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Author:	WRc		

Pre-Trial Audit of the Planetary and South West Water Ocean Alkalinity Enhancement Pilot - Summary

1. Introduction

1.1 Background

Planetary and South West Water plan to introduce magnesium hydroxide into the final effluent pipe at Hayle Wastewater Treatment Works (WwTW) during a 90-day trial that primarily aims to study the safety and efficacy of OAE (Ocean Alkalinity Enhancement) with the possibility of sequestering carbon in a deployment that could come in the future. The Environment Agency (EA) has a responsibility to ensure that the planned trial will have no adverse environmental impacts and that robust controls are in place before and during the trial, giving confidence to all stakeholders.

1.2 Scope and objectives

The Water Research Centre (WRc) has been commissioned by the EA to undertake a desk-based pre-trial audit. This will assess information provided by Planetary and South West Water with the aim of ensuring that the EA's requirements for the trial are met. The pre-trial audit will review Planetary's plans to minimise and monitor environmental impact, review the carbon sequestration calculations, and aim to ensure that potential impacts at the WwTW are adequately considered.

2. Audit findings

2.1 Magnesium hydroxide audit

The magnesium hydroxide audit looked at two areas, the manufacturing quality and the social responsibility of the sourcing.

Regarding manufacturing quality, there is no traceability of the material from the mine and along its transport, milling and storage journey. There is also no confirmation of exactly at what stage the samples were tested as other contaminates may have been introduced at the milling stage if there was no quality control. It is recommended that the brucite currently in Southampton is tested again (using the same parameters as completed previously) in the UK by a laboratory accredited to ISO 17025:2017 with samples taken randomly (i.e. not from the top of the storage sacks).

Regarding social responsibility, while sourcing from China may not always carry high risks, due to the health and safety risks associated with mining, and the lack of available data on company governance, sourcing from China is not recommended without ‘on the ground’ due diligence. Other risks, such as environmental, are also present in the region, with little evidence to demonstrate the likelihood or severity of their presence within this supply chain. WRc would not recommend that Planetary use the same source of brucite in the future, unless comprehensive auditing was undertaken to better understand the level of risk, and check it is within a reasonable level.

2.2 WwTW permit and process audit

The addition of magnesium hydroxide at Hayle WwTW takes place after the final effluent system and therefore does not affect the performance of the treatment plant. The impact of the dosing near to the discharge point in the bay is not expected to increase the suspended solids (transparency of the treated sewage) by more than a few milligrams per litre. This is a small increase compared to the suspended solids concentration permitted in the final effluent.

The dissolution process (the interaction of seawater with dissolved magnesium hydroxide) is complex. The Planetary model includes the effects of pH but not of temperature. pH has a greater effect on the dissolution rate than temperature does, with dissolution decreasing as pH increases. The effect of ignoring the temperature effect reduces the dissolution rate at lower temperatures, which results in a lower pH because of the reduced concentrations of dissolved magnesium hydroxide. The lower pH then results in an increase in the dissolution rate. The effect of ignoring the temperature effect on dissolution rate is therefore unclear, because of the interaction with the pH effect, where low pH increases dissolution, low temperature reduced dissolution, and low dissolution results in lower pH values. It is therefore not clear if the impact of the dissolution rate is over-stated, and further studies to include temperature are recommended.

2.3 Magnesium hydroxide dispersion modelling audit

The marine dispersion models used for this investigation, Delft2D, and CORMIX, are appropriate and have been built following recognised and accepted methodologies and data. The hydrodynamic model (Delft2D) has not been calibrated against any field data, although some historic data (ADCP) have been used to compare and verify against the results. The model performs reasonably well against the ADCP data but tends to overpredict ebb flows.

CORMIX was used to determine how the discharge should be modelled in the hydrodynamic model. CORMIX is a relatively simple mixing model and its output is used to confirm the plume extent and mixing within a water column in the near and mid-field areas of the outfall. The CORMIX results confirmed that the discharge, with its tendency to rise to the surface and become almost fully mixed at the mid-field (~50 m from the outfall), could be represented adequately by assuming it would be fully mixed within one grid cell in the hydrodynamic model with its current grid resolution.

It is noted that the hydrodynamic model tends to overpredict the ebb flows, as shown when compared to those from the ADCP data, and this would over predict the effects of dispersion and mixing. This may have implications for the water quality and dispersion modelling, although the WRc modelling report suggests that this is not likely to be the case.

2.4 Environmental toxicology assessment

Planetary developed an Environmental Quality Standards (EQS) screening tool to compare metal concentrations at various dosing rates assuming average effluent flow rates and 100% dissolution of metals (which is highly unlikely and therefore overly conservative). The subsequent dilution of the effluent by the receiving ocean would significantly bring the individual concentrations of the metals below their respective EQS, even at times of lowest dilution by the ocean. Therefore, adverse effects on the marine organisms are not anticipated following exposure to the metals. This has been based on the results of the magnesium hydroxide sample analysis provided by Planetary which, as mentioned in Section 2.1, were not fully auditable.

Magnesium hydroxide (MH) is of low acute toxicity to aquatic organisms and of low chronic toxicity to microalgae. The concentration of magnesium hydroxide below which adverse effects on marine organisms will most likely not occur (predicted no effect concentration, PNEC) derived by Planetary or WRc is highly conservative due to the relatively high uncertainty factors used to ensure protection of aquatic life because of the limited data available on its toxicity. Therefore, the ratio of the predicted environmental concentrations (PEC) of MH and its PNEC suggests a potential risk to marine water. However, the physico-chemical properties of MH, its breakdown pathway and the fact that magnesium ions are ubiquitous in the natural environment, support that MH poses a low risk to the aquatic environment. Furthermore, this PNEC assessment is open for revision, since it is very likely that magnesium hydroxide actually poses a lower risk to marine organisms than the PNEC currently suggests. Taking all aspects into account (length of proposed trial, dosing concentrations, etc), it is likely that the risk to marine organisms from MH in this trial is very low. The availability of long-term data on fish, crustaceans and other marine species would lead to the use of a lower uncertainty factor in the PNEC calculation, and thus a higher PNEC and the resulting risk would be lower. Although, the generation of additional chronic toxicity data on fish, crustacean and at least two other marine species would refine the PNEC, it could be challenging to achieve due to the difficulties in maintaining a stable concentration in water for the entire length of the toxicity test required to generate chronic data.

2.5 Review of Carbon Sequestration Calculations

Carbon dioxide removal (CDR) efficiency is a measure of the actual amount of carbon stored long-term in comparison to the maximum amount possible for the mass of magnesium hydroxide added. Several processes can result in a CDR efficiency of less than 100%. For example, sinking of partially dissolved magnesium hydroxide or alkalinity enhanced water to the deep ocean before exchanging CO_2 with the air would reduce CDR efficiency. Increases in ocean alkalinity can encourage the chemical or biological formation of limestone (calcium carbonate), which could reduce or reverse the intended ocean uptake of carbon.

Planetary's magnesium hydroxide dispersal modelling shows dilution and dispersion result in near undetectable changes to seawater chemistry outside the 125m mixing zone surrounding the outfall. There is a *medium* risk of calcium carbonate formation within this zone.

The proposed monitoring has measures to assess calcium carbonate formation and provides adequate coverage within the mixing zone for tracking the impacts of the project and verifying the model results at weekly intervals. An additional sampling point beyond the 125m mixing zone is recommended to verify the predicted small changes to seawater chemistry.

Planetary have stated that the modelling reviewed was not intended to represent the proposed trial, and an improved model is currently under development. The model used to assess potential CDR efficiency contains satisfactory carbonate chemistry modelling but does not currently include the effects of biology on air- sea gas exchange, adding a small amount of uncertainty to the amount of carbon being drawn into the sea. The peak proposed dosing rates are 17x higher than the modelled dosing rates. The effects on water chemistry of the proposed dosing rate would be less than 17x the modelled effects, due to the solubility of the magnesium hydroxide. It is likely that the current model underestimates CDR efficiency (it predicts efficiency of 60% in winter and 26% in summer) due to alkalinity leaving the modelled area, overpredicted ebb flows (Section 2.3), and assumptions around dissolution rates.

A CDR efficiency of 73% or greater is required to produce a net carbon offset in this project. This threshold includes the carbon footprint of shipping the magnesium hydroxide from China, so net offset can be achieved at lower efficiencies if lower carbon sources of magnesium hydroxide are used (Section 2.1). There is potential for significant net carbon removal from scaling this approach, likely limited by the amount of magnesium hydroxide required.

Any enquiries relating to this report should be referred to the Author at the following address:

WRc
Water Research Centre Limited (**WRc**),
Frankland Road, Blagrove, Swindon,
Wiltshire, SN5 8YF

Telephone: + 44 (0) 1793 865000
Project Manager: WRc
Email: solutions@wrcgroup.com
Website: www.wrcgroup.com