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NITROUS OXIDE EMISSIONS FROM MARINE WASTEWATER DISPOSAL A LIFE CYCLE ASSESSMENT STUDY

INTRODUCTION AND RESEARCH SIGNIFICANCE:

Nitrous oxide (N_2O) is a significant greenhouse gas (GHG) that is increasingly contributing to atmospheric global warming and stratospheric ozone destruction. Anthropogenic nitrogen production, which started at the beginning of the twentieth century, has led to an acceleration of the global nitrogen cycle (Bange 2006). This has resulted in a 20% increase in the level of atmospheric nitrous oxide since the pre-industrial period and has consequently led to a sharp increase in the amount of nitrogen supplied to coastal and open-ocean environments (Galloway and Cowling 2002).

Wastewater treatment plants (WWTPs) generate nitrous oxide during conventional biological treatment processes, which is released into the atmosphere. The quantity of nitrous oxide produced when nitrogen-rich wastewater is discharged to coastal waters is a substantial knowledge gap today (Foley *et al.* 2010). Sydney discharges a significant volume (>1 GL) of nitrogen-rich primary-level effluent into the surrounding coastal waters each day (SWC 2010). The potential downstream nitrous oxide emissions associated with this practice represent an un-costed and potentially significant cost liability for the wastewater industry in terms of its indirect GHG emissions profile (Foley and Lant 2007).

This project compares two hypothetical upgrades (Scenarios 1 and 2) to secondary-level treatment with the current primary-level treatment (Scenario 0) using North Head WWTP as a case study. In order to assess the net environmental impact from a GHG emissions perspective, this project has applied the quantitative life cycle assessment (LCA) technique to model the proposed upgrades.

MAJOR FINDINGS AND OUTCOMES:

The results of the LCA highlight the significant role of energy consumption and N_2O emissions in the overall GHG profile of a WWTP. The production of energy and N_2O emissions contributed to >90% of the global warming potential (GWP), or carbon-footprint, in each modelled scenario. Figure 1 illustrates the contribution of these two categories to the total GWP for each scenario.

The data in Figure 1 shows that the GWP of Upgrade 1 (S1) and Upgrade 2 (S2) are some 7.8 and 12.1 times higher, respectively, than that of the base case (S0). It can also be seen that the production of energy is the greatest contributor to the GWP in the two hypothetical upgrade scenarios – it alone accounts for more than six times (S1=6.2, S2=9.4) the total GWP of the base case. N_2O emissions are shown to increase in the hypothetical upgrade scenarios (S1=1.3, S2=1.5). This is due to the N_2O emission factor for the treatment of wastewater being higher than the corresponding emission factor for ocean disposal.

Overall, the results of the GWP analysis show that the GHG emissions performance of North Head WWTP decreases as the level of wastewater treatment increases. In particular, it has been shown that the production of energy has the greatest impact on the GWP for the two hypothetical upgrade scenarios. Similarly, it has been shown that increasing the level of treatment also increases the N_2O emissions in the system due to higher rates of N_2O production during the modeled biological N removal processes. For this study, the energy requirements and N_2O emissions were based on values taken from the literature.

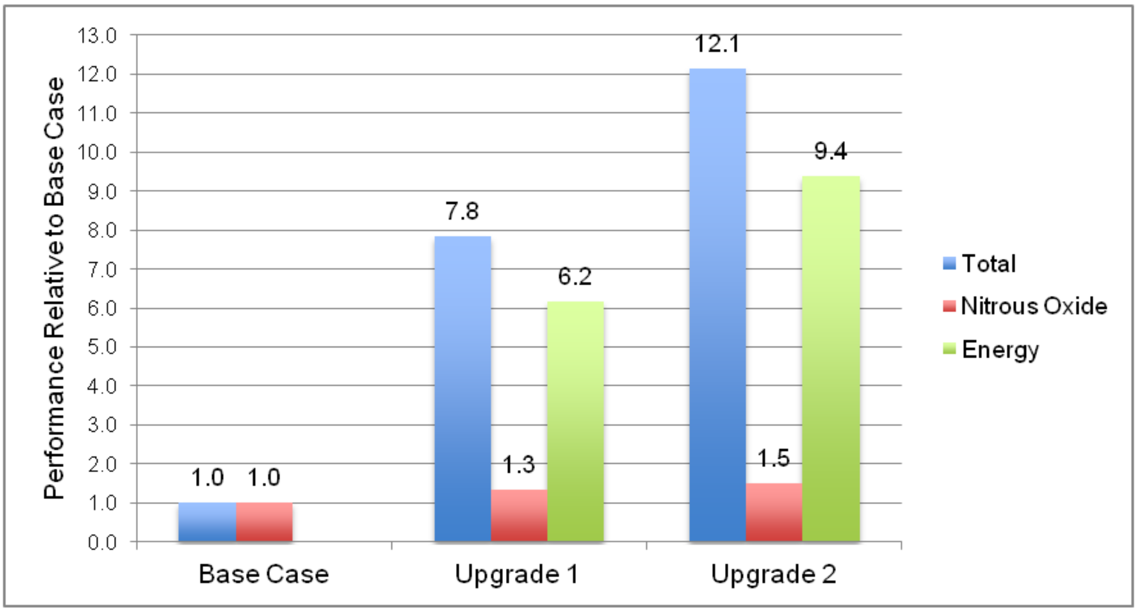

Figure 1 – Contribution to Global Warming Potential (GWP)

CONCLUSIONS:

As it stands, the environmental performance of North Head WWTP is connected to the production of energy in New South Wales, which is mainly from the burning of fossil fuels (Foley *et al.* 2010). The model investigated the impact of renewable energy resources, such as hydropower, on the GHG emissions profile of the WWTP and found that it significantly decreased the overall environmental impact of increased treatment. Of particular interest, the hydropower investigation showed that under those conditions, the most significant contributor to GWP was N_2O emissions. Under these circumstances it would be more advantageous for a WWTP to consider the environmental impacts associated with the release of N_2O from treatment and disposal.

Based on the results of this study, there is no clear best option for North Head WWTP. The level of N_2O emissions from the treatment and marine disposal of wastewater represented a significant area of uncertainty in the analysis. From a GHG emissions profile perspective, the additional treatment caused an increased environmental burden on the system. The ideal scenario would be for North Head WWTP to include secondary-level treatment that was powered by renewable energy resources. There are a number of factors, however, that represent a problem for Sydney Water to upgrade the facilities. Most notably of these is the additional land required for additional treatment processes, which is limited in suburban Sydney.

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FURTHER RESEARCH SUGGESTIONS:

Following the completion of the study, there are a number of areas that were identified as requiring further research:

- Marine N_2O emission factors
- Energy recovery options from fertiliser use and biogas capture
- Broader integration of renewable energy technologies in WWTP (i.e. hydropower, biogas recovery)
- Extraction and application of nutrients from municipal wastewater

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