

C-Flow PLT Case Study I

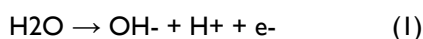
Destruction of Formic Acid



Clare Fairfield, Senior Scientist
clare.fairfield@ctechinnovation.com

Electrochemistry has potential to contribute to a cleaner environment. One area where its application can be of great benefit is wastewater treatment. Most environmental pollutants can be successfully eliminated or converted to non-toxic materials by one or more electrochemical processes, including electrolysis, electrocoagulation and electrocoagulation/flotation and electro dialysis. This case study will focus on electro-oxidation.

Chemical processes for the treatment of waste water are known. Polluted waters can be treated with ozone, or other powerful oxidants but the total organic carbon removal is low (approximately 30 % of starting material). With chemical processes, although the organic pollutants can be near completely eliminated, the level of total organic carbon still remains a problem. The process also requires the addition of other chemical reagents which may leave behind unwanted contaminants. For these reasons, electro-oxidation holds many advantages over chemical processes. It is applicable to a wide range of pollutants and does not require high temperature or pressure to complete. The reaction can be driven until full oxidation to carbon dioxide is achieved, reducing the total organic content to very low levels. This occurs at a significant rate in the potential region of oxygen evolution and it is commonly assumed that electro-generated hydroxyl radicals are active in the degradation of organic molecules. The hydroxyl radicals are produced directly from water according to equation (1);



C-Tech Innovation are market-leading in the creation and validation of electrochemical systems, some of which have been toward wastewater treatment including extensive collaboration and supply to the nuclear industry.

In this case study the direct electro-oxidation of formic acid is demonstrated, first at a laboratory scale using a C-Flow Lab 5x5 electrochemical cell and compared with results achieved at pilot scale with the C-Flow PLT unit. Formic acid was chosen due to its simplicity. Having only one carbon, the reaction proceeds quickly and requires only two electrons for oxidation to carbon dioxide. The reaction pathway is shown in Figure 1.

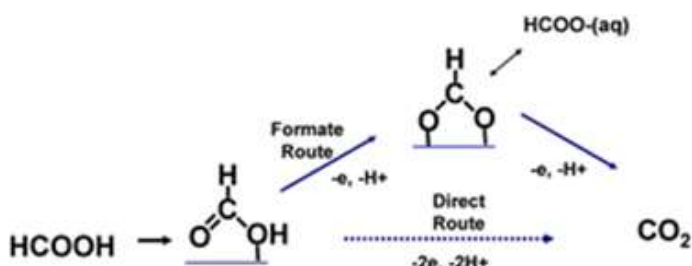


Figure 1; formic acid oxidation mechanism

Apparatus

A 5x5 cm C-Flow LAB cell was first used to validate the electrochemical oxidation at a small (1 litre) scale.

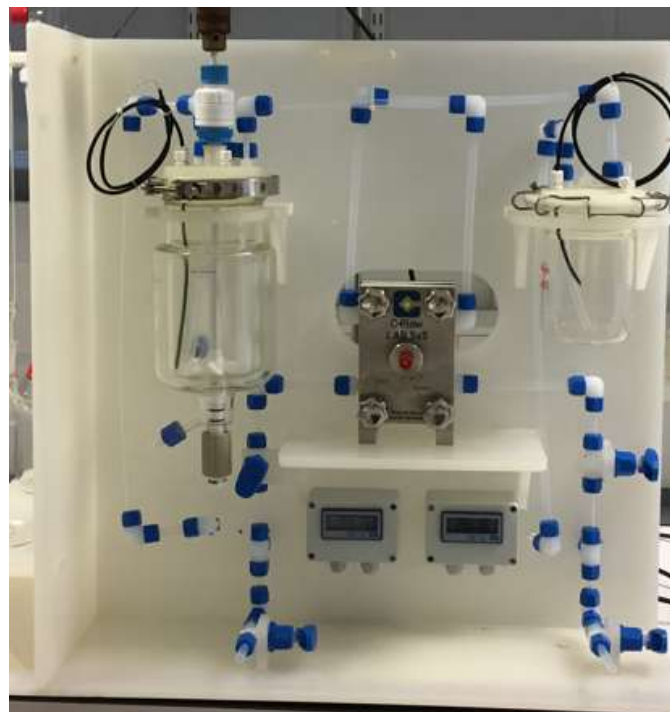


Figure 2 – Laboratory scale test equipment

After validation in the laboratory, the reaction was completed with the C-Flow PLT cell and test platform, operating in 10-50 L volume scale.



Figure 3: C-Flow PLT



C-Flow is a registered trademark of C-Tech Innovation Ltd

C-Tech Innovation Ltd Capenhurst
Technology Park CH1 6EH
United Kingdom

+44 (0) 151 347 2900
info@ctechinnovation.com
www.ctechinnovation.com

The C-Flow PLT cell has an active area of 20 x 30 cm (600cm²). The components of used in both cells were;

Table 1: Organic destruction cell components

	Material
Anode	DSA
Anolyte	Nitric acid (3M, Puriss reagent grade, Sigma Aldrich LOT SZBD0390V) with 3% w/w addition of formic acid (Sigma Aldrich, >95%, MKB-V5742V).
Membrane	Nafion 324
Cathode	Titanium
Catholyte	Nitric acid (3M, Puriss reagent grade, Sigma Aldrich LOT SZBD0390V)

Bulk electrolysis experiments were carried out with a power supply of suitable specification to deliver current required to operate at 4000 A/m² (10 A) for the lab cell and 2000 A/m² (125 A) for the pilot cell.

To effectively compare the two cell types, the electrolyte flow rates were adjusted so that a similar flow velocity (0.2 m/s) could be achieved through both cell sizes. This equated to 3L/min through the C-Flow Lab cell and 18L/min through the C-Flow PLT.

The destruction of organic in the anolyte solution was measured by frequently sampling the anolyte tanks in both experiments and measuring the total organic carbon (TOC) in solution. This was completed by a colorimetric technique using Hach Lange cuvettes (tests LCK 381) and spectrometer (DR500).



Figure 3 – TOC Measurements

Results

The charts in Figure 4 and Figure 5 show the decrease in total organic content in the anolyte solution over time for the laboratory and pilot scale test respectively. Both show a linear decline over the concentration range tested.

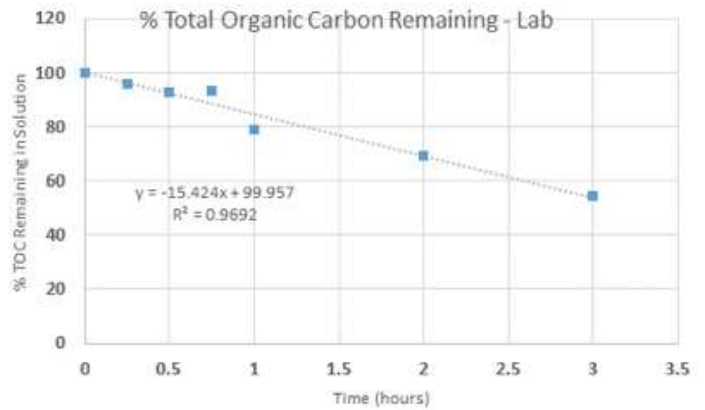


Figure 4: Decline in total organic carbon in laboratory scale experiment

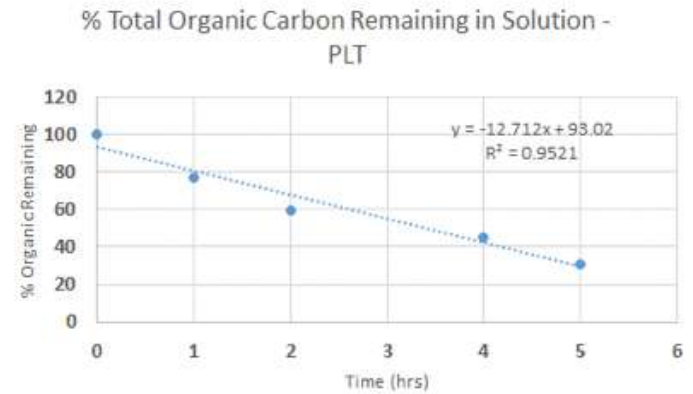


Figure 5: Decline in total organic carbon in pilot scale

In order to compare the performance in both experimental scales, the organic oxidation (in moles) per Amp of current applied was calculated and plotted over time. This shows that the oxidation rate is remarkably similar.

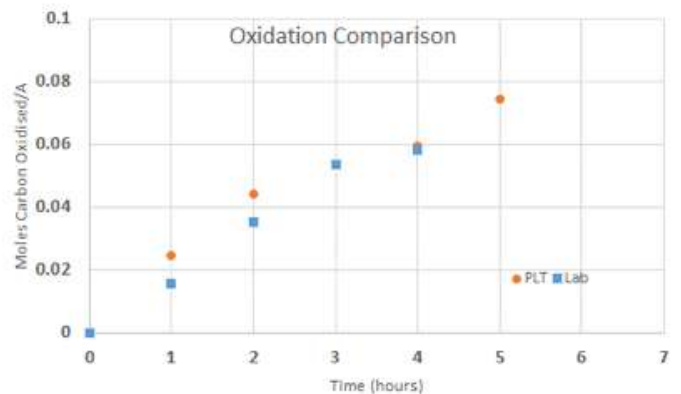


Figure 6: Performance comparison – LAB versus PLT

Table 2 shows the cumulative current efficiency calculated in both the laboratory and pilot scale electro-oxidation of formic acid. At both scales a comparable and high current efficiency has been achieved.

Table 2: Current Efficiency Comparison

	LAB	PLT
Current efficiency (%)	80.3	79.5

Conclusions

Electro-oxidation is a useful and effective tool in the removal of unwanted organics in waste waters. In this case study, the destruction of formic acid has been demonstrated, with the method initially developed and checked at a laboratory scale before proceeding to effectively scale up the reaction to pilot scale. The results achieved with the C-Flow Lab 5x5 cell were readily replicated with the C-Flow PLT.



C-Flow
Electrochemical Range