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Techno-economic evaluation of a tandem dry batch, garage-style digestion-compost process for remote work camp environments

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ABSTRACT

The extraction of natural resources often involves housing workers in remote work camps far from population centres. These camps are prevalent in northern Alberta where they house approximately 40,000 workers involved in oil sands processing. The central, full-service cafeterias at these camps produce a significant quantity of food and cardboard waste. Due to their remote nature, these camps face high waste disposal costs associated with trucking waste long distances to the landfill. In this study, we investigated the techno-economic feasibility of on-site treatment of food and cardboard waste in a tandem dry batch, garage-style anaerobic digestion-compost process in which the waste material is converted into renewable energy used to heat the camp water supply and a nutrient-rich soil amendment for local land reclamation projects. Dry batch digestion and windrow composting pilot trials were performed on a simulated work camp waste in order to assess technical performance. The quality of the final compost was found to meet regulatory standards. A complete mass balance was then developed for a facility treating 3000 tonnes food waste and 435 tonnes waste cardboard annually. An economic assessment of such a facility was performed and, depending on the level of capital support and recognition of carbon credits for landfill methane mitigation, would require waste disposal costs to be between \$115 and \$195 CAD per tonne to meet financial criteria for project selection in Alberta's oil and gas industry.

1. Introduction

Natural resources are a significant contributor to the Canadian economy where, depending on the definition, they contribute between 9.8 and 16.6% to Gross Domestic Product (GDP) and employ up to 300,000 people (Cross, 2015). In natural resource sectors such as mining, forestry and oil and gas, projects are frequently located far from major population centres which make it necessary to house workers in remote work camps. These camps vary in their size from a mobile camp consisting of a trailer housing less than 10 workers, to semi-permanent structures housing anywhere from 2000 to more than 5000 workers that are associated with large oil and gas and mining projects. Outside oil and gas and mining, remote workforce accommodation is used during construction of large infrastructure projects such as large hydroelectric dams. The sudden influx of workers that result with commencement of large resource and infrastructure projects often overwhelms local housing availability, making work camps a solution used worldwide to manage short-term or sudden spikes in the local labour force. An example of such is found in Canada where, in northern Alberta (AB), dozens of work camps house workers involved in oil sands processing. The 2012 census reported the work camp population at just under 40,000, an increase of 11.6% from 2010 (Regional Municipality of Wood Buffalo, 2012).

Due to the remote nature of these camps, they have high operating costs associated with trucking supplies such as food and fuel into the camp and trucking waste out. Work camps north of Fort McMurray, AB typically truck their waste to the Wood Buffalo Regional Landfill south of the town, a distance that in some cases exceeds 100 km. The long transport distances and high labour costs create a strong financial incentive to not only reduce waste but also to implement on-site waste treatment options to reduce costs.

Remote work camps produce significant amounts of food waste from a central cafeteria and waste cardboard from supplies shipped to the camp in boxes. Oil field workers staying at the camp typically eat two meals a day at the cafeteria which creates an efficient environment for the collection of waste food from preparations in the kitchen and from the dining hall. The operational model of these full-service cafeterias is similar to that of restaurants, which facilitates estimating their waste generation via publicly available restaurant waste information. A typical restaurant

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will produce approximately 0.48 kg per diner of which 65% is the result of food preparation, 30% from plates and 5% spoilage (Sustainable Restaurant Association, 2010). This suggests that the total quantity of food waste from work camp cafeterias in the Wood Buffalo region could be as high as 14,000 tonnes per year. These cafeterias also produce significant quantities of waste cardboard. A survey of the composition of mixed solid waste produced from restaurants in the UK revealed that cardboard accounted for 10% by mass of total mixed solid waste while food waste accounted for 44% (WRAP UK, 2011). This ratio implies that waste cardboard from the cafeterias of remote work camps in the region could be as much as 3000 tonnes per year not including waste cardboard associated with the lodging operations.

Composting as an on-site treatment option appears attractive as it would eliminate the need to transport waste to the landfill and produce a valuable soil amendment for local land reclamation projects. However, there could be concern over food waste odours near lodges which would be both a nuisance to workers and an attractant for wildlife such as bears. Implementation of an anaerobic digestion process upstream of composting would help neutralize the food-like attraction of the waste before composting and produce renewable energy to off-set fossil fuels. Tandem anaerobic digestion and composting has the added benefit of being the most environmentally beneficial way to treat food waste based on a life cycle analysis (Levis and Barlaz, 2011) which improve on the sustainability of remote work camps.

While several options exist for anaerobic treatment, the relatively high solids content of the two organic waste streams, food waste and cardboard, favors a dry digestion option. The additional wastewater treatment requirements associated with a wet digestion process would inflate operating costs considerably in this high cost environment. So, a dry batch, garage-style digester is well suited. Dry batch, garage-style digestion involves mixing fresh waste with an inoculum (typically a portion of the digestate from the previous batch) and sealing the substrate in a gas-tight container which creates an anaerobic environment where microbes break down organic matter to produce energy in the form of biogas, mainly methane and carbon dioxide. During the process, leachate is collected in a stirred tank reactor (percolate digester) to facilitate biogas production from the liquid portion before being pumped back to the top of the dry digester to percolate through the substrate to improve process kinetics (Fig. 1). The process involves limited water addition, minimized water handling issues and the dry nature of the digestate facilitates downstream composting.

In this study, we explored the techno-economic feasibility of implementing a tandem dry batch, garage-style, anaerobic digestion-composting process to treat food waste and waste cardboard associated with remote work camps in northern Alberta and integrating produced heat from the biogas into the camp's hot water supply. We evaluated the technical performance of a simulated work camp waste in a pilot dry batch anaerobic digestion unit and subsequent downstream composting in a simulated windrow. Performance data was used to create an overall mass balance and to size a small-scale garage-style dry digestion unit. Economics were evaluated using estimated capital and operating costs provided by a vendor and adjusted for the elevated northern Alberta cost structure to determine the waste disposal cost where implementation of this process meets financial criteria of the oil and gas sector under several funding assistance scenarios.

2. Material and methods

2.1. Alberta Innovates – Technology Futures (AITF) dry digestion pilot plant

The AITF dry digestion pilot plant is designed to simulate an industrial dry batch, garage-style, digestion process (Fig. 2). The pilot consists of two custom-built; 500 L working volume garage-style stainless steel dry digesters (60.9 cm W × 76.2 cm H × 152.4 cm L) and one custom-built, adjustable working volume (150–300 L) cylindrical continuous stirred tank percolate digester (76.2 cm D; 90 cm H). All digesters are insulated and jacket heated with electric heating pads to maintain temperature as measured by industrial thermocouples within the vessels. Digester pH is continuously monitored in the dry digesters with industrial pH probes (Endress and Hauser, Reinach, Switzerland) located in the liquid (top) portion of grit traps at the back of each dry digester. Leachate from each dry digester passes through a flow meter on its way to the percolation digester to measure flow rate. A sample port is located in each return line. In the percolation digester, liquid is mixed by a recirculation pump with a pH probe (E&H) in the piping to monitor pH. Percolate is returned to the top of the dry digesters via a peristaltic pump where it is applied to a perforated steel grating on top of each dry digester to ensure even distribution of fluid over the substrate surface. Produced biogas passes through a cooling zone to condense a portion of moisture and thereafter through a rotary flow meter (Ritter GmbH, Bochum Germany) before being routed to a Calibrex foil bag for gas composition analysis via gas chromatography on a Galvanic Micro-GC (Calgary, AB) for methane, carbon dioxide, hydrogen sulphide, nitrogen and oxygen concentrations. Gas volume, gas composition, pH, temperature, percolation and heating are measured and controlled via a central PLC and HMI.

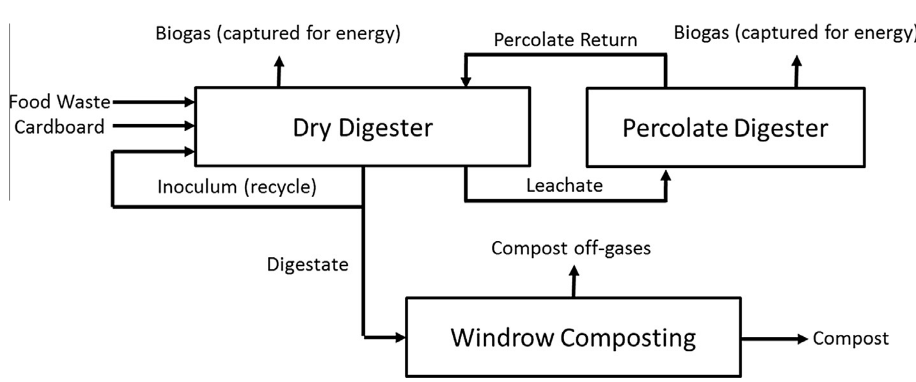

Fig. 1. Flowchart illustrating material flow through the tandem dry batch digestion compost process. Solid substrates (food waste, cardboard) are mixed with a solid inoculum (portion of previous batch digestate) and sealed in dry batch digester. Liquid leachate from the substrate is digested in a continuous stirred tank reactor (percolation digester) before being returned to the top of the substrate in the dry digester in a closed loop system. Upon completion of the batch, the solid digestate is removed from the dry digester, a portion is recycled as inoculum for the next batch with remainder being windrow composted to produce a high quality, stable final compost product.