Pilot Scale Treatment of Liquid Hog Manure Using an Electrochemical Reactor

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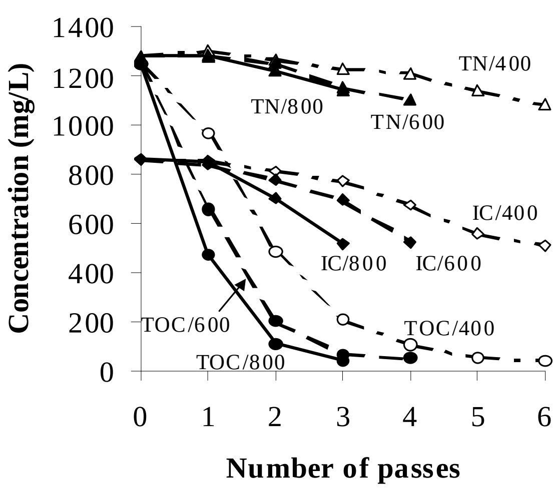
In previous work supported by Ontario Pork we showed that the offensive odour of liquid hog manure could be mitigated by passing an electric current through the solution (electrolysis). Electrolysis is a potentially “green” remediation technology that uses electricity (electrons) rather than added chemicals to drive chemical reactions. Among its advantages are the low cost of electricity compared with chemical remediation agents, although parasitic electrochemical processes such as water electrolysis may lower current efficiency. The success of remediation depended on the material used for the anode (positive pole) of the electrochemical cell; the most successful anodes used materials that promote the formation of reactive hydroxyl radicals at their surfaces.

The concept of odour nuisance is poorly defined, both scientifically and in the regulatory framework. We defined the ***quality*** of smell as follows: **A** = extremely unpleasant (raw hog manure smell); **B** = moderately unpleasant; **C** = slightly unpleasant; **D** = neither pleasant nor unpleasant. The ***intensity*** of smell was determined using the concept of “Threshold Odor Number” (TON), which is the number of times that the sample must be diluted with water before the odour becomes just detectable. In each case members of our research group were used as an “organoleptic panel”.

$$TON = (A+B) / A$$

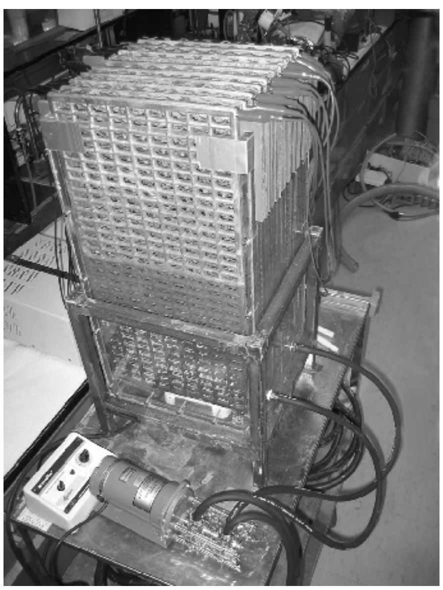
where A = mL of sample and B = mL of odor-free water that must be added to A so that the odour of the solution is just detectable.



Using stainless steel cathodes and either the novel anode material boron-doped diamond (BDD), which is available commercially (Figure) or Ti/SnO_2 as anode, the progress of electrolysis was followed in terms of changes of total organic carbon (TOC), inorganic carbon (IC), and total dissolved nitrogen (TN) from the solution. The numerical values on the labels in this figure represent the current (mA) through the micro-reactor. With a sufficient number of passes, up to 96% of the TOC was lost, representing mineralization of manure organics to CO_2 and water. Loss of IC was due to stripping of dissolved CO_2 by the gases evolved at the electrodes upon electrolysis of water. The evolution of odor quality correlated with the reduction of TOC, changing from the initial offensive odor of manure to a neutral odour after three passes through the reactor. The odour intensity simultaneously fell from initial TON = 2000 to TON = 100 after one pass through the reactor and TON = 20 after three passes at a current of 600 mA. Unlike the TOC, the TN was not affected by electrolysis, indicating that the deodorized liquid had retained its fertilizer value. We have also examined briefly the influence of the electrolytic process on bacterial counts. This analysis was conducted in order to explain why solutions electrolyzed to a near-odourless state could be stored for several weeks without redeveloping an off-odour, even though the solutions still contained a substantial residual TOC.

The small scale of the foregoing reactions inevitably left doubt about whether odour remediation could be achieved on a larger, more practical scale. Our first attempt at scale-up involved the construction of a 1 liter Plexiglas reactor, with internal dimensions 4 x 4 x 6 inches. Four anodes and four cathodes were mounted in parallel and supplied in series with current from a Golden Source DC power supply (30V-20A). Stirring was achieved with a magnetic bar, two inches long, using an external magnetic stirrer. The reactor was operated in recirculation mode using a Masterflex peristaltic pump, which pumped a total of 3 L of whole raw manure through the electrochemical unit and back into the reservoir. This system was designed to test indirect-acting (hydroxyl radical forming) anodes using whole, non-centrifuged manure containing solids. The cathodes were grids of mild steel. Although BDD was the most successful anode material at the level of the micro-scale reactor, it was too expensive to use even at a pilot plant scale. We therefore used Ti/SnO_2, which was obtained commercially, and the cheaper Pb/PbO_2, which was prepared in our laboratory from grids of an alloy that was 94% lead and 6% antimony, by making the grids the anode of an electrochemical cell. During 4 h at a current of 1 A, the TON gradually fell from 1000 to 200, while the odour quality changed initial from “A” (extremely unpleasant) to “C” (only slightly unpleasant). Because of the high concentration of solids present in whole manure, no attempt was made to study changes in TOC and related parameters as a result of treatment.

We also constructed a 27 L Plexiglas reactor with internal dimensions 1 x 1 x 2 ft (approx. 0.3 x 0.3 x 0.6 m). Ten anodes (Pb/PbO_2) and ten cathodes (iron grids) were mounted vertically in parallel and supplied in series with current from the Golden Source DC power supply. The active surface area for each electrode was 1 x 1 ft. Stirring was accomplished with a magnetic bar, 5 in (13 cm) long, and an external magnetic stirrer. The reactor was designed to function in both continuous and batch mode. When used in continuous mode the reactor was attached to a Masterflex peristaltic pump with two heads, each of which was capable of a maximal flow rate of 2.9 L/min. These were connected to the two entry ports at the bottom of the reactor. In batch mode, the entrances to the reactor were plugged. The lead/antimony grids were activated to form a layer of lead dioxide as described above.



The reactor was operated in our laboratory in batch mode at 20 A, after charging the unit with 27 L of manure collected from Arkell Research Station. After 3 h of operation during which the voltage difference between the electrodes was 5 V, the quality of the odor changed from A (highly unpleasant, raw manure) to C (mildly unpleasant). The power usage during this period was 20 A × 5 V = 100 W, hence over the course of 3 h, the energy expenditure was 0.3 kWh, corresponding to an electricity cost of about 2¢, equivalent to 74¢ m^{-3}.