Greenhouse gas emissions during biosolid production and stockpile management

dc.contributor.author	Majumder, Ramaprasad	
dc.date.accessioned	2014-08-24T23:47:18Z	
dc.date.available	2014-08-24T23:47:18Z	
dc.date.issued	2014	
dc.identifier.uri	http://hdl.handle.net/11343/41951	
dc.description	© 2014 Dr. Ramaprasad Majumder	
dc.description.abstract	Wastewater treatment plants generate the greenhouse gases methane (CH4), carbon dioxide (CO2), and nitrous oxide (N2O) during the treatment process of wastewater. Greenhouse gas (GHG) emissions from waste and wastewater treatment plants (WTPs) are often calculated based on simple emissions factors or mathematical models. The large uncertainties associated with GHG accounting in the wastewater industry are associated with methods of calculation and lack of measured data, or validation with, actual GHG flux. Direct measurements of GHG emissions from	en_US

wastewater treatment plants are rare and do not exist for some key process steps, such as sewage sludge drying or biosolid storage and management. The main aim of this thesis was to directly measure and assesses GHG emissions from sewage sludge drying, storage of biosolid stockpiles and alternative storage and management options such as shallow stockpiles planted with trees. The GHG emissions during sludge drying were measured in a semi-controlled, under cover drying experiment. Emissions of CH4, CO2 and N2O were measured from biosolid stockpiles of three different age classes using the manual chamber over 21-24 months at the Western Treatment Plant in Melbourne. The same approach was used to investigate GHG emissions from an unplanted shallow biosolid stockpile and a shallow biosolid stockpile planted with willow (Salix reichardtii) trees over a 14 months period. The sludge drying process produced mean cumulative emissions for CH4 of 297 kg CO2-e Mg-1 dry biosolids, for CO2 of 76 kg Mg-1 and for N2O of 10 kg CO2-e Mg-1, indicating that sludge drying is dominated by CH4 emissions, whilst CO2 and N2O emissions were smaller or negligible. The CH4 emissions during sludge drying were four times greater from anaerobic pot derived sludge than aerobic lagoon derived sludge, probably because the solid content was greater. First order decay model was applied to predict CH4 and CO2 emissions, and these estimates were between 1.35 and 2.28 fold greater than direct measured estimates of GHG emissions, depending upon the set ratio of CH4:CO2. The stirring of sludge during the air-drying process increased CO2 emissions and decreased CH4 emissions, as stirring enhanced aerobic conditions, which was likely to reduce methanogenesis and therefore reduce subsequent CH4 emissions. This study demonstrated that GHG emissions from sludge drying are significant, but there are limited management options to reduce the overall emissions. Biosolid stockpiles of different age classes were also a significant point source of GHG emissions. The youngest biosolid stockpile (<1 year old) had the greatest GHG emissions of 90.3 kg of CO2-e per Mg of biosolid per year. Stockpiles between 1 and 3 years old emitted less GHG (~60 kg CO2-e Mg-1 yr-1) and the oldest stockpiles emitted the least GHG (~28 kg CO2-e Mg-1 yr-1). Methane emissions were negligible in all biosolid stockpiles but the relative contribution of N2O and CO2 changed with stockpile age. The youngest stockpiles emitted two thirds of their GHG emissions as N2O, whereas CO2

emissions dominated GHG emissions from the oldest stockpile. This study did not detect any seasonal variability in GHG emissions and did not observe a correlation between GHG flux and environmental variables such as biosolid temperature, moisture content or nitrate and ammonium concentration. First order decay model estimates of CH4 emissions from these stockpiles were again higher as compared to the direct measured estimates but followed a similar trend with increasing age of stockpile. The results suggest that labile organic material in stockpiles is decomposed over time and that aerobic nitrogen transformation processes lead to significant N2O emissions. Carbon decomposition favors CO2 over CH4 production probably because of aerobic stockpile conditions or CH4 oxidation in the outer stockpile layers. Although GHG emissions decreased with stockpile age they still present a substantial GHG flux to the atmosphere and a detailed investigation if different management options could lead to a reduction of GHG emissions was therefore warranted. The GHG measurements from three different biosolid storage and management systems showed that all stockpiles were a large source of GHG emissions. The smallest emission was observed from the conventional large (130-150 m long, 50-60 m wide and 10-12 m high) stockpile (38 kg CO2-e Mg-1 dry biosolid), the greatest from the unplanted shallow (50 m long, 40 m wide and 0.5 m deep) stockpile (65 kg CO2-e Mg-1). The greater GHG emissions from the shallower stockpiles are likely due to the greater surface area to volume ratios, as shallower stockpiling will expose more biosolids to environmental conditions. GHG emissions were dominated by N2O and CO2 in all stockpile options, whilst CH4 emissions were negligible (< 2%) from the large stockpile and the shallow stockpiles were actually a CH4 sink. Biomass production by willow trees in the shallow stockpiles was substantial with 12 Mg of biomass per hectare per year (equivalent to 4.4 kg CO2-e Mg-1 biosolid yr-1) but this only offset 8% of the GHG emissions from the shallow planted stockpile. These data highlight that biosolid stockpiles are significant point sources for GHG emissions and that alternate management options such as shallow application or plant biomass production in stockpiles will likely lead to increases in GHG emissions rather than reductions. Finally, the GHG emissions from biosolid production and management were considered on a whole treatment plant at WTP. Overall, biosolid production and

	management produced a total of 48,362 Mg of CO2-e per year and these are coming from >3 yo biosolids stockpile (40,038), sludge air drying pan (4,172), 1-3 yo biosolids stockpile 2,277), unplanted shallow stockpile (109) and planted shallow stockpile (32). The bulk of these emissions (83%) were produced by the old biosolid stockpiles (>3 years old) and this is related to the large amount of biosolids stored in old stockpiles at the WTP (close to 1.5 million Mg). Sludge drying adds around 20,000 Mg of new biosolids each year and this is associated with 4,100 Mg of CO2-e per year, or 9% of the total emissions. About 58% of the total GHG emissions from biosolid production and management are CO2 emissions, 34% are N2O and only 8% are CH4. Most of the CH4 is emitted during the sludge drying process, whilst almost all of the N2O is emitted during biosolid storage. The National Greenhouse Energy and Reporting calculation estimated a total direct GHG emission footprint of 92,350 Mg of CO2-e as CH4 and N2O for 2012/13 from wastewater treatment process at the WTP. This estimate did not include any GHG emissions from the sludge air-drying process, stockpiles and biosolid management. My data estimate that sludge drying and biosolid management at the WTP add an additional 22% (20,406 Mg CO2-e) of direct CH4 and N2O emissions to the overall GHG emissions of the treatment plant. It is the first study to directly measure GHG emissions of biosolids and it highlights that biosolids are an important point source for GHG emissions that adds substantially to the overall GHG footprint of wastewater treatment plants. My study also highlights that there are no easy management options to reduce these GHG emissions. This further emphasizes that wastewater treatment plants around the world urgently need to consider alternative options of biosolid use, because stockpiling is the only option that is persistently being used,which is a potential source of GHG emissions.	
dc.subject	biosolids	en_US
dc.subject	greenhouse gas, stockpile	en_US

dc.subject	sewage sludge	en_US
dc.subject	carbon offset	en_US
dc.title	Greenhouse gas emissions during biosolid production and stockpile management	en_US
dc.type	PhD thesis	en_US
melbourne.affiliation.department	Forest and Ecosystem Science	
melbourne.affiliation.faculty	Melbourne School of Land and Environment	
melbourne.thesis.supervisorname	Stefan Arndt	
melbourne.contributor.author	Majumder, Ramaprasad	
melbourne.accessrights	This item is currently not available from this repository	