Kinetic evaluation of the mesophilic culture in the presence of waste PCBs: Inhibition of the microbial culture

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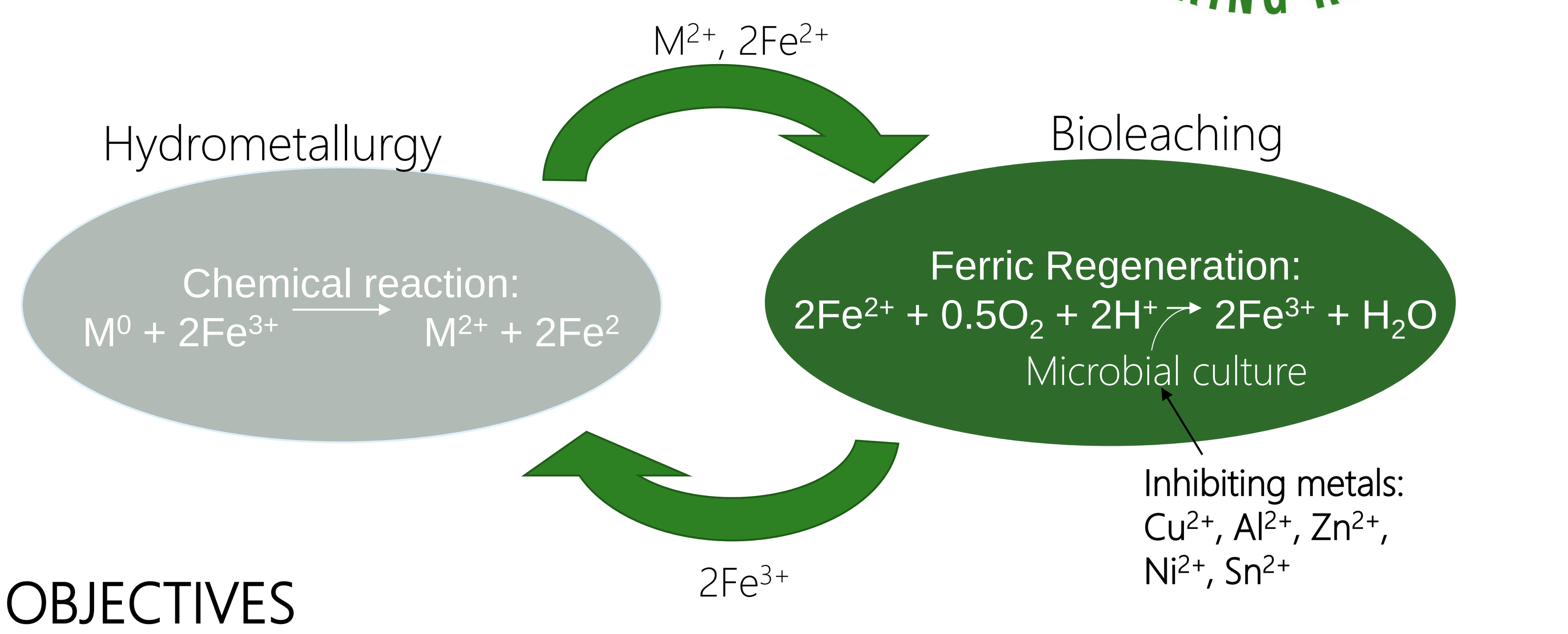
INTRODUCTION

Electronic waste (eWaste) is the largest growing waste stream in the world, accounting for 44.7 Mt of waste in 2017[2]. Within eWaste, printed circuit boards (PCBs) contain the largest amount of recoverable heavy metals, which include gold, silver, palladium, copper, aluminium, zinc, nickel and tin[1].

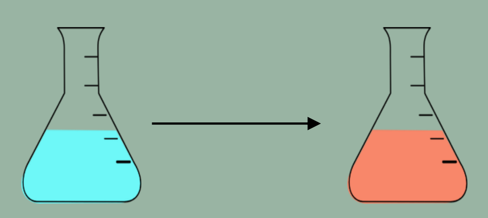
Metals can be extracted from e-waste via metallurgical processes. A hybrid process, combining chemical and biological leaching processes, can be the most efficient for metal extraction as it reduces the waste and raw material load by regenerating the ferric iron (leach agent) from the ferrous iron[3]. In order to regenerate ferric iron via microbial oxidation, the microorganisms would need to be able to perform the ferrous iron oxidation in the presence of the heavy metals.



OBJECTIVES

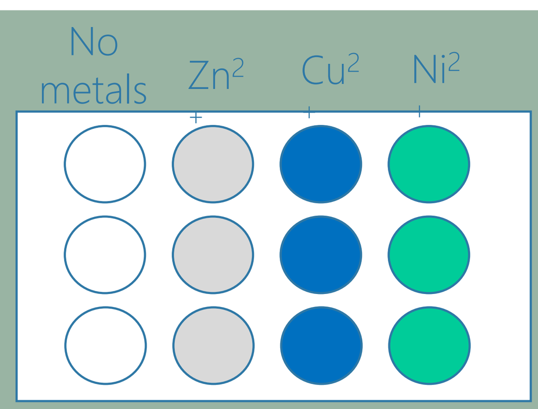
The ferric regeneration process involves the use of iron-oxidising bacteria as a catalyst. The potential toxicity of the metals, which inhibit the iron oxidation and growth of the microbial culture (predominantly *Leptospirillum Ferriphilum)*, is investigated along with the potential adaptation of the microorganisms to these inhibitory metals.

METHODS



Adaptation of Cultures

- Adapted to increased concentrations of mixed metals and copper
- Sub cultured every 3 days

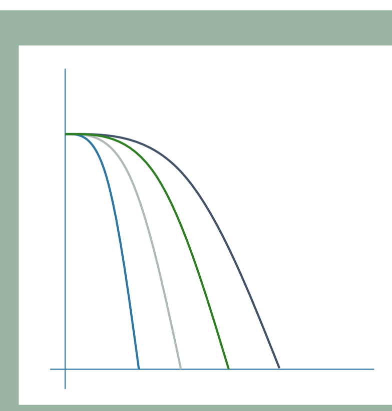


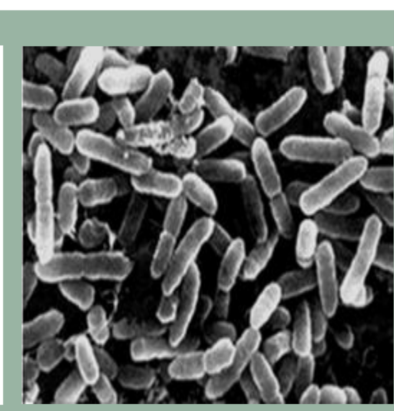
Microwell Plate Experiments

- Exposure tests to the various individual metals found in PCBs
- Done in triplicate

Conditions

- Agitated at 140rpm at a temperature of 37°C
- Samples taken at intervals to track microbial oxidation





Measurements

- Spectrophotometric assay to determine ferric iron and total iron concentrations
- Cell counts using oil immersion at 1000x magnification on a light microscope

Model Theory

$$q = \frac{q_{max} \times S}{K_S + S} \xrightarrow{\text{Competitive Inhibition}} q = \frac{q_{max} \times S}{K_S(1 + \frac{I}{Kiic}) + S}$$

Where:

q_{max} = maximum specific iron oxidation rate ($mg_{Fe2+}/mg_{Biomass}.h$)
S = substrate concentration (mg/L)
K_s = half saturation concentration (mg/L)
I = concentration of inhibitor (mg/L)
K_{iic} = competitive inhibition constant (mg/L)

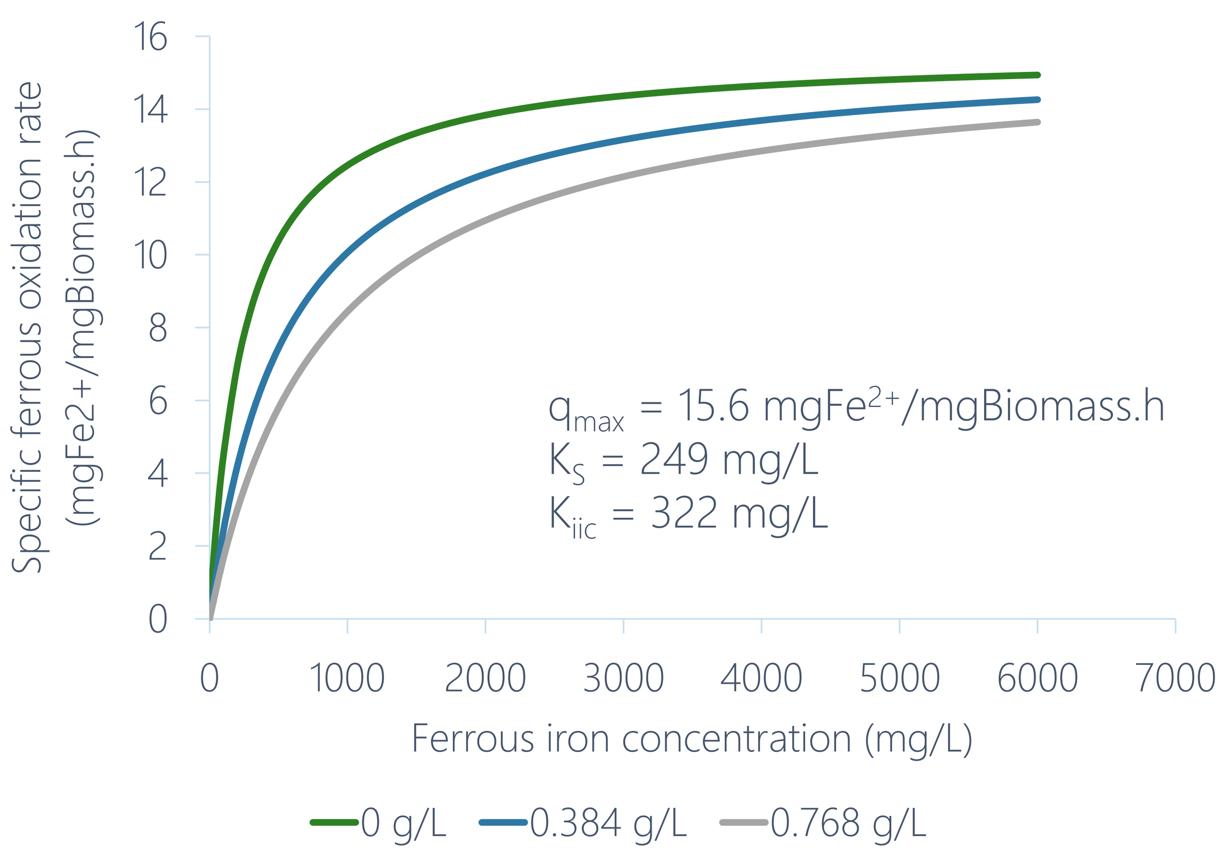


Figure 2: Kinetic models (Haldane competitive) for the various copper exposure concentrations

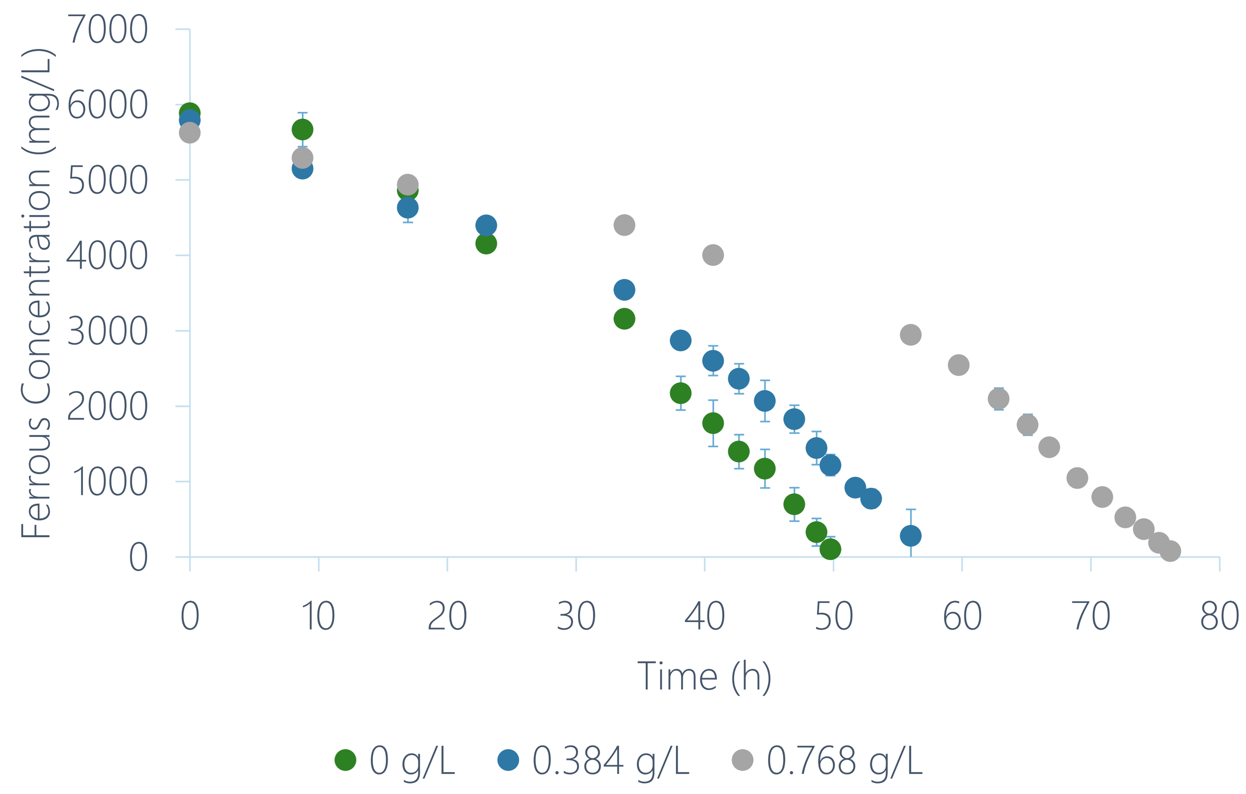


Figure 2: Ferrous concentration profiles for the various copper exposure concentrations

Table 1: Key microbial performance and kinetic significance data

Copper Exposure Concentration (g/L)	Ferrous oxidation rate (mg/L.h)	Kinetic Model Correlation Coefficient (R^2)
0	263	0.95
0.38	162	0.62
0.77	145	0.93

RESULTS

- Copper exposure tests were done in the range of 0 - 0,768 g/L (which is 0 – 2% of copper that can be found in a PCB mixture).
- Oxidation rates decreased with an increase in copper concentration, as seen in Table 1
- An increased lag period, coupled with a decrease in oxidation rates indicate an inhibitory effect by copper
- Further kinetic modelling, as seen in Figure 2, indicates that the mechanism for inhibition is competitive
- The competitive inhibition constant (K_{iic}) implicitly affects the K_S , resulting in a decrease in specific oxidation rate over time

Conclusions & Recommendations

- The kinetic results show an increase in toxicity to the microbial culture with an increase in copper concentrations, with the mechanism of inhibition determined to be competitive.
- Adaptation of the cultures are ongoing with current cultures being maintained with up to 4 g/L of copper, as well as up to 1 g/L of mixed metals
- Further analysis will be required at higher concentrations of copper exposure, as well as exposure tests on the adapted cultures

ACKNOWLEDGEMENTS FROM THE AUTHOR

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