i.e., nutrient) focus of watershed management strategies paired with the complexity of Mn biogeochemical cycling.

2. Research objectives
This research focuses on investigating the role geology plays in reservoir water quality and watershed management via mapping of the sources and biogeochemical pathways controlling concentrations of Mn within a reservoir watershed. Specifically, the roles of 1) watershed geology, anthropogenic activity and resultant Mn-laden sediment transport and 2) aeration-induced variations in reservoir water quality are assessed.

3. Study site and methods
The project study site is Blagdon Lake, an aerated drinking-water supply reservoir managed by Bristol Water, located in the southwest region of the United Kingdom (Figure 1). The reservoir has a maximum depth of 11 m and volume of 8.5 x 10^6 m^3. Blagdon Lake is used as a ‘natural laboratory’ in which oxygen and mixing can be manipulated (via aeration) and correlated to shifts in water-column and sediment Mn concentrations.

Field campaigns in summers 2017 thru 2019 focused on characterising oxygen and Mn dynamics within Blagdon Lake and the surrounding watershed, including a local historic Mn mining site dating back to the early 1900s, on seasonal and catchment-wide scales to establish a reservoir-focused mass balance of oxygen and Mn (aerated) monitoring included water-column and sediment core sampling for oxygen and Mn (total and soluble) concentrations and YSI-Xylem EXO3 multi-probe water column profiling along a reservoir transect.

Blagdon Lake is equipped with a destratifying bubble-plume aeration system consisting of seven bubble plumes deployed on the bottom sediment. Bubble-plume placement is intended to optimise mixing of reservoir water closest to the dam outtake (Figure 3). Destratifying (i.e., fully mixing) aeration systems are used by almost all UK drinking-water utilities to combat Mn and algal problems in their supply reservoirs (Figure 4). Conversely, stratification-preserving (i.e., hypolimnetic) aeration/oxygenation systems are commonly used by US utilities.

4. Results & Discussion
Watershed mass balance results (Figure 5) show that local geology and sediment transport within the watershed control reservoir Mn concentrations, with Blagdon Lake behaving largely as a Mn sink. This is particularly critical in the deeper reservoir region near the dam and treatment-plant outtake where bubble-plume aerators are creating high levels of sediment resuspension, as indicated by reduced oxygen near the sediment and in regions of the bubble plumes (Figure 6). A direct correlation between the start of Blagdon aeration in the mid 1990s, increased water-column Mn (Figure 7a) and increased Mn concentrations in reservoir sediment is observed, highlighting that aeration is having an influence on sediment retention of influent catchment Mn (Figure 7b).

5. Conclusions
- Initial results show that local geology and sediment transport within the watershed control Mn concentrations in Blagdon Lake, which behaves as a Mn sink. These results are highly relevant for the optimisation of reservoir aeration, comprehensive watershed management and sustainable drinking-water supplies.
- Work is ongoing to develop future management strategies that minimise detrimental impacts of naturally occurring biogeochemical processes as well as optimising technical solutions, such as engineered aeration, to ultimately better protect our drinking water supplies more sustainably.

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Literature cited:
3) European Communities (Drinking Water) Regulations (2007).