DETECTION OF ESCHERICHIA COLI AND STAPHYLOCOCCUS AUREUS ON SENSORS WITHOUT IMMOBILIZATION BY IMPEDANCE SPECTROSCOPY

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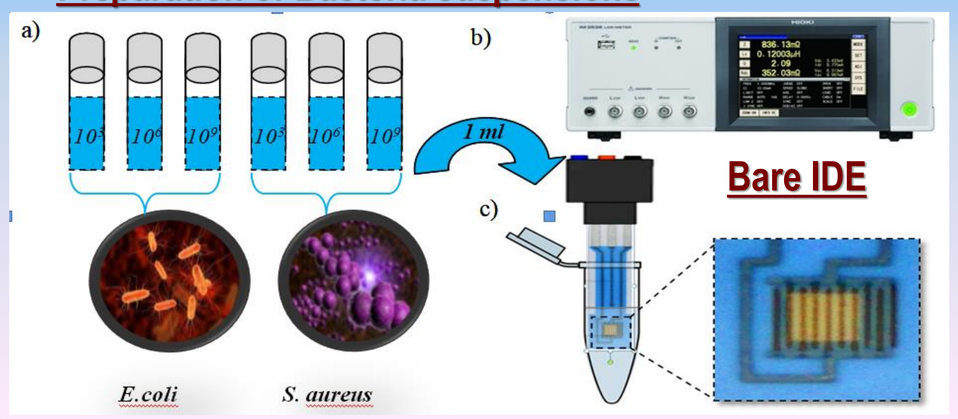
Motivation

The use of impedance spectroscopy (IS) to detect and study bacterial growth has increased significantly in recent decades due to the availability of inexpensive and easy-to-use impedance sensors. IS method (AC f=4 Hz-8 MHz at a constant amplitude of 1 V) and Pt-IDE sensors were used to detect and monitor different concentrations (10^3, 10^6, 10^9 CFU/ml) of both live and dead bacterial cells *Escherichia coli* (*E.coli*) and *Staphylococcus aureus* (*S.aureus*) prepared in deionized water (DH_2O). All measurements were conducted at temperature 24±1ºC and the immersion sample volume was 1 ml. The analysis of the impedance spectra based on Nyquist and Bode plots shows a significant difference in resistance with increasing concentration for both types of bacteria and the presence of characteristic changes in the frequency range 10-100 kHz. We also observed difference in the time dependences of impedance. The semicircle-shaped portion of the Nyquist plots obtained at high frequencies corresponds to the faradic transfer of electrons on the electrodes, while the spectrum obtained at low frequencies provides information on the diffusion process of transferring bacterial waste products in solution to the electrode surface. The presence of live bacteria E.coli led to a decrease in the impedance value compared to dead cells, the value of R_s+R_{ct} decreased about two times.

Preparation of Bacteria suspensions

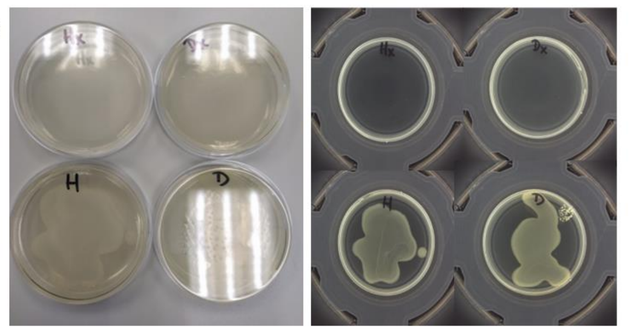


E.coli in DH_2O

a)

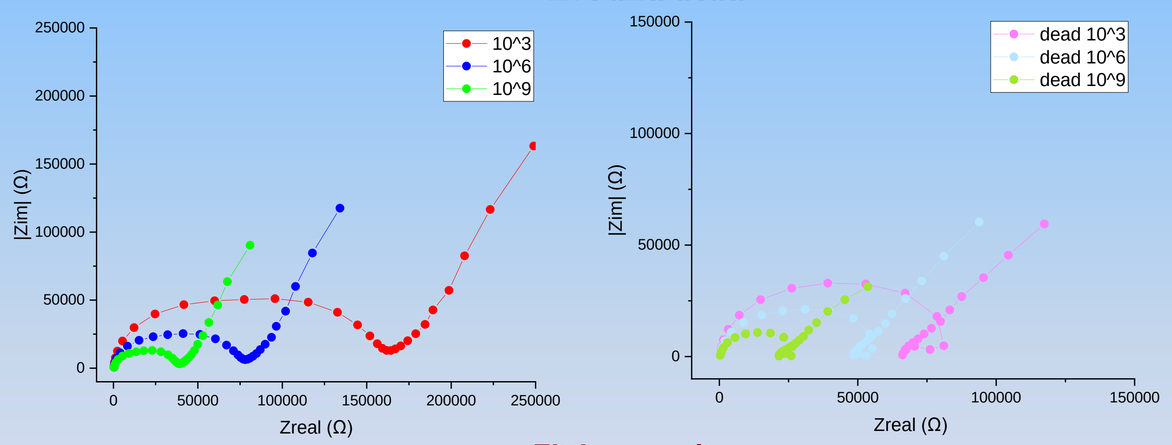
E.coli, CFU/ml	DH2O (pH 9.19)
• 10^3	• 9.19
• 10^6	• 9.67
• 10^9	• 8.87

b)



Results

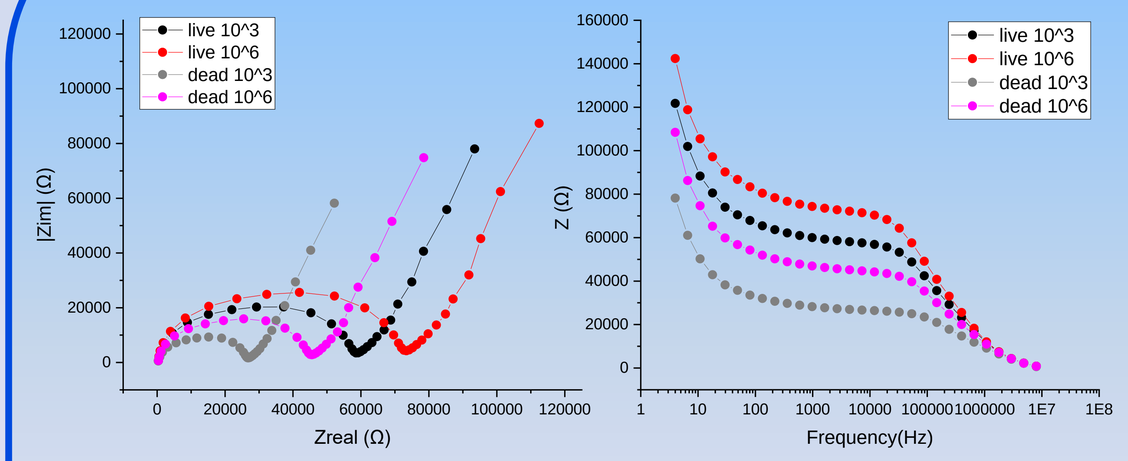
Impedance spectra (Nyquist and Bode plots) of *E.coli* (10^3, 10^6, 10^9 CFU/ml): live and dead



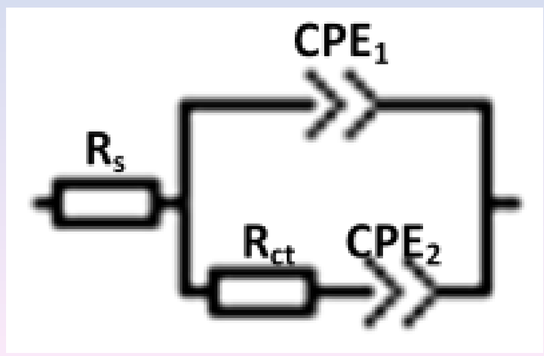
Fitting results

CFU/ml	Live						Dead					
	Rs, Ω (×10^{-14})	Rct, kΩ	CPE1 (×10^{-10})	n1	CPE2 (×10^{-7})	n2	Rs, Ω (×10^{-14})	Rct, kΩ	CPE1 (×10^{-11})	n1	CPE2 (×10^{-6})	n2
10^3	9.31	166	5.55	0.74	5.86	0.69	8.69	70.24	1.37	0.99	1.88	0,60
10^6	9.01	80.53	7.04	0.74	7.59	0.71	8.64	50.52	4.05	0.93	1.85	0.61
10^9	8.79	41.08	8.86	0.73	9.56	0.72	7.26	22.67	1.33	1.00	4.08	0.50

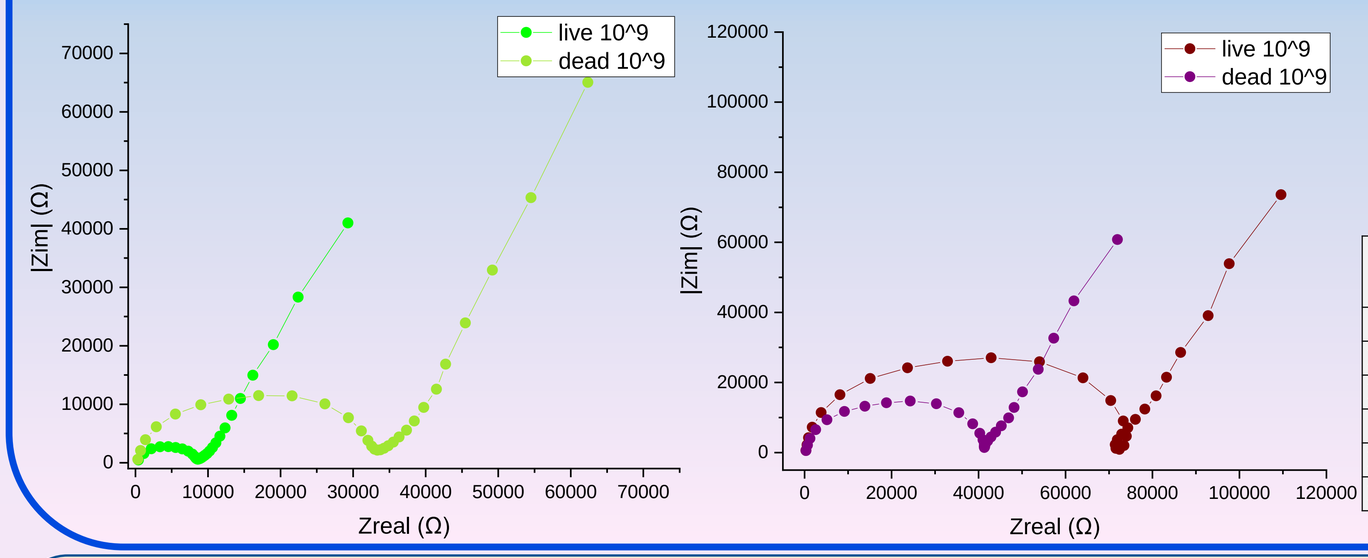
E.coli live and dead

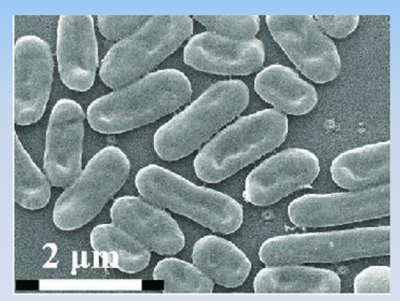


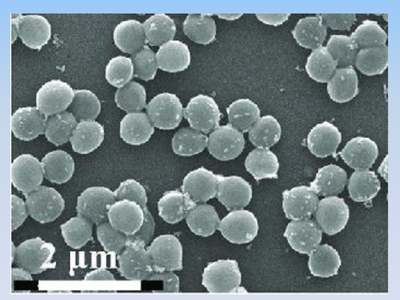
Electrical circuit



Impedance spectra live/dead *E.coli* and *S.aureus*







10^9 CFU/ml	Rs, Ω (×10^{-14})	Rct, kΩ	CPE1	n1	CPE2 (×10^{-6})	n2
E.coli						
Live	1.60	9.21	8.86×10^{-09}	0,70	2.26	0,70
Dead	1.62	32.70	5.39×10^{-10}	0.77	1.35	0.72
S.aureus						
Live	9.59	73.46	1.36×10^{-10}	0.85	1.23	0.70
Dead	9.58	58.37	1.73×10^{-10}	0.83	1.40	0.67

Conclusions

The proposed method of selective detection of bacterial cells can be used to identify two types of bacteria (*E. coli* and *S. aureus*), to qualitatively characterize the differences between dead and live cells, and to estimate their concentration in samples with an unknown number of bacteria per unit volume.

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