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Microbial Adhesion and Surface Modifications of Sulphide Minerals Relevant to Flotation and Flocculation

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Introduction

- Materials of biological origin act as flotation reagents
- Enhanced flotation caused by application of bacteria with hydrophobic surface
- Depressed flotation using cells with hydrophilic character
- Chemolitotrophic bacteria posess hydrophilic surface and work as depressants
- *At. ferrooxidans* – different effect of depression on sulphide minerals

Aim

- Characterisation of bacterial surfaces
- Study the surface changes of bacteria after adaptation to copper and zinc ions
- Study the adhesion of cells to mineral surfaces
- Characterisation of mineral surfaces before and after bacterial treatment
- Study the effect of cells on flocculation and flotation

Characterisation of bacterial cells – Zeta potential

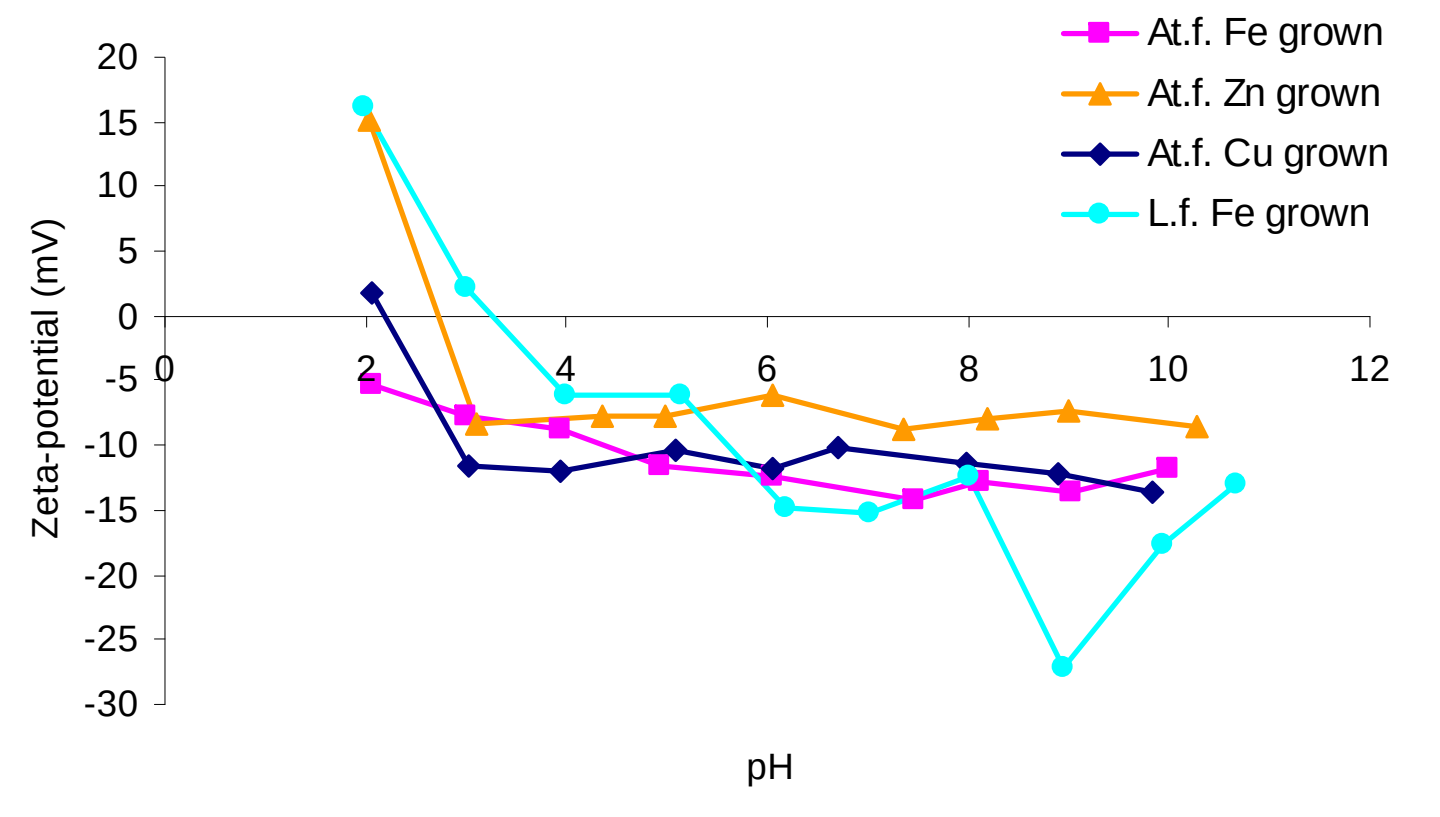

Fig. 1. Zeta-potential of *Acidithiobacillus ferrooxidans* and *Leptospirillum ferrooxidans* relative to pH.

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Characterisation of bacteria – FTIR

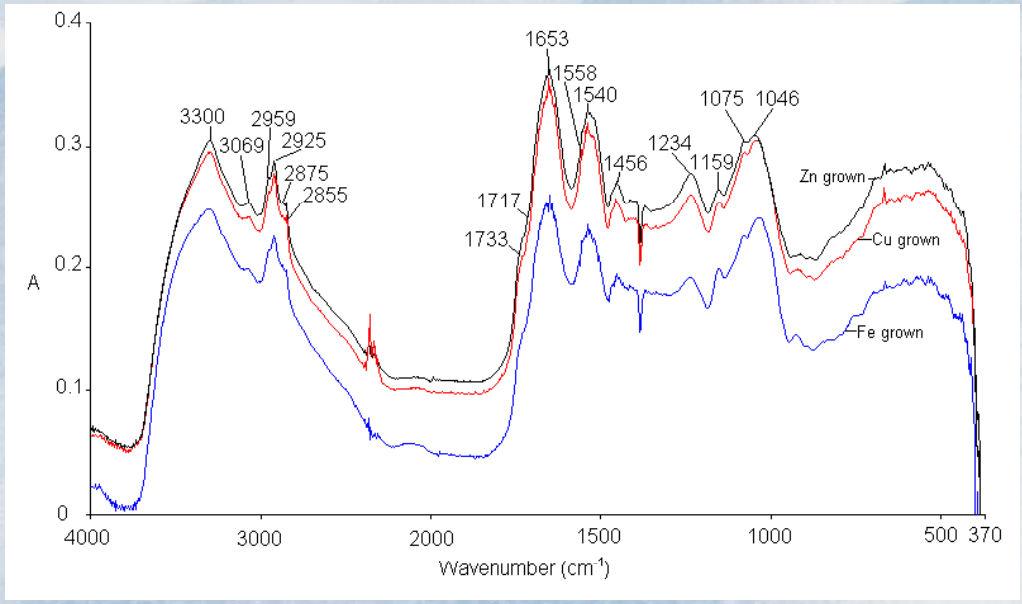

Fig. 2. FTIR absorbance diagram of *At. ferrooxidans* cells.

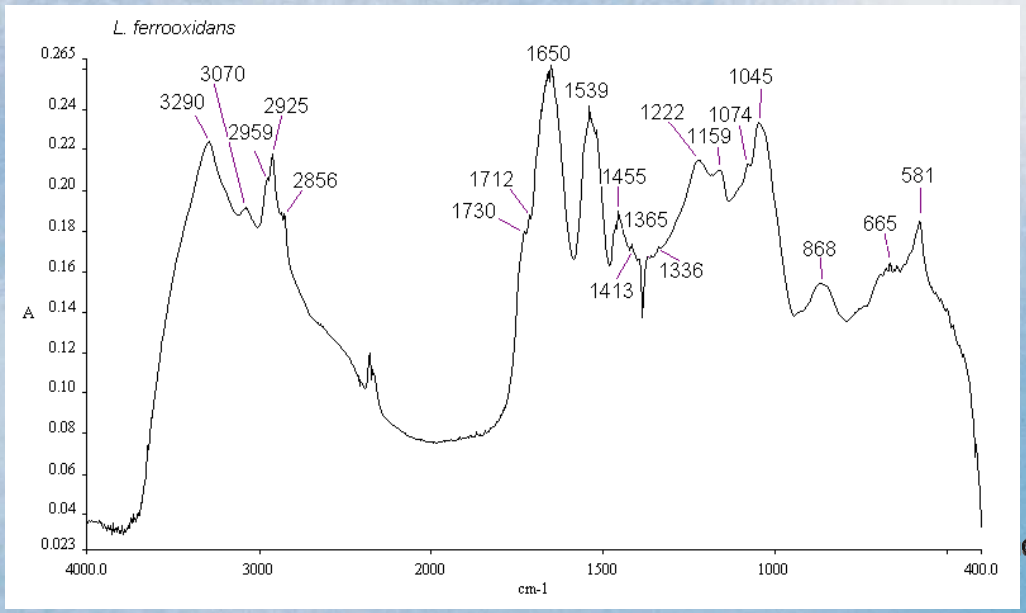

Fig. 3. FTIR absorbance diagram of *L. ferrooxidans*.

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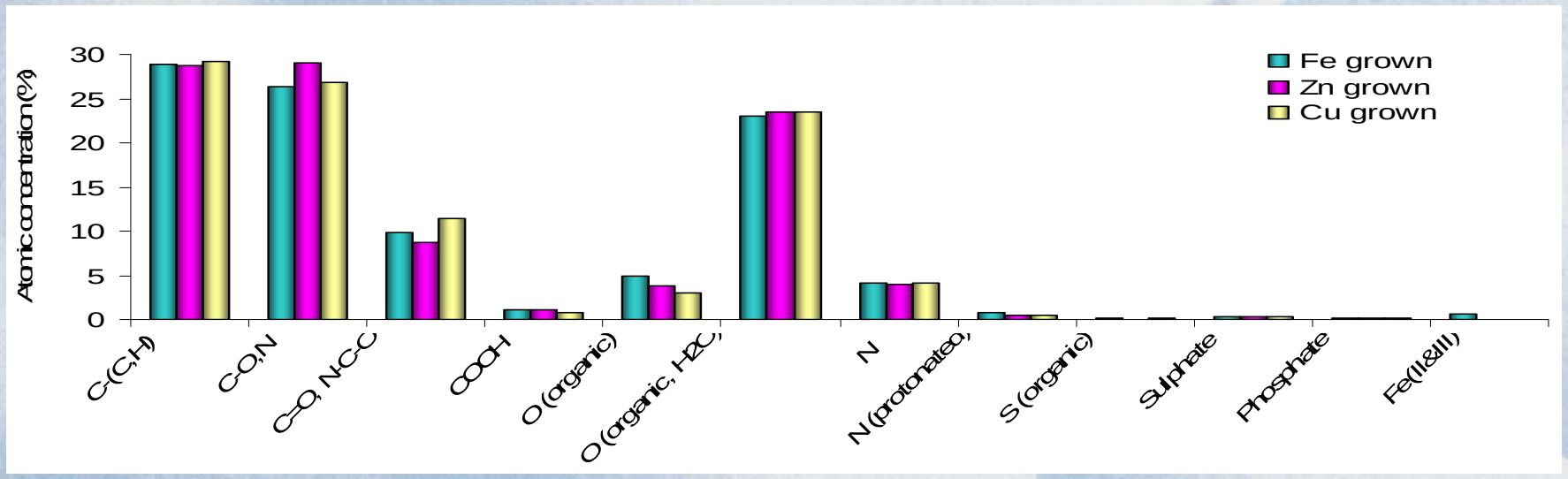
Characterisation of bacteria - XPS



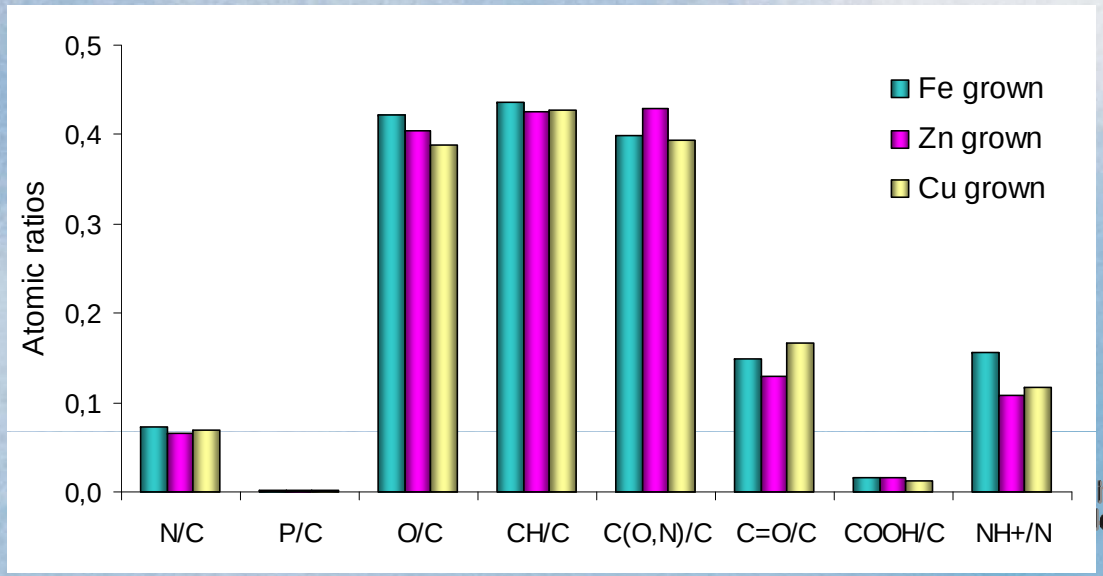


Fig. 4. XPS analysis of different *At. ferrooxidans* cells.

Fig. 5. XPS analysis of different *At. ferrooxidans* cells, relative elemental visualisation.

Characterisation of bacteria – Contact angle

Material	Contact angle θ				Surface energy γ (mJ.m^{-2})				
	Water	Diiodo-methane	Bromo-naphtalene	Formamide	total	γ^d/γ^{LW}	γ^P/γ^{AB}	γ^+	γ^-
Pyrite	61.00	---	10.40	8.15	53.75	43.87	9.88	4.01	6.08
Chalcopyrite	71.76	---	39.66	43.46	42.39	34.93	7.47	2.20	6.34
At.f. Fe grown	**33.00**	53.50	36.00	32.50	48.55	34.31	14.24	1.11	45.57
At.f. Zn grown	**26.57**	---	40.00	29.73	49.54	34.78	14.76	1.06	51.46
At.f. Cu grown	**7.50**	---	35.55	14.80	55.36	36.67	18.68	1.55	56.43
L.f. Fe grown	**30.50**	55.30	42.30	32.50	48.34	32.43	15.91	1.36	46.47

Bacterial adhesion

- Number of cells adhered on the surface is in correlation with the effect of biotreatment on flotation or flocculation
- Different strains of the same species adhere differently
- Adhesion to minerals is different
- Growth substrate influences the adhesion

Adhesion of *At. ferrooxidans* and *L. ferrooxidans* to sulphide minerals

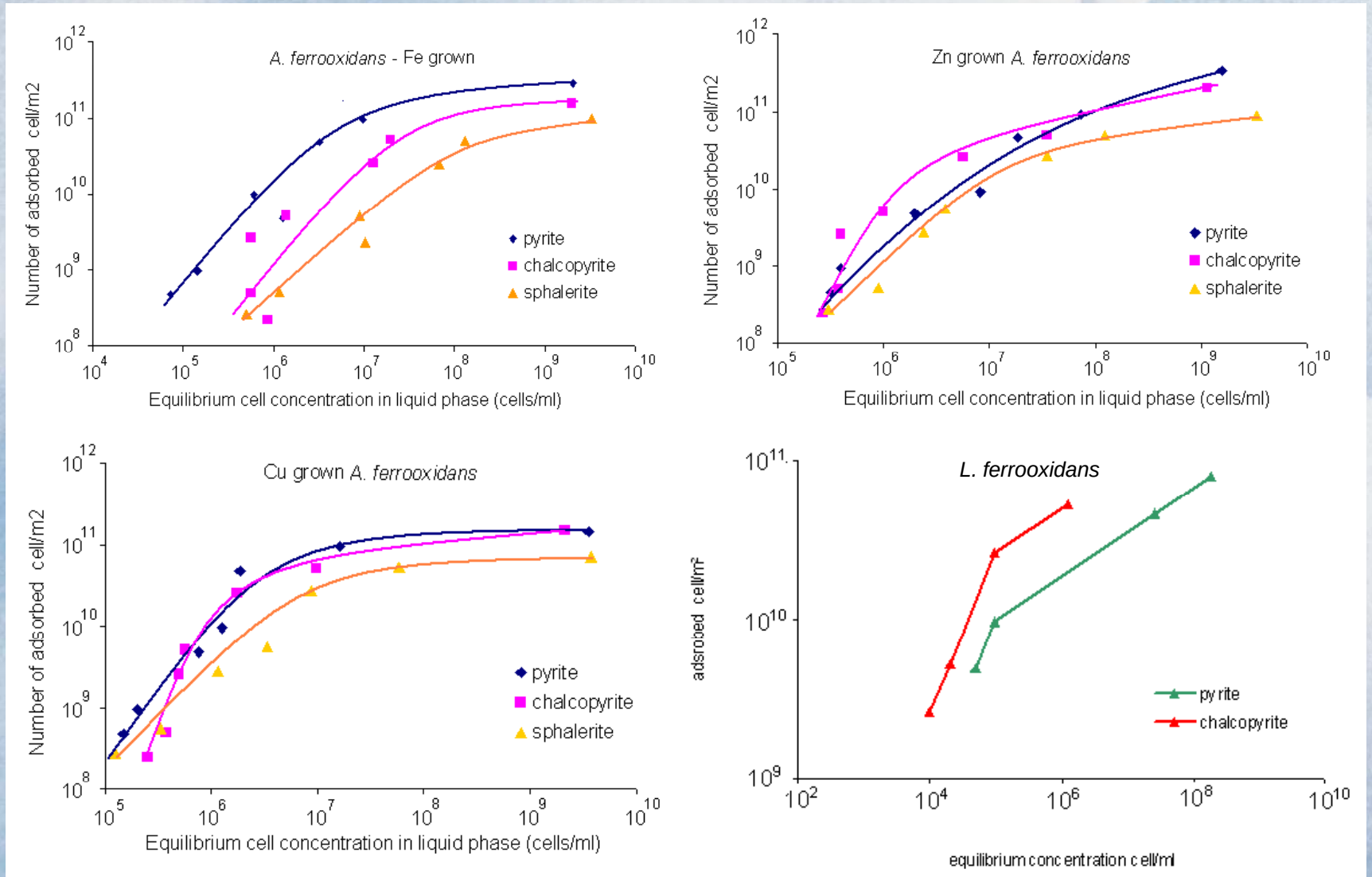


Fig. 6. Adhesion isotherms of different cells

Adhesion – Thermodynamic approach

Mineral – Bacteria System	Free energy of adhesion ΔG_{adh} (mJ.m^{-2})		
	ΔG_{adh}^{LW}	ΔG_{adh}^{AB}	ΔG_{adh}^{total}
Pyrite - *At. ferrooxidans*	-4.65	-10.29	**-14.93**
Pyrite - Cu grown *At. ferrooxidans*	-5.42	-4.66	**-10.08**
Pyrite - Zn grown *At. ferrooxidans*	-4.80	-7.83	**-12.63**
Pyrite - *L. ferrooxidans*	-4.01	-9.30	**-12.25**
Chalcopyrite - *At. ferrooxidans*	-2.95	-8.10	**-12.11**
Chalcopyrite - Cu grown *At. ferrooxidans*	-3.44	-1.70	**-5.14**
Chalcopyrite - Zn grown *At. ferrooxidans*	-3.05	-5.21	**-8.26**
Chalcopyrite - *L. ferrooxidans*	-2.55	-7.06	**-9.61**
Sphalerite - *At. ferrooxidans*	-3.65	6.30	**2.65**
Sphalerite - Cu grown *At. ferrooxidans*	-4.26	14.03	**9.78**
Sphalerite - Zn grown *At. ferrooxidans*	-3.77	10.27	**6.50**

Adhesion of cells to minerals – DLVO

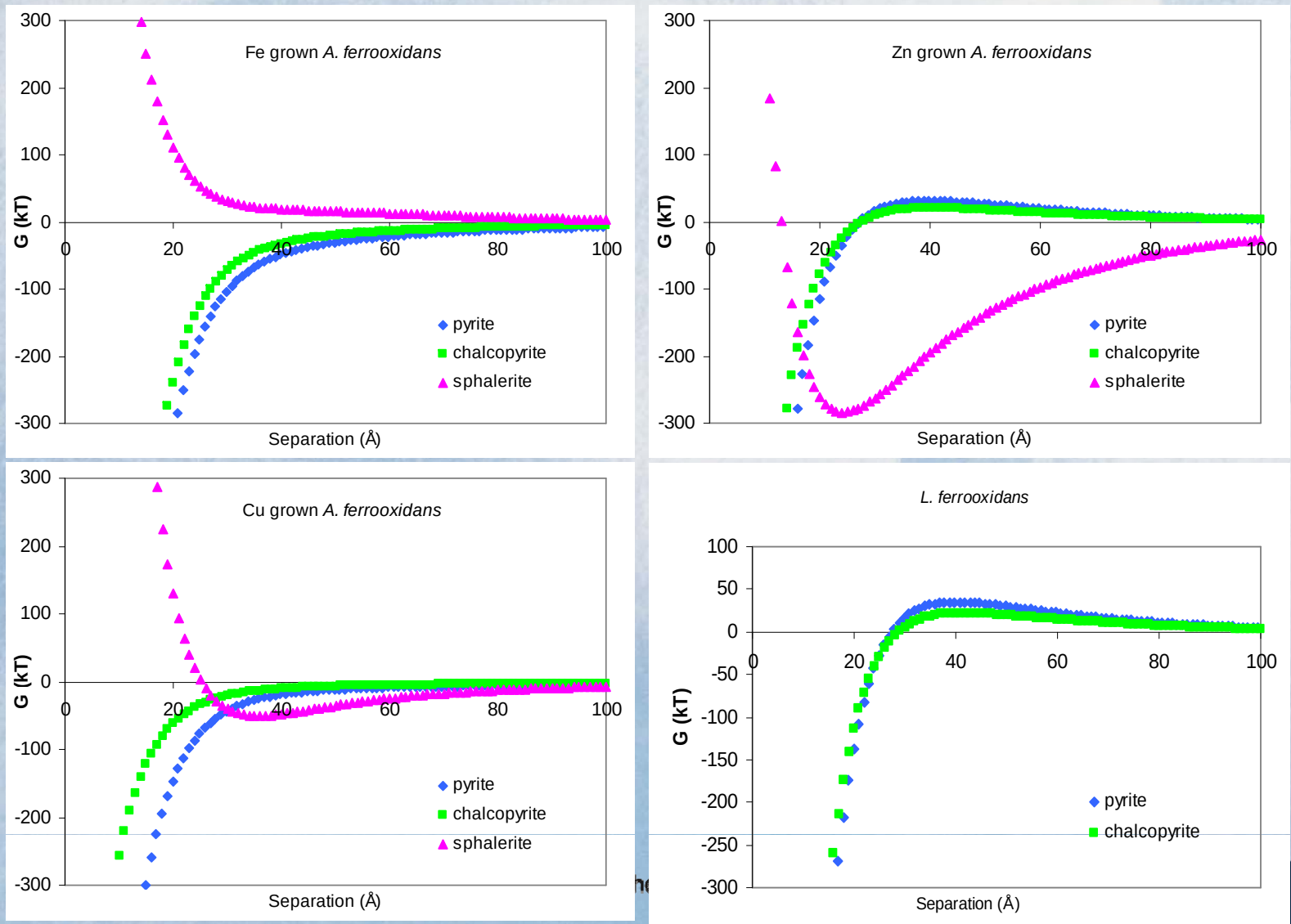
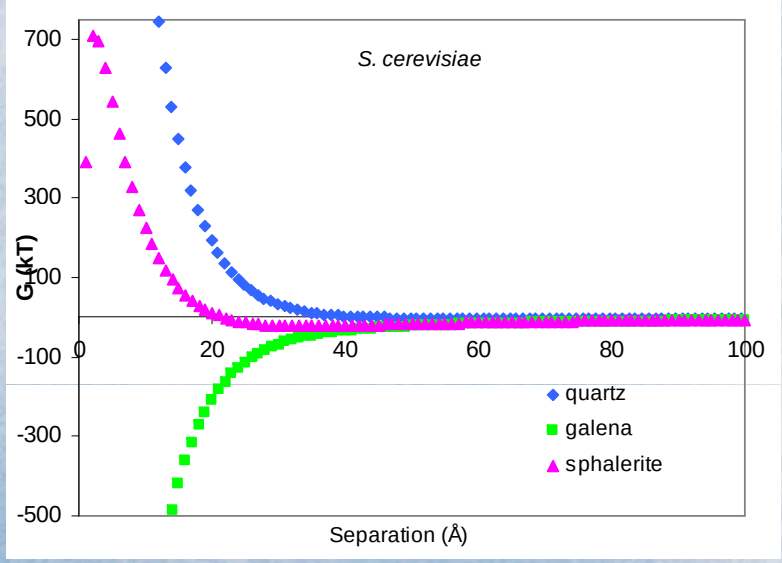


Fig. 8. Total interaction forces between bacteria and sulphide minerals

Yeast cells adhesion to minerals



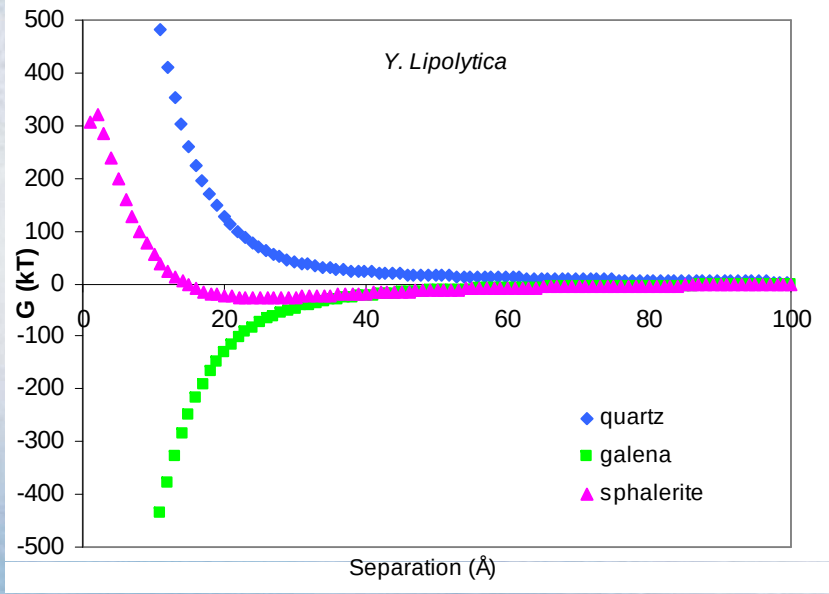


Fig. 9. Total interaction forces between yeast cells and different minerals

Bacteria induced flocculation

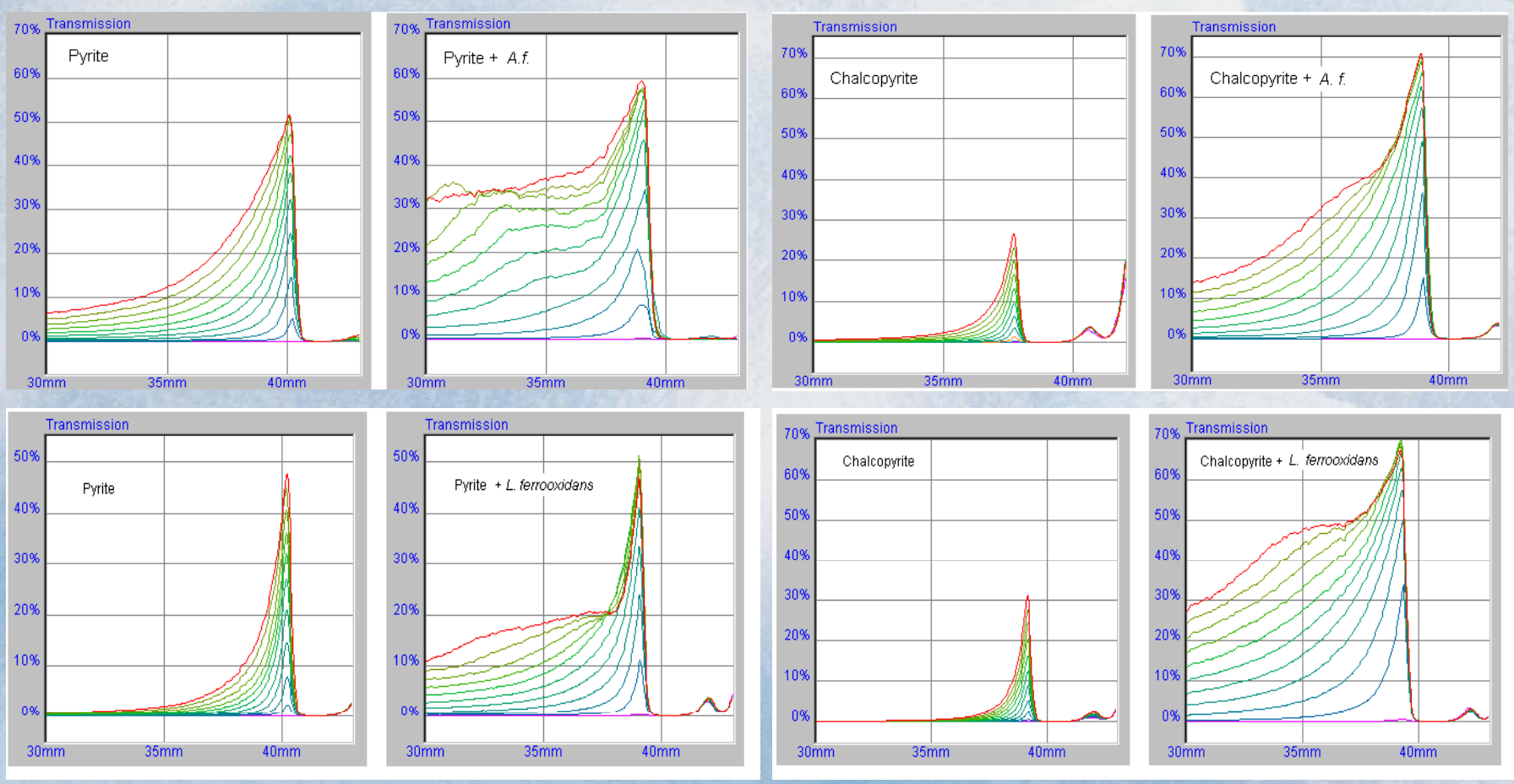


Figure 10. Transmission Graph of pyrite and chalcopyrite suspensions after 10 minutes before and after bacterial treatment

(Bio)mineral processing – Flotation

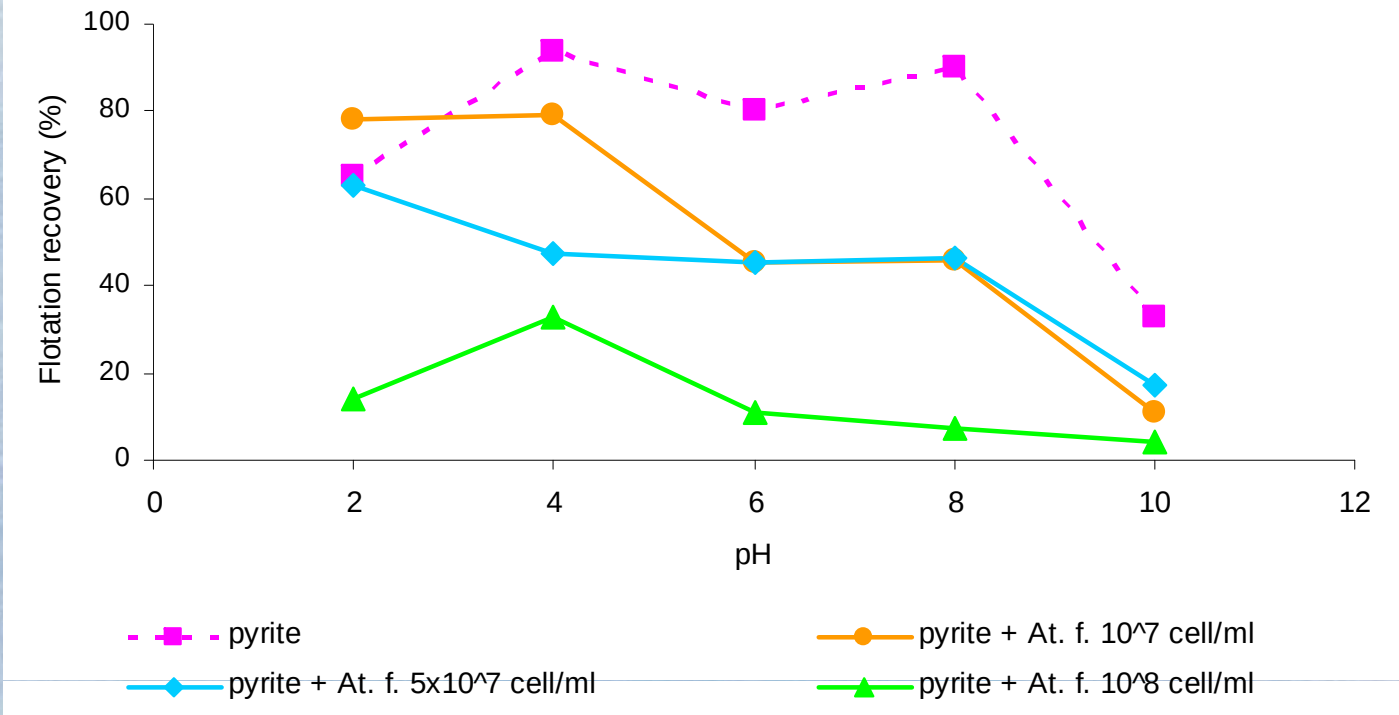


Fig. 11. Flotation of pyrite using different concentrations of *At. ferrooxidans* relative to pH.

(Bio)mineral processing – Flotation

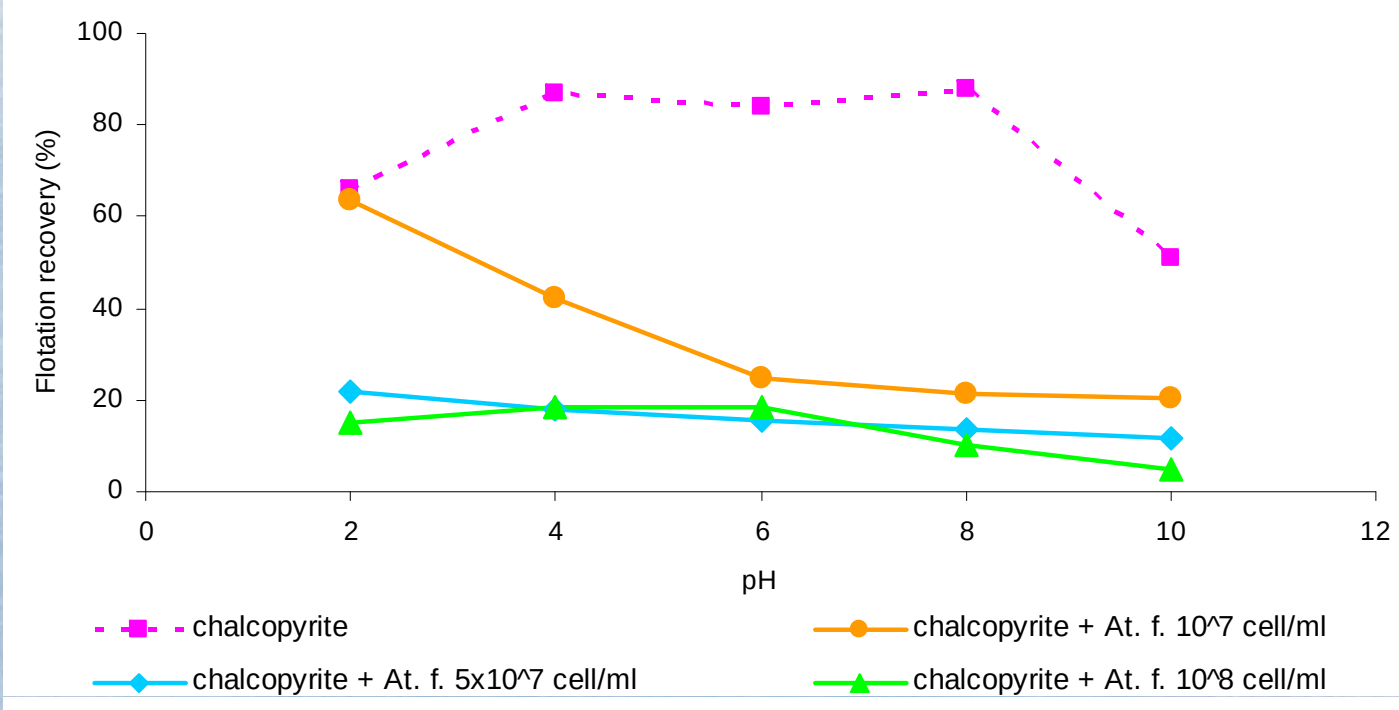


Fig. 12. Flotation of chalcopyrite using different concentrations of *At. ferrooxidans* relative to pH.

(Bio)mineral processing – Flotation

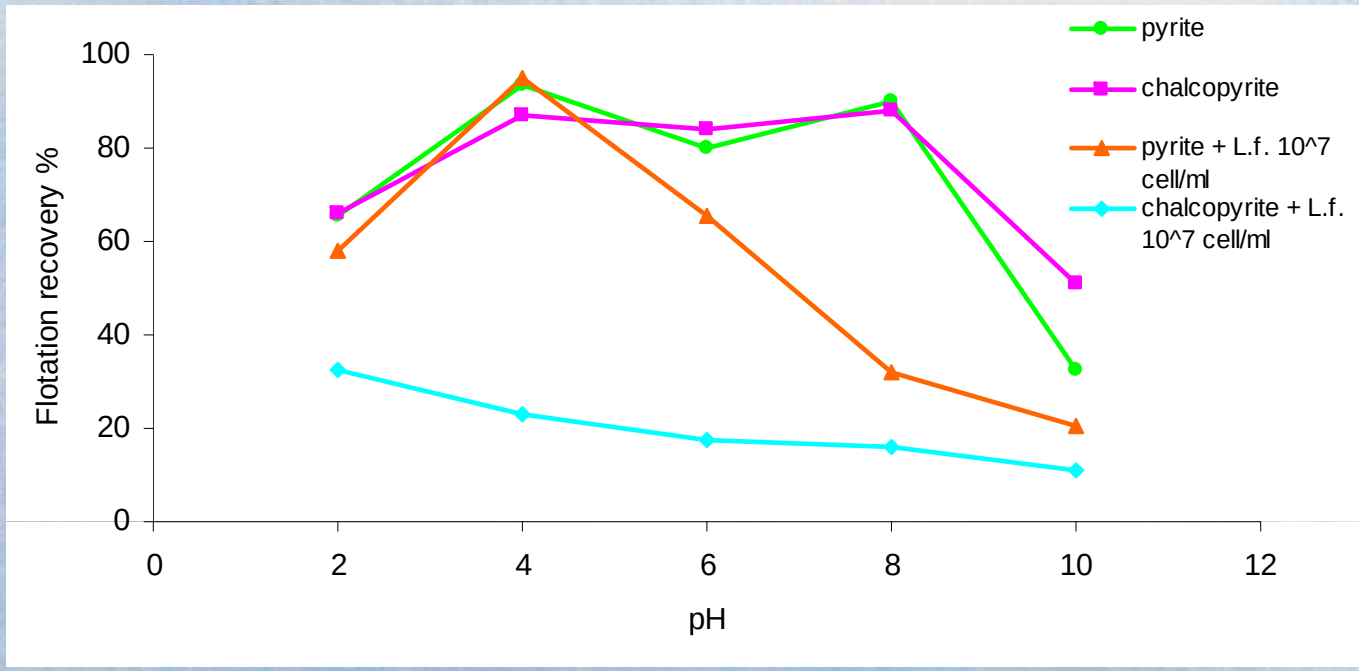


Fig. 13. Flotation of pyrite and chalcopyrite relative to pH

(Bio)mineral processing – Flotation

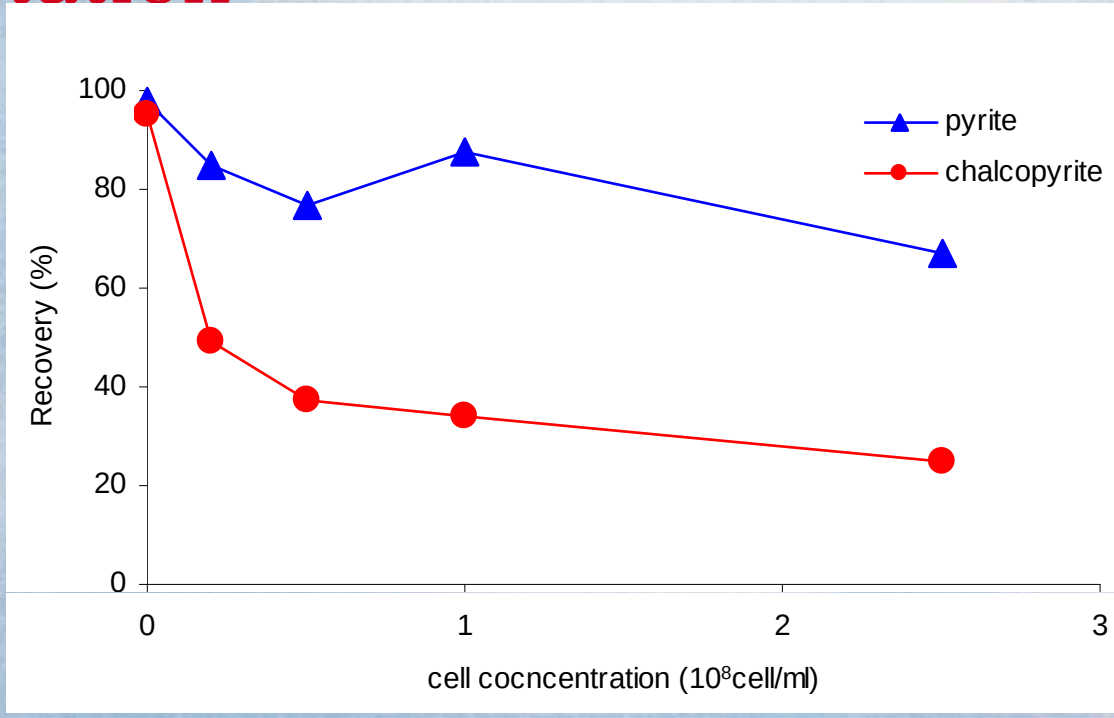


Fig. 14. Flotation of pyrite and chalcopyrite using different concentrations of *L. ferrooxidans* at pH 4.

Summary

- Different surface charge of *Acidithiobacillus* and *Leptospirillum* cells
- Different adhesion – *Acidithiobacillus* cells prefer adhesion to pyrite and *Leptospirillum* cells to chalcopyrite
- Change of surface charge, hydrophilicity, adhesion and chemical composition of surface after metal ion adaptation
- The differences in adhesion are caused by differences in charge and hydrophobicity of bacterial species
- Both species influenced the flotation and flocculation but the processes are more selective after *L. ferrooxidans* treatment

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Thank You for your attention

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