

DEVELOPMENT AND TESTING OF FILTER MEDIA FOR REMOVAL OF DISSOLVED METALS

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ABSTRACT (200 WORDS MAXIMUM)

Stormwater is a complex mixture of dissolved, colloidal and particulate species. When developing and testing filter media to treat dissolved metals we must bear in mind the role of colloid and particulate retained in the filter. These latter species have the capacity to bind dissolved metal ions in much the same way as the filter media itself. It is for this reason that performance testing must ultimately involve full scale field trials with real runoff. Conversely, it is the variable nature of runoff that makes media development particularly difficult. Laboratory simulations allow accurate benchmarking under well controlled, reproducible conditions. An outline of Stormwater360's current development and testing programme is presented, along with performance comparisons for dissolved metals removal by various media.

KEYWORDS

filtration media dissolved metals zeolite slag

PRESENTER PROFILE

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1 INTRODUCTION

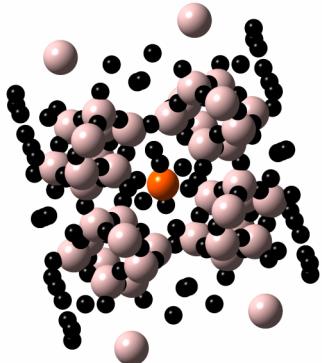
Runoff from roads and urban pavement carries contains environmentally significant loadings of zinc, copper, lead, cadmium, and other heavy metals. These metals may exist as dissolved species, or bound to particulate within the runoff. Generally, dissolved metals are found to be more bioavailable, and therefore pose more of a toxicity risk to aquatic life in receiving waters. Copper and zinc are generally of most concern in stormwater, since they are common, and have a significant dissolved fraction.

The speciation of metals in stormwater run-off is complex. They may exist as dissolved species, but often sorb to particulate and colloidal components of the run-off. The partitioning between these species is a consequence of multiple factors and is potentially very dynamic. Whilst the demonstration of any stormwater best management practice (BMP) must necessarily involve field testing, it is a time-consuming and expensive practice. Laboratory testing is viewed as an accessory to field testing. By isolating specific variables it provides the opportunity to investigate simpler systems. The results of laboratory testing, however, may not be directly extrapolated to BMP performance in the field.

Removal of a dissolved metal ion from solution requires either that the ion be 'precipitated' from solution, 'adsorbed' to the surface of a solid substrate, or that it 'exchanges' with another ion from an ion-exchange medium. Currently, the most practicable, and well researched filtration medium in this regard is zeolite. Zeolites are a 2008 Stormwater Conference

family of aluminosilicate minerals. They possess a crystalline structure which may be described as a lattice of cavities or cages, and are typically found with sodium, potassium or other (non-heavy) metal ions bound within the cages. Figure 1 shows the crystal structure of the naturally occurring zeolite, clinoptilolite. The orange sphere represents the metal ion bound within the aluminosilicate cage. It is free to exchange with a metal ion in solution, and this is the mechanism by which zeolites may remove dissolved heavy metals from solution.

Figure 1 Crystal structure of exchanged clinoptilolite, a naturally occurring zeolite.



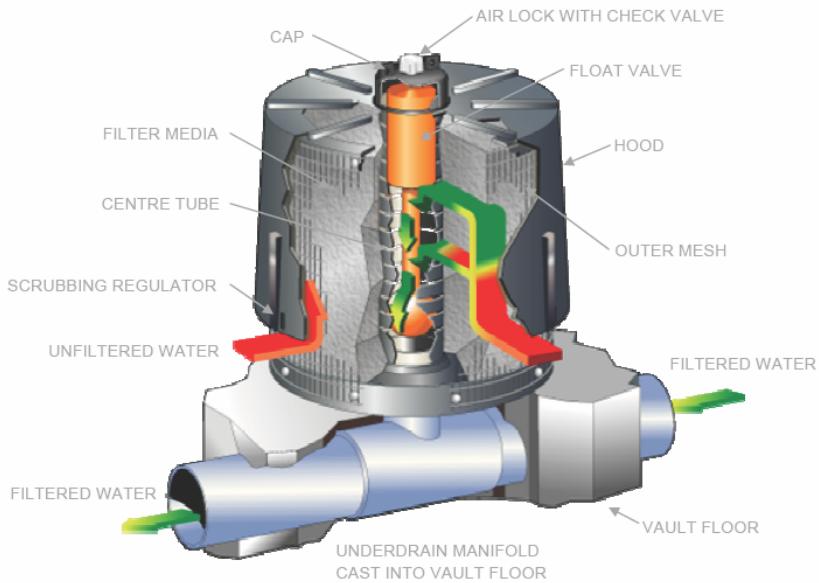
Iron and steel making slags have also shown some potential to remove dissolved heavy metals. These byproducts of the iron and steel making industry are mixtures of metal oxides. They typically have a high surface area, and the surface is capable of adsorbing dissolved metal ions from solution. We have performed initial investigations using melter slag and electric arc furnace slag from the Glenbrook Steel Mill. The former is an iron-making slag, the latter a steel-making slag.

An important step in using materials such as zeolites or iron and steel slags in working filtration devices is establishing how their performance changes as a function of flow rate through the filtration device. In other words we are not concerned with the filtration media's ultimate capacity for heavy metal ions, but instead the removal efficiency that can be expected, given a particular contact time. The concept of contact time incorporates both the surface area presented to the solution and the time the surface and solution spend in close association. Given sufficient contact time we could essentially achieve total removal.

2 MEDIA TESTING

2.1 LABORATORY SETUP AND PROCEDURES

Figure 2 Schematic of the StormFilter



The Stormwater Management StormFilter® (StormFilter), as shown in Figure 2, is a siphon-actuated filtration unit with the capacity to treat a full range of pollutants in urban runoff, including total suspended solids (TSS), soluble heavy metals, oil and grease, and total nutrients. Various filter media may be used to target these pollutants, including perlite for TSS, oil and grease; granulated carbon for organic compounds; and zeolites for soluble heavy metals. Flow through the filtration unit is controlled by a flow-restrictor disc at the filter outlet.

In order to develop media for use in the Stormwater Management StormFilter® (StormFilter) we utilize 1/24th scale versions of the full size device. These horizontal flow columns (HFCs) are capable of being operated at a controlled flow rate, as are the full size StormFilters. They filter radially, from the outside to the inside of the device, as do the full-size units, and have the same bed-depth and geometry as the StormFilter.

Figure 3 Horizontal Flow Column test units

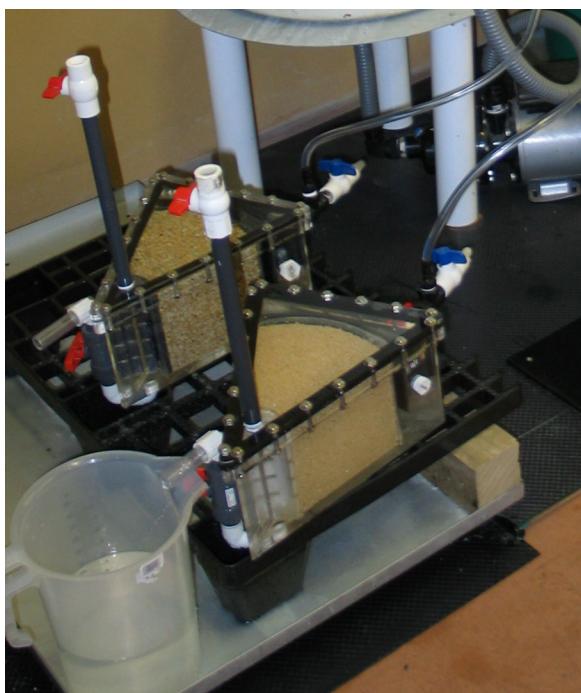


Figure 4 HFC test apparatus



The experimental set-up is shown in Figure 4. Up to 150 L of test solution is prepared in a large polyethylene reservoir. It drains from a centrally located exit in the base of the reservoir to a pump. This pump is a screw design in order to retain the suspension of any sediment. It pumps at 25 L min^{-1} , thus pumping the entire volume of the reservoir every 6 minutes. The test solution is pumped to a 3-way splitter valve. Initially, the splitter valve is set to direct all of the pumped flow back into the reservoir, effectively mixing the solution. Once thorough mixing has been achieved, the splitter valve is set to direct a portion of the flow (typically between 25% and 50% of total) to the constant head reservoir. With provision of adequate flow, this reservoir remains full to the level of the downward sloping pipe which returns excess solution to the main reservoir. As such a constant head of 1 m is maintained that drives the test solution through each

HFC. Up to 3 HFCs may be used at any one time, permitting a parallel testing arrangement. The blue-handled valves in the photo permit influent samples to be taken prior to the test solution passing through each HFC. Test solution that enters the HFC passes through the media from the broad end to the narrow end of the wedge. Here it exits the HFC via a flow-control valve. Effluent samples are taken at this point.

Flow through the HFC is calibrated via a 5 L graduated measuring cylinder and a stopwatch. Flow through the cartridge is controlled, up to a maximum of 2.5 L min^{-1} ; being the equivalent of the maximum of 60 L min^{-1} of a full scale StormFilter filtration unit. 25 L of solution were passed through each HFC at the appropriate flow rate before influent and effluent samples were collected. This is approximately 12 times the fluid volume within a packed HFC; sufficient to effectively flush the device of prior, retained solution.

3 COMPARISON OF NEW ZEALAND ZEOLITE WITH MELTER SLAG AND ELECTRIC ARC FURNACE SLAG FOR REMOVING DISSOLVED ZINC AND COPPER

Figure 5 displays the treatment efficiencies for removal of dissolved copper and zinc as a function of flow rate. A treatment efficiency of 100% corresponds to total removal from solutions.

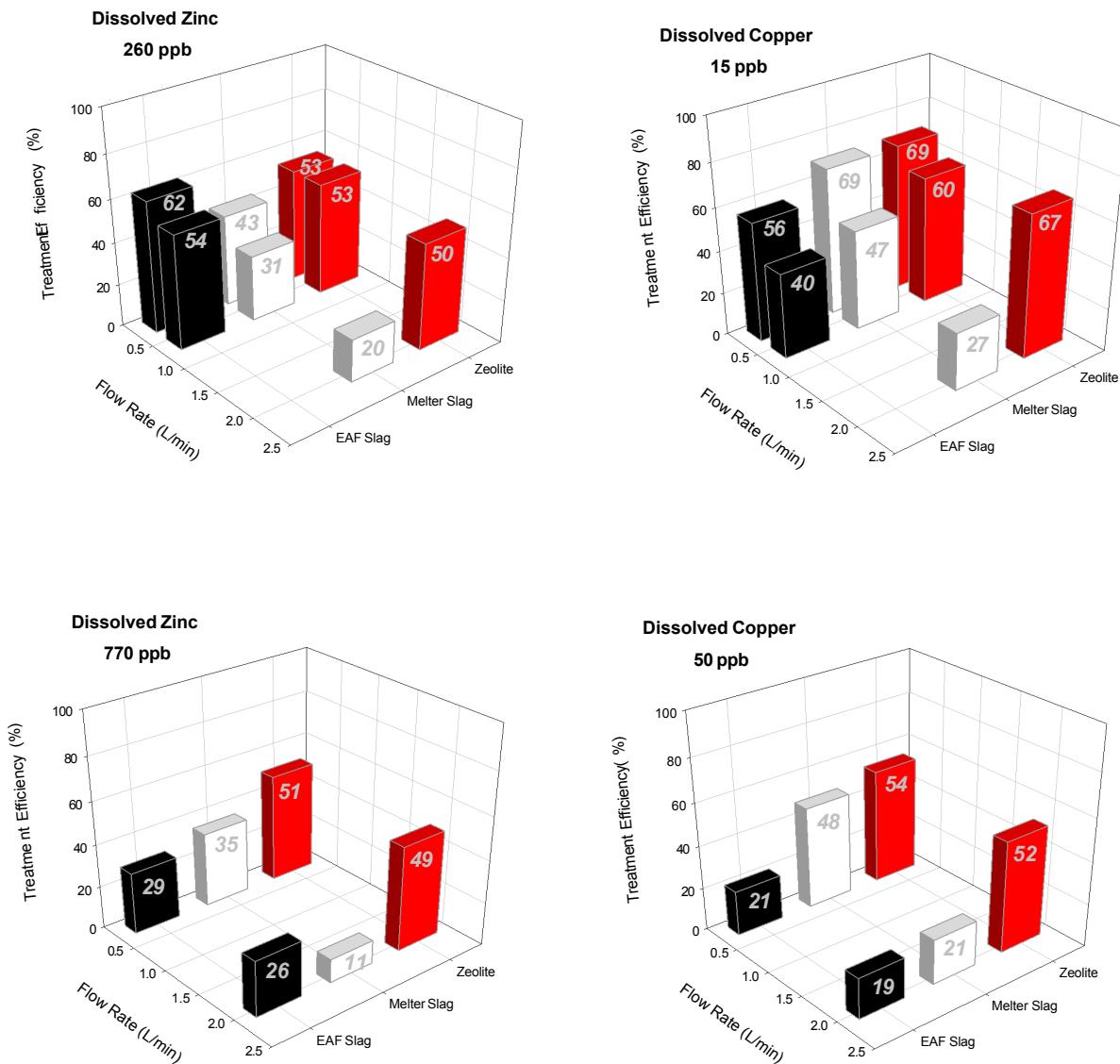
Dissolved concentrations of 260 ppb zinc and 15 ppb copper represent levels of these contaminants that might be considered at the high end of the normal range. Concentrations of 770 ppb zinc and 50 ppb copper represent very high, acutely toxic concentrations.

Flow rates of 2, 0.6 and 0.2 L min^{-1} were used. These correspond to 48, 14 and 5 L min^{-1} flowing through full scale StormFilters.

It can be seen that at low flow rates all media give very similar performance. With 260 ppb zinc and 15 ppb copper solutions, treatment efficiencies for zeolite and both slags are all in the range 43 to 69%. As the flow rates are increased the treatment efficiencies for zeolite change very little, whereas those of melter slag and electric arc furnace slag are significantly reduced.

When we move to more concentrated solutions of zinc (770 ppb) and copper (50 ppb) we see once again that the zeolites give a very consistent treatment efficiency, whereas the performance of both slags has been diminished.

Figure 5 Treatment Efficiencies for Dissolved Zinc and Copper Removal



4 CONCLUSIONS

New Zealand zeolites perform very well across a range of concentrations and flow rates for the removal of dissolved copper and zinc. When used with similar media particle sizes NZ iron and steelmaking slags give comparable results to zeolite at low flow rates. However in highly elevated metals concentrations and at high flow rates the New Zealand zeolite's performance is currently superior.

Present investigations are focused on improving the performance of both slags by utilizing a finer media, and thus increasing their contact time. In particular, if their treatment efficiency can be improved at higher flow rates they become good candidates to replace zeolites, the most currently used technology.

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