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Dear Martin

RETENTION PROPERTIES OF SIRG FOR PHOSPHATE IN STORMWATER

I refer to your brief in regard to your requirement for me to conduct laboratory and scientific validation of Eclipse Soils' new SIRG product, in my capacity as an independent expert geochemist with extensive research and technical publications experience.

I can confirm that I have now completed this work and set out the findings in summary here.

I also refer you to the attached full scientific report which I have produced, whilst setting out this correspondence to summarize the findings in simplified, less technical but nevertheless concise terms.

1 BACKGROUND

Eclipse Soils have developed a new product marketed as Phosphorus Retentive Filter Media containing "SIRG" (super iron rich grit) which when placed as a basal layer in urban stormwater infiltration basins will remove phosphorus by its adsorption from the infiltrating stormwater onto the SIRG mineral matrix.

In this way, stormwater exiting the infiltration basin can be treated so that the receiving groundwater and surface water environments are protected from the detrimental effects of excessive phosphorus loadings.

The export in urban stormwater of phosphorus from urban areas has been shown as a major contributor to the poor water quality conditions which are commonly experienced in estuaries, rivers and wetlands on the Swan Coastal Plain, because the natural sands upon which development has occurred are very poor at retaining applied phosphorus.

Initial hydrogeochemical modelling by Eclipse indicated that a 300 mm layer placed as the basal layer of an infiltration basin constructed so as to fully infiltrate the volume of stormwater generated by a typical urban catchment by the 1:1 year average recurrence interval storm event would remove phosphorus from the stormwater for a period of 100 years..

The hydrological design criterion selected here comprises the core performance requirement for compliance with the Department of Water's Better Urban Water Management policy platform.

The phosphorus removal lifetime objective represents the maximum time horizon for planning, identified in the Western Australian Planning Commission's State Planning Strategy document.

Eclipse Soils' fundamental requirement of this independent scientific review is to validate that SIRG material can perform to these specifications.

2 PHOSPHATE

- Phosphorus is strongly adsorbed to Fe- and Al- oxides in soils as H2PO4-. Adsorption is strongest in the pH range of 4-7 and decreases above and below this range.

- Travel times of phosphate are determined by the ratio between quantities of adsorbed and dissolved phosphate (=distribution coefficient) and are difficult to derive mathematically because of non-linearity in the distribution and a slow and ongoing reaction with soil materials.

- Travel times can be estimated with an empirical equation derived from column leaching experiments and incorporating distribution coefficient, non-linearity, reaction rate, layer depth and infiltration rate.

- Distribution coefficient and PRI are simply related.

3 METHODOLOGY

3.1 Existing PRI Data

- Previous results of PRI measurements of a range of blends of SIRG with infiltration carrier medium are summarized.

- PRIs were converted to dissolved (C_m) and adsorbed (C_s) concentrations with a simple equation (see Equation 8 in the full report)

- Results were compared with concentrations obtained from batch adsorption measurements of phosphate in a 10% blend of SIRG with sand after 1, 7 and 28 days following a procedure described in full in the attached detailed report.

3.2 Time Dependent Batch Adsorption of Phosphate

- A laboratory procedure was used to obtain data for distribution of phosphate in SIRG over a period of one month within a range of solution concentrations relevant to urban stormwater. The equilibrating solution was tap water instead of a solution with a major ion composition and pH of stormwater.

- Resulting data were considered appropriate and relevant for further processing into adsorption isotherms and for estimating adsorption and reaction parameters in the time dependent equation for adsorption of phosphate to SIRG (see Equation 5 in the full report).

4 DATA ANALYSIS

- PRI data obtained after equilibrating for 18 h (Appendix A) and time-dependent adsorption data after 24 h were processed and plotted as adsorption isotherms.

- There was relatively large scatter of data which can possibly be explained by the variability of pH and an apparent trend of increasing pH with time. Variability in the composition of SIRG blends with infiltration carrier mudium and presence of fine suspended particulate matter from SIRG in sampled solutions could also be contributing factors.

- The data showed a clear trend of increasing adsorption of phosphate with time. Data also suggest an almost linear relationship between C_s and C_m up to solution concentrations of about 1 mg P/L, above which PRI data suggest a strong increase in convexity of the isotherm.

- Concentrations of dissolved (C_m) and adsorbed (C_s) phosphate calculated from batch adsorption data after 1, 7 and 28 days were plotted logarithmically.

- Logarithmic representation and linear regression allows C_s and C_m to be fitted to a time dependent adsorption equation (Equation 5 in full report). The time dependent reaction parameter in this equation is calculated to be not significantly different from 0.5, which is typical of diffusion of a solute into a porous medium.

5 ESTIMATION OF TRAVEL TIMES

Travel times were defined as the time for the phosphate concentration at a particular depth in soil to increase by 1% of the input concentration, From previous work (referenced in full report) with column leaching experiments at different rates of flow it was found that travel times, defined in this way, could be fitted to an empirical equation (Equation 7 in full report). This equation allows travel times of phosphate to be estimated from flow rate of water and from C_s, C_m and reaction parameters for phosphate in SIRG.

It is important to note that after an increase at depth in the phosphate concentration by 1% of the input concentration in a leach-drain, it will take as long again for the concentration at that depth to approach the input concentration in stormwater.

It is also important to realize that, though practically useful, the empirical equation used to calculate travel times should not be relied on to predict breakthrough times far beyond the time scale within which the reaction parameters for phosphate in SIRG are obtained. In practice, however, in view of the very slow advection of phosphate in soils, there is no alternative and the empirically calculated travel times should be considered a best first estimate.

Breakthrough times for phosphorus applied at concentrations of between 0.1 mg/L and 0.6 mg/L and applied at hydraulic loading rate of 25 m/yr were calculated as travel times with the empirically derived equation for different depths of layers of blends of infiltration carrier medium with SIRG.

Solution concentrations were based on recent Department of Water publications and represent typical average and upper levels for phosphorus in Perth stormwater.

The hydraulic loading rate was calculated by Eclipse Soils as a representation of the normalized annual hydraulic loading for an infiltration basin sized to infiltrate the 1: 1 yr (1 hr) ARI stormwater flow from a typical urban catchment engineered to meet the hydraulic performance criteria set down in the Department of Water's Better Urban Water Management platform.

The results, which are explained in a detailed set of tables and graphs in the full report, show that:

- SIRG has an extremely high phosphorus retention capacity,

- Breakthrough times for phosphorus (to reach at the exit point of the basin the arbitrary figure of 1% of the input concentration) exceed the Eclipse target lifetime of 100 years by a very significant length of time for layers of 300 mm of blends of 10% SIRG with infiltration carrier medium.

- Exceedance of the lifetime target in the way the data demonstrate assists in reaching a high level of confidence that the limitations to the veracity of the data deriving from factors including the term of lifetime estimate compared to the soil/solution contact times used in the laboratory measurements, and the mathematical and time dependent issues in determining travel times of phosphorus in porous adsorptive media should not diminish the expectation that the material will perform as proposed by Eclipse Soils.

6 CONCLUSIONS AND DISCUSSION

Breakthrough times for phosphorus to reach the (arbitrary) figure 1% of the input concentration at the point of exit from the basin exceed the Eclipse target lifetime of 100 years by a very significant length of time.

This means that it is reasonable to promote the SIRG product on the basis that if installed using the formulation used by Eclipse soils and tested by this independent validation work, and subjected to hydraulic and phosphorus loadings used in the validation calculations, then 100 years of phosphorus removal lifetime can be expected with good confidence.

It is important to note that these lifetime predictions are not only based on hydrogeochemical analysis, but are dependent upon practical factors including:

- Installation of SIRG, such that correct depths and aerial distributions within stormwater infiltration basins are assured.

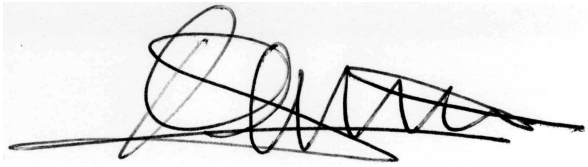
- Stormwater infiltration basins are correctly designed so that scour and erosion cannot redistribute the SIRG layer in the basins.

- Accuracy and precision of the present set of data used to calculate lifetimes much greater than the timespans over which the data were obtained could be improved to further increase the level of certainty in the findings of this work. Factors identified as needing further attention in this respect are duration of batch adsorption measurements, effects of flow rate on hydrodynamic dispersion and of properties of SIRG affecting hydrodynamic dispersion, sampling precision and solution chemistry.

7 CONCLUDING REMARKS

I trust this summary report is sufficient for your purposes and that the information provided in my detailed full report is of assistance to you.

Yours sincerely,



DR ROBERT GERRITSE

Attachment: Full Report: Retention properties of SIRG for phosphate in stormwater