PERFORMANCE ASSESSMENT OF STORMINATOR™ BARREL: A DISSOLVED METAL TREATMENT SYSTEM

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ABSTRACT

Dissolved metals from roof runoff are increasingly recognized as a key source of ecotoxic metals into our urban waterways (Chakravarthy et al., 2019; Charters et al., 2016; Müller et al., 2019). Previous studies of untreated roof runoff quality indicate typical zinc concentrations from zinc-based roofs of >1,000 µg/L (and up to 56,000 ug/L) and copper concentrations from copper roofs of >1,000 µg/L (and up to 9,000 ug/L), with 80-100% in dissolved form (Charters et al., 2021). Stormwater, including roof runoff, is often untreated prior to discharge in the receiving waterway, and where it is treated, the treatment system typically targets sediment and associated particulate metal removal, with dissolved metals passing through largely unmodified (Clark & Pitt, 2012; Kaya et al., 2022).

The Storminator™ downpipe treatment technology has been developed at the University of Canterbury, and units trialled to date have successfully removed dissolved copper and zinc from roof runoff. A larger configuration – the Storminator™ Barrel – has recently been developed that gives opportunity for servicing large, poor condition industrial roofs. However, real-world performance data was needed to characterize: a) the system's metal removal performance on different roof types, b) how performance changes both over time and under varying influent concentrations, and c) compare treated effluent quality between established and newly installed systems.

Six Storminator™ Barrels were installed on metal roof downpipes at the University of Canterbury: three on an old copper roof, two on a newly painted galvanised roof and one on an old Zincalume® roof (Table 1). Barrels 1-3, on the copper roof, were installed nine months before Barrels 4-6 were installed on the zinc-based roofs. The Storminator™ Barrel units are connected to a downpipe, diverting runoff through the treatment unit, where the runoff passes under gravity flow through treatment media before discharging into the stormwater network. The systems incorporate waste mussel shells to provide effective dissolved metal removal within a small footprint and simple-to-maintain unit.

Table 1. Individual barrel, roof and treatment media details for sampled units.

Unit	Roof type	Roof age and condition	Serviced roof area (m^2)
Barrel 1	Copper	59, heavily patinated	30
Barrel 2	Copper	59, heavily patinated	30
Barrel 3	Copper	59, heavily patinated	68
Barrel 4	Painted galvanised	Repainted 3 years ago	49
Barrel 5	Painted galvanised	Repainted 3 years ago	49
Barrel 6	Zincalume® [1]	23 years, poor condition	85

[1] Zincalume® coated steel: alloy coating of 43.5% zinc, 55% aluminium and 1.5% silicon over steel base.

Untreated (inflow) and treated (outflow) roof runoff samples were collected for 17 rain events between April 2023 and January 2024, using 1 L HDPE containers. First flush (FF) samples (defined as the first 1L of runoff) and second stage (SS) samples (defined as runoff taken at least 1 hour after start of rain event) were collected where possible for the same event to identify any intra-event variation in influent quality and system performance. A wide range of rainfall characteristics was able to be sampled across the sampled events. The length of antecedent dry period ranged from 0.6-17.2 days and average intensity ranged from 0.2-6.4 mm/hr.

Samples were analysed for dissolved copper, dissolved zinc, turbidity, alkalinity and pH, via acid preservation total metals digestion and inductively coupled plasma mass spectrometry (ICPMS) analysis, following Methods 3030B and 3125B (American Public Health Association, 2005). Turbidity was measured using a HACH 2100P Turbidimeter. Alkalinity was measured by titration with 0.1M hydrochloric acid (HCl), to pH 4.5. pH was measured using an EDT Microprocessor RE357Tx. Method blanks were taken for each dissolved metals sample set, with duplicates and triplicates added for every 10 and 20 samples, respectively. Triplicates readings were taken and averaged for the turbidimeter.

Results to date show that Barrels 1-3, on the copper roof, removed 88% of the influent dissolved copper on average (range of 67-99%) (Figure 1). The influent concentration averaged 2,811 µg/L (range of 876-9,225 µg/L) (Figure 2). The resultant effluent concentration averaged 209 ug/L (24-1,475 µg/L). While further reduction in this concentration will occur when mixing and diluting in the receiving environment, the effluent is still substantially above the local water quality limit of 1.8 µg/L (Environment Canterbury, 2023). Alternative roofing materials should therefore be encouraged or regulated for by local Councils and building authorities to avoid the generation of ecotoxic copper from new roofs. For existing copper roofs, extended and multi-stage treatment approaches should be investigated to provide enhanced copper removal.

Barrels 4-6 removed 96% of the influent dissolved zinc on average (range of 89-99%) from the zinc-based roofs. Even with the high zinc concentrations generated by the poor condition Zincalume® roof (average of 1,302 µg/L dissolved zinc; range of 330-2,716 µg/L), removal rates remained high and the effluent concentrations from Barrels 1-3 averaged 31 µg/L (range of 4-75 µg/L). It is therefore likely that the mixed instream limit of 15 µg/L for zinc (Environment Canterbury, 2023) will be met in the receiving waterways with this treatment system in place.

Higher removal rates were consistently observed to correlate with higher influent dissolved metals concentrations, corroborating the general observation from literature that higher removal efficiency can be achieved with higher strength pollutants due to the increased opportunity for pollutant contact with the treatment media (Clark & Pitt, 2012). However, even at lower influent concentrations, the percent removal performance was high: minimum of 67% for copper from copper roofs and 89% for zinc from zinc-based roofs. Overall, the consistently high percent removal indicates that the systems' performance is relatively independent of the influent concentrations observed to date and therefore the condition of the roof. Furthermore, the system is likely to be effective at a range of storm event sizes, due to this independence of performance from any influent variability caused by dilution effects in a high intensity or long duration storm.

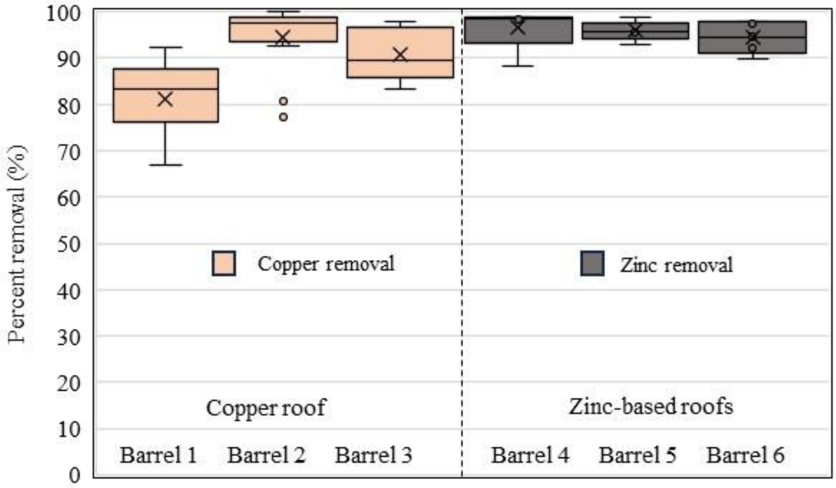

Figure 1. Percent removal for dissolved copper from copper roofs and dissolved zinc from zinc-based roofs, across all sampled events. Note, zinc from the copper roofs and copper from zinc-based roofs not shown as they were measured at much lower concentrations and are not the pollutant of concern from these roofs.

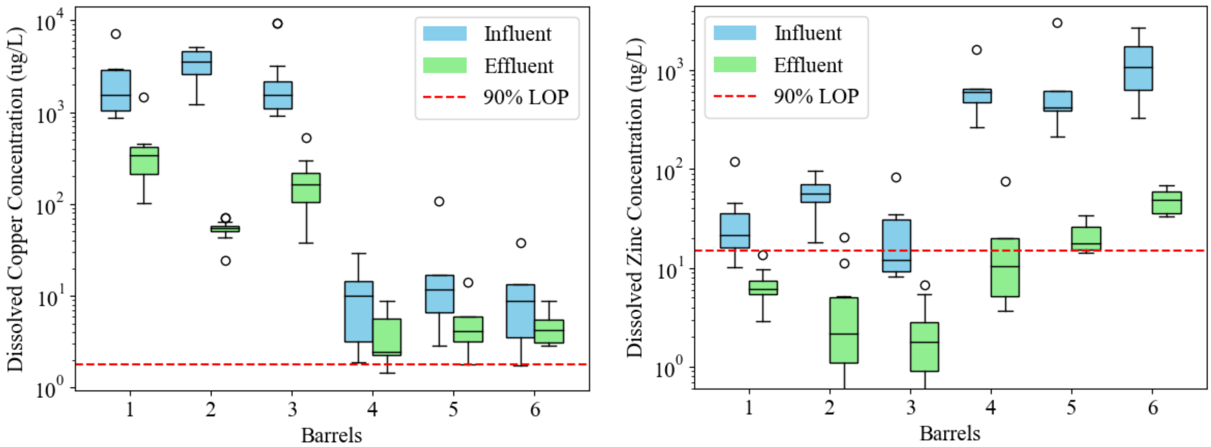

Figure 2. Influent and effluent concentrations for dissolved copper and zinc across all sampled events, compared to local receiving waterways instream guideline values for 90% Level of Protection (LOP) of aquatic ecosystems.

With Barrels 1-3 installed nine months earlier than Barrels 4-6, the alkalinity and turbidity was compared between the established and newly installed Barrels to characterize changes in alkalinity and turbidity over time as the system is flushed by multiple rain events. Alkalinity was elevated in newly installed Barrels 4-6, indicating flushing of fine particles was occurring from the new media, however, this reduced to the same alkalinity found in established Barrels 1-3 (45 mg/L as $CaCO_3$) after five rain events. Similarly, turbidity was elevated in Barrels 4-6 from a peak of 115 NTU before reducing to <20 NTU within the first five events, confirming the Barrels flush quickly and return turbidity to close to influent levels. The established barrels were found to reduce turbidity from influent levels, with very low turbidity (<1.5NTU) produced for all sampled events.

In conclusion, the Storminator™ Barrel system consistently removes >89 % of zinc from zinc-based roofs up to 3,000 µg/L influent dissolved zinc and >67% of copper from copper roofs for influent concentrations of up to 9,000 µg/L dissolved copper. Zinc removal rates were consistently very high, with minimal variation despite variation in rain event characteristics. The Zn effluent concentrations are near or below the mixed instream guideline concentrations for the receiving waterway, demonstrating the effectiveness of the treatment system as a stormwater management measure for catchment protection. There was more variability in copper removal rates across the sampled rain events (67-99% compared to 89-99% for zinc). While substantial dissolved copper reductions were achieved, the resultant effluent from the treated copper roofs with dissolved copper concentrations still exceeded the mixed instream water quality limit by a factor of >100. This highlights the scale of the ecotoxicity issues of copper roof runoff in our urban areas and the need for targeted dissolved metal treatment systems on roofs, combined with building materials regulation.

Sampling and performance analysis continues on all six systems to further characterise the system's performance under a wider range of rainfall conditions. This data will also inform media life expectancy as indicated by how removal rates reduce over time. Hydraulic analysis of maximum flow capacity (before bypass) is also ongoing to better characterise the expected treatability performance for various rainfall zones.

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KEYWORDS

Zinc, copper, waste resources, mussel shells, polluted roof runoff