Javid, L., Bremner, C., McNally, S., Lewis, G. D., and Padhye, L.P., 2019. Role of bioremediation in nutrient removal from runoffs for light-weight media. In: *Nutrient loss mitigations for compliance in agriculture*. (Eds L.D. Currie and C.L. Christensen). http://flrc.massey.ac.nz/publications.html. Occasional Report No. 32. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand. 5 pages.

ROLE OF BIOREMEDIATION IN NUTRIENT REMOVAL FROM RUNOFFS FOR LIGHT-WEIGHT MEDIA

Lamis Javid[a], Courtenay Bremner[c], Stephen McNally[c], Gillian D. Lewis[b] and Lokesh P. Padhye [a]

[a]Department of Civil and Environmental Engineering, The University of Auckland, Auckland
[b]School of Biological Sciences, The University of Auckland, Auckland
[c]WSP-OPUS, Level 9 Majestic Centre, 100 Willis Street, Wellington 6011
Email: l.padhye@auckland.ac.nz

Abstract

The increase in agricultural runoff has led to leaching of inorganic nitrogen and the runoff of phosphorus contaminants that are often carried downstream resulting in damaged ecological habitats and poor water quality. Our study focuses on understanding the role of microbial activity for bioremediation of runoff contaminants within novel light-weight media. The media can be installed in patches, trenches, or in standalone units to intercept surface or near surface runoff. Work to date shows high but variable microbial activity between media of different compositions. Media compositions also affected water flow and retention time. The media dominated by compost yielded lower flow rates (and higher water holding capacity) while other non-soil media components experimented with showed higher flowrate and better microbial activity. The removal efficiency of Total Dissolved Solids (TDS) ranged from 50 to 70% while for nitrate it was up to 65%. The ongoing work will evaluate optimal conditions to promote the growth of specific biodegrading populations in light-weight media.

Keywords: light-weight media, bioremediation, nutrients, solids, agriculture.

Introduction

Rapid urbanisation has led to extensive land use changes and an increase in impervious surfaces. It has a direct impact on the water resources causing degradation of the water quality and water flow into the streams. It also has a severe effect on the stream biodiversity and ecosystem.

Most of the non-urban land surface is pervious, but because of the high proportion of land use for agriculture, a large amount of water and nutrients drain from these areas. Fertilisers are used in these areas to sustain their crops, fields and animals. The use of fertilisers has led to a global decrease in food shortage by an increase in food production by up to 50% (Qiao et al., 2015). A large amount of fertilisers, pesticides and animal waste applied to the land has resulted in a decline in the quality of the runoff and having a direct impact on the natural ecosystem. The effect on the natural ecosystem is associated with an increased level of nutrients, suspended solids and pesticides. (Jordan et al., 2003).

The presence of an excess amount of nutrients in the runoff leads to eutrophication and algal blooms which is one of the top quality concerns for the water bodies. The algae that float on the surface of the water inhibit the growth of the plants growing in the bed of the streams by blocking the sunlight. This growth also leads to a decrease in dissolved oxygen level which is needed by other organisms present in the water body (Smith, 2009).

The pesticides often pose a problem for the natural environment by affecting the non-target species of organisms. The high concentration pesticides present in the runoff enter the water bodies and kill the microorganisms that are essential for the stream ecosystem (Dellamatrice, 2014). Finally, the suspended solids that get carried to the stream ecosystem eventually leave the suspension solution and get deposited on the streambed habitats. These solids block the sunlight from the plants growing in the stream beds or fill in the existing rock formation of the fish habitats. These deposited sediments with time can also cause elevation of these water bodies causing issues of flooding (Walker et al., 2006).

There has also been an expansion of industrial agriculture which has led to excessive manure creation. The excess manure is not used and is accumulated on the farms which can run into the streams due to lack of proper storage. The lagoons that are used for deposition of manure are also susceptible to overflows and breaks (Lory, 2008). Excessive amounts of the primary nutrients and other pollutants that are discharged into water systems have globally degraded the water environment (Kronvang et al. 2009; Elser 2012). This degradation is attributed to nutrient surpluses, especially contributed from agricultural activities (Grizzetti et al. 2012; Withers et al. 2014). The management of nutrient emissions from agriculture is essential for reducing the impact of eutrophication on water bodies.

Considerable emphasis has been placed on the development of technologies and practices to mitigate nutrients from runoff. However, with continued urbanisation, population growth, limited and costly land, combined with flood control concerns there is a need for the development of a system to provide greener infrastructure with minimal land use. Low impact designs (LID) are developing increasing interest across the world. The most common LIDs in New Zealand are rain gardens, ponds, wetlands, and green roofs (Auckland Council, 2013). The light-weight media proposed in this study can be used to mitigate the nutrients, solids and other pollutants present in the runoff from different sources with minimal land use. This study emphasis on bioremediation of the nutrients and other pollutants present in the runoff using the novel light-weight media.

Bioremediation

Bioremediation is the use of micro-organisms like bacteria to remediate the pollutants (King et al., 1997). The hazardous pollutants that have been studied include pesticides, organochlorides, synthetic dyes, polychlorinated biphenyls, polycyclic aromatic hydrocarbons, synthetic polymers, etc. Bioremediation with a blend of microbes can be used to remove contaminants from any contaminated sites (Alvarez et al., 2005). Their ability to adapt to extreme condition makes microbes favourable to be used to remediate or degrade environmental hazards.

In this study, the microbial community across different light-weight media will be studied. The microbial communities present will be evaluated for their ability to degrade the pollutants present in the runoff.

Experimental Study

Media preparation

Three different media were prepared with combining compost, coconut coir, vermiculite, zeolite, Activated carbon, Perlite. The compost alone was used as the control for the experiments.

Preparation of synthetic runoff

The synthetic runoff was made using Milli-Q water with the amendments listed by Davis et al., 2006. $NaNO_3$ as nitrate, NH_2CH_2COOH as organic N, Na_2HPO_4 as phosphorus, and $CaCl_2$ as dissolved solids were added to the stock solution and then stirred on the magnetic stirrer until the clear solution was obtained.

Experimental Set up

Three different types of media and compost control were subjected to synthetic runoff for nine weeks. All the experiments were conducted in triplicates. The dosing of this runoff was done thrice weekly. Effluent (runoff) and media samples were collected weekly for analysis. The effluent samples were analysed for nutrients and hydrocarbon removal.

Nutrient Analysis

The effluent samples were filtered using CA Membrane Filters. The filtered effluent samples were analysed for nitrate, phosphate and chloride ions using Ion-Chromatography (Thermo Fisher Scientific).

Hydrocarbon Analysis

Effluent samples were analysed for hydrocarbon removal using USEPA Method 8310(Wise et al.,2015)**.** This method involves the extraction of hydrocarbon using solid phase extraction and further analysis using Gas-Chromatography/Mass Spectrometry (Shimadzu).

Microbial Analysis

Preparation of media suspensions

Dry soil (1 g) was stirred for 60 min with 50 ml of sterile distilled. Serial dilutions of the supernatant were prepared after the suspension had been allowed to stand for 30 min.

Inoculation and incubation

Samples of the proper dilution (0.1ml) were spread over the surface of solidified agar plates with a sterile glass rod. These plates were then incubated at 25º C for seven days.

Results

Nitrate Removal

The three different were able to remove nitrate up to 65% across a time interval of 9 weeks. These media performed better than Compost control.

Solids Removal (Total dissolved solids)

The three different media performed better than compost in solid removal for a time interval of 9 weeks. The removal efficiency ranged from 50 to 70%.

Microbial Analysis

The results show high but variable microbial activity between media of different compositions.

Media Type	Microbial population (CFU/g ± SD)
Compost	**44.00E + 06 (6.00E+06)**
Media 1	**52.00E + 06 (8.00E+06)**
Media 2	**38.00E + 06 (3.00E+06)**
Media 3	**39.00E + 06 (6.00E+06)**

Table 1: Microbial population in CFU/g

Conclusions

In the present study, preliminary results suggest that all three media can support the growth of the microbial community that can help in nutrient and hydrocarbon degradation. The media sample (soil) analysis for contaminants and microbial community will further, confirm the results obtained to date.

Acknowledgements

Funding for this research is provided from Callaghan Innovations, New Zealand, WSP-OPUS International Consultants Limited (NZ) under R&D Student Fellowship Grant.

References

Alvarez, P. J., & Illman, W. A. (2005). *Bioremediation and natural attenuation: process fundamentals and mathematical models* (Vol. 27). John Wiley & Sons.

Auckland Council. (2013). Living roof review and design recommendations for stormwater management. Auckland Council Technical Report TR 2013/045.

Davis, A. P., Shokouhian, M., Sharma, H., & Minami, C. (2006). Water quality improvement through bioretention media: Nitrogen and phosphorus removal. *Water Environment Research*, *78*(3), 284-293.

Dellamatrice, P., & Monteiro, R. (2014). Main Aspects of pollution in the Brazilian rivers by pesticides. *Journal of Agricultural and Environmental Engineering, 18(12), 1296-1301. Retrieved April 2, 2015.*

Elser, J. J. (2012). Phosphorus: a limiting nutrient for humanity?. *Current opinion in biotechnology, 23(6), 833-838.*

Grizzetti, B., Bouraoui, F., & Aloe, A. (2012). Changes of nitrogen and phosphorus loads to E uropean seas. *Global Change Biology*, *18*(2), 769-782.

Jordan, T. E., D. F. Whigham, K. H. Hofmockel, and M. A. Pittek. 2003. Nutrient and sediment removal by a restored wetland receiving agricultural runoff. *Journal of Environmental Quality 32:1534-1547.*

King, R. B., Sheldon, J. K., & Long, G. M. (1997). *Practical environmental bioremediation: the field guide*. CRC Press.

Kronvang, B., Behrendt, H., Andersen, H. E., Arheimer, B., Barr, A., Borgvang, S. A., & Schwaiger, E. (2009). Ensemble modelling of nutrient loads and nutrient load partitioning in 17 European catchments. *Journal of Environmental Monitoring*, *11*(3), 572-583.

Lory, J. A. (2008). *8. Using Manure as a Fertilizer for Crop Production.*

Qiao, C., Liu, L., Hu, S., Compton, J. E., Greaver, T. L., & Li, Q. (2015). How inhibiting nitrification affects nitrogen cycle and reduces environmental impacts of anthropogenic nitrogen input. *Global change biology, 21(3), 1249-1257.*

Smith, V., & Schindler, D. (2009). Eutrophication science: Where do we go from here? *Elsevier Current Trends, 24(4), 201-207.*

Walker, D., Baumgartner, D., Gerba, C., & Fitzsimmons, K. (2006). *Chapter 18: Surface Water Pollution. In Environmental and Pollution Science (2nd ed.). Oxford: Elsevier.*

Wise, S. A., Sander, L. C., & Schantz, M. M. (2015). Analytical methods for determination of polycyclic aromatic hydrocarbons (PAHs)—a historical perspective on the 16 US EPA priority pollutant PAHs. *Polycyclic Aromatic Compounds, 35(2-4), 187-247.*

Withers, P., Neal, C., Jarvie, H., & Doody, D. (2014). Agriculture and eutrophication: where do we go from here?. *Sustainability*, *6*(9), 5853-5875.