REFFERENCES

Adriaens, P. and Hickey, W.J. 1994. Physiology of biodegradative microorganisms. In D.L. Stoner (ed.), **Biotechnology for the treatment of hazardous waste.** Florida: CRC Press, Inc.

Aiking,H., Govers,H. and Riet,J.V. 1985. Detoxification of mercury, cadmium and lead in *Klebsiella aerogenes* NCTC 418 growing in continuous culture. **Appl. Environ. Microbiol.**50:1262-1267.

Alloway, B.J., ed. 1995. **Heavy metals in soils.** 2nd ed., pp. 122-147. London:Chapman and Hall.

Atlas.R.M. and Bartha,R. 1981. **Microbial Ecology Fundamentals and Applications.** Addison-Wesley Publishing Company, Inc. Philippines.

Batstone, R., Smith, J.E. and Wilson, D., eds. 1989. The safe disposal of hazardous wastes: the special needs and problems of developing countries. Vol.II. Washiton, D.C.: The World Bank.

Beveridge,T.J. 1989a. Metal ions and bacteria. In T.J. Beveridge and R.J. Doyle (eds.), **Metal ions and bacteria.** New York: John Wiley & Sons, Inc.

Beveridge,T.J. 1989b. Role of cellular design in bacterial metal accumulation and mineralization. In L.N.Ornston, A.Balows and E.P.Greenberg.(ed.), **Annu. Rev. Microbiol.** Vol.43. pp.147-171. California. Annual

Bhattacherjee,J.W. 1986. Effect of cadmium and zinc on microbial adhesion, growth,and metal uptake. **Bull. Environ. Contam. Toxicol.** 36:396-400.

Blackwell,K.J., Singleton,I. and Tobin,J.M. 1995. Metal cation uptake by yeast: a review. **Appl.Microbiol.Biotechnol.** 43:579-584.

Boyle, C.D. and Reade, A.E. 1983. Characterization of two extracellular polysaccharides from marine bacteria. **Appl. Environ. Microbiol.** 46(2): 392-399.

Brady,D,Stoll,A.D., Starke,L. and Duncan,J.R. 1994. Chemical and enzymatic extraction of heavy metal binding polymers from isolated cell walls of *Saccharomyces cerevisiae.* **Biotechnol. Bioeng.** 44:297-302.

Brady,D.and Duncan,J.R. 1994. Bioaccumulation of metal cation by *Saccharomyces cerevisiae.* **Appl.Microbiol.Biotechnol.** 41:149-154.

Brierley, C.L., Brierley, J.A. and Davidson, M.S. 1989. Applied microbial processes for metals recovery and removal from wastewater. In T.J. Beveridge and R.J. Doyle (eds.), **Metal Ions and Bacteria** New York: John Wiley & Sons, Inc.

Brown,M.J. and Lester,J.N. 1979. Metal removal in activated sludge: The role of bacterial extracellular polymers. **Wat.Res.** 13: 817-837.

Brown,M.J. and Lester,J.N. 1980. Comparison of bacterial extracellular polymer extraction. **Appl.Environ.Microbiol.** 40(2):179-185.

Brown,M.J. and Lester,J.N. 1982a. Role of bacterial extracellular polymers in metal uptake in pure bacterial culture and activated slude-I. Effects of metal concentration. **Wat.Res.** 16:1539-1548.

Brown,M.J. and Lester,J.N. 1982b. Role of bacterial extracellular polymers in metal uptake in pure bacterial culture and activated slude-II. Effects of mean cell retention time. **Wat.Res.** 16:1549-1560.

Burke,B.E. and Pfister,R.M. 1986. Cadmium transport by a Cd^{2+}-sensitive and a Cd^{2+}-resistant strain of *Bacillus subtilis*. **Can.J.Microbiol.**32:539-542.

Burn. D.T., Townshend, A. and Carter, A.H. eds. 1981. Inorganic reaction chemistry volume 2: reactions of the elements and their compounds. pp. 81-86. New York : John Wiley & Sons.

Butt,T.R. and Ecker,D.J. 1987. Yeast metallothionein and applications in biotechnology. **Microbiol. Rev.** 51(3):351-364.

Carvalho,R.P.de, Chong,K.H. and Volesky,B. 1994. Effects of leaded alginate on metal biosorption. **Biotechnol.Lett.** 16(8):875-880.

Charmnarong, T.1999.**Removal of soluble copper by exopolysaccharide isolated from copper-resistant bacterial isolates.** Master's Thesis, Chulalongkorn University.

Chen,J.H., Lion,L.W., Ghiorse,W.C. and Shuler,M.L. 1995. Mobilization of adsorbed cadmium and lead in aquifer material by bacterial extracellular polymers. **Wat.Res.** 29(2):421-430.

Cheremisinoff, P.N., ed. 1995. **Handbook of water and waste water treatment technology**, pp. 413-447. Marcel Dekker, Inc.

Congregado, F and others, 1985. Preliminary studies on the production and composition of the extracellular polysaccharide synthesized by *Pseudomonas* sp. EPS-5028. **Biotechnol. Lett.** 7(12): 883-888.

Cotton, F.A. and Wilkinson, G., eds. 1980. **Advanced inorganic chemistry a comprehensive text.** 4 th ed., pp.589-603. New York : John Wiley & Sons, Inc.

Delost, M.D. 1997.ed. **Introduction to diagnostic microbiology: a text and workbook.** pp. 164-205. St.Louis : Mosby, Inc.

Doherty,F.G., Failler,M.L. and Cherry,D.S. 1988. Metallothionein-like heavy metal binding protein levels in asiatic clams are dependent on the duration and mode of exposure to cadmium. **Wat.Res.** 22(7):927-932.

Domingue, G.J. 1983. The entericbacilli : medically significant enterobacteriaceae and Vibrionaceae. In N.R. Rose and A.L. Baron (eds.), **Microbiology: basic principles and clinical applications** pp. 155-179. New York : Macmillan Publishing Company.

Doyle, R.J. 1989. How cell walls of gram positive bacteria interact with metal ions. In T.J. Beveridge and R.J. Doyle (eds.), **Metal Ions and Bacteria** New York: John Wiley & Sons, Inc.

Doyle,J.J., Marshall,R.T. and Pfander,W.H. 1975. Effects of cadmium on the growth and uptake of cadmium by microorganism. **Appl. Microbiol.** 29(4):562-564.

Dubois, M., Gilles, K.A., Hamilton, J.K., Rebers, P.A. and Smith, F. 1956. Colorimetric method for determination of sugars and related substances. **Anal.Chem.** 28(3):350-356.

Ehrlich, H.L. 1994. Inorganic hazardous waste amenable to biological transformation. In D.L. Stoner (ed.),pp.27-39. **Biotechnology for the treatment of hazardous waste.** Florida: CRC Press, Inc.

Ensley, B.D. 1994. Genetic strategies for strain improvement. In D.L. Stoner (ed.), **Biotechnology for the treatment of hazardous waste.** Florida: CRC Press, Inc.

Fergursson, J.E., e.d. 1990. **The heavy elements : chemistry, environmental impact and health effects.**Oxford:Pergamon Press.

Ferris,F.G. 1989. Metallic ion interaction with the outer membrane of gram-negative bacteria. In T.J. Beveridge and R.J. Doyle (eds.), **Metal Ions and Bacteria** New York: John Wiley & Sons, Inc.

Flemming,H.C., Schmitt,J. and Marshall,K.C. 1996. Sorption properties of biofilms. In W.C.Frostner (ed.). **Sediments and Toxic Substances.** pp.115-157. Germany, Springer.

Gadd, G.M. 1983. The use of solid medium to study effects of cadmium, coper and zinc on yeasts and yeast-like fungi:applicability and limitations. **J. Appl. Bacteriol.** 54:57-62.

Gadd,G.M. 1990a. Metal tolerance. In C.Edwards, ed.,**Microbiology of extreme Environments.** Buckingham: Open University Press, Celtic Court

Gadd, G.M. 1990b. Heavy metal accumulation by bacteria and other microorganisms. **Experientia.** 46:834-839.

Geesey, G.G. and Jang, L. 1989. Interaction between metal ions and capsular polymers. In T.J. Beveridge and R.J. Doyle (eds.), **Metal Ions and Bacteria** pp.325-358. New York: John Wiley & Sons, Inc.

Gehrke, T., Telegdi, J., Thierry, D. and Sand, W. 1998. Importance of extracellular polymeric substances from *Thiobacillus ferrooxidans* for bioleaching. **Appl. Eniviron.Microbiol.** 64(7):2743-2749.

Ghosh, S. Sadhukhan, P.C., Chaudhuri, J. Ghosh, D.K. and Mandel, A. 1996. Volatilization of mercury-resistant bacterial cells. **J. Appl. Bacteriol.** 81: 104-108.

Gourdon, R.,Rus,E.,Bhende,S.and Sofer,S.S. 1990. Mechanism of cadmium uptake by activated slude. **Appl.Microbiol.Biotechnol.** 34:274-278.

Hallas, L.E. and others. 1982. Factors affecting the toxic effect of tin on estuarine microorganisms. **Appl. Environ.Microbiol.** 44(1): 193-197.

Higham,D.P., Sadler,P.J. and Scawen,M.D. 1984. Cadmium-resistant *Pseudomonas putida* synthesizes novel cadmium proteins. **Science.** 7(sep):1043-1045.

Higham,D.P., Sadler,P.J. and Scawen,M.D. 1985. Cadmium resistance in *Pseudomonas putida*: growth and uptake of cadmium. **J.Gen. Microbiol.** 131:2539-2544.

Holmes, J.D. and others. 1997. Cadmium-specific formation of metal sulfide 'Q-particles' by *Klebsiella pneunoniae*, **Microbiol.** 143:2521-2530.

Houba,C. and Remacle,J. 1984. Removal of cadmium by micro-organisms in a two-stage chemostat. **Appl.Environ.Microbiol.** 47:1158-1160.

Hoyle,B. and Beveridge,T.J. 1983. Binding of metallic ions to the outer membrane of *Escherichia coli*. **Appl.Environ.Microbiol.** 46(3):749-752.

Hoyle,B.D. and Beveridge,T.J. 1984. Metal binding by the peptidoglican sacculus of *Escherichia coli* K-12. **Can.J.Microbiol.** 30:204-211.

Hutchins, S.R., Davidson, M.S., Brierley, J.A. and Brierley, C.L. 1986. Microorganisms in reclamation of metals. In L.N. Ornston (ed.) **Annu. Rev. Microbiol.** Vol.40, pp. 311-336. California: Annual Reviews Inc.

Ji, G. and Silver, S. 1995. Bacterial resistance mechanisms for heavy metals of environmental concern. **J. Indust.Microbiol,** 14:61-75.

Joho,M., Imai,M. and Murayama,T. 1985. Different distribution of Cd^{2+} between Cd-sensitive and Cd-resistant strains of *Saccharomyces cerevisiae.* **J. Gen. Microbiol.** 131:53-56.

Kefela,M.I. and others. 1994. Cadmium biosorption and toxicity to laboratory grown *Xanthomonas campestris*. In D.L.Pyle (ed.). **Separation for Biotechnology 3.** p.249-254. Cambridge, Bookcraft (Bath) Ltd.

Koneman, E.W., Allen, S.D., dowell, V.R. and Summer, H.M., eds. 1984. **Color atlas and textbook of diagnostic microbiology.** 2 nd ed., pp. 448-449. Philadelphia : J.B. Lippin Cott Company.

Krueger, C.L. and Sheikh, W. 1987. A new selective medium for isolating *Pseudomonas* spp. from water. **Appl. Environ. Microbiol.** 53(4) : 895-897.

Kuhre, W.L., ed. 1995. **Practical management of chemicals and hazardous wastes.** pp.182-195. New Jersey : Prentice-Hall, Inc.

Kuhn,S.P. and Pfister,R.M. 1989. Adsorption of mixed metals and cadmium by calcium alginate immobilized *Zoogloea ramigera.* **Appl.Microbiol.Biotechnol.** 31:613-618.

Kurek, E. and others. 1982. Sorption of cadmium by microorganisms in competition with other soil constituents. **Appl.Environ.Microbiol.** 43(5):1011-1015.

Kuyucak,N. and Volesky,B. 1988. Biosorbent for recovery of metals from industrial solutions. **Biotechnol.Lett.** 10(2):137-142.

Laddaga,R.A., Bessen,R. and Silver,S. 1985. Cadmium-resistant mutant of *Bacillus subtilis* 168 with reduced cadmium transport. **J. Bacteriol.** 162:1106-1110.

Laddaga, R.A. and Silver, S. 1985. Cadmium uptake in *Escherichia coli* K-12. **J. Bacteriol.** 162(3): 1100-1105.

Lamberg,P.A. 1988. Isolation of exopolysaccharides. In I.C.Hancock and I.R. Poxton (ed.). **Bacterial Cell Surface Techniques.** p.121-125 John Wiley and Sons.

Laws. E.D., ed. 1981. **Aquatic pollution an introduction text,** pp.301-351. New York: John Wiley&Sons.

Linstedt, K.D., Houck, C.P. and O'Connor, J.T. 1971. Trace element removals in advanced wastewater treatment processes. **J. Wat. Pollut. Control Fed.** 43: 1507-1513.

Lowry, O.H., Rosebrough, N.J., Farr, A.L. and Randall. R.J. 1951. Protein measurement with the follin phenol reagent. **J.Biol.Chem.** 193:265-275.

Macaskie,L.E. and Dean,A.C.R. 1982. Cadmium accumulation by micro-organisms. **Environ.Technol.Lett.** 3:49-56.

Macaskie,L.E. and Dean,A.C.R. 1984a. Heavy metal accumulation by immobilized cells of a *Citrobacter* sp. **Biotechnol. Lett.** 6(2):71-76.

Macaskie,L.E., Dean,A.C.R. 1984b. Cadmium accumulation by immobilized cells of *Citrobacter* sp. **Environ.Technol.Lett. 5:177-186.**

Margaritis, A. and Pace, G.W. 1985. Microbial polysaccharides. In M. Moo-Young (ed.), **Comprehensive biotechnology the principle: Applications & regulations of biotechnology in industry, agriculture and medicine.** Vol.3, pp.1005-1044.

Marquis,R.E., Mayzel,K. and Carstensen,E.L. 1976. Cation exchange in cell walls of gram-positive bacteria. **Can.J.Microbiol.** 22:975-982.

Maruyama, T., Hahnan, S.A. and Cohen, J.M. 1975. Metal removal by physical and chemical treatment processes. **J. Wat.Pollut.Control Fed.** 47(5):962-975.

Marzal,P., Seco,A. and Gabaldon,C. 1996. Cadmium and zinc adsorption onto activated carbon: influence of temperature, pH and metal/ carbon ratio. **J.Chem.Technol.Biotechnol.** 66:279-285.

Matis,K.A. and Zouboulis,A.I. 1993. Flotation of cadmium-loaded biomass. **Biotechnol.Bioeng.** 44:354-360.

McCutcheon,F.G. and Musgrave, J.R. 1954. Cadmium. In C.A.Hampel, (ed.), **Rare Metals Handbook.** pp.1-86. Reinhold publishing corporation: New York.

Meijer, G.W., Beems, R.B., Janssen, G.B., Vaessen, H.A.M.G. and Speijers, G.J.A. 1996. Cadmium and atherosclerosis in the rabbit reduced atherogenesis by superseding of iron. **Food. Chem.Toxic.** 34:611-621.

Mowell, J.L. and Gadd, G.M. 1984. Cadmium uptake by *Aureobasidium pullulans.* **J. Gen. Microbiol.** 130:279-284.

Nakajima,A. and Sakaguchi,T. 1986. Selective accumulation of heavy metal by microorganisms. **Appl.Microbiol.Biotechnol.** 24:59-64. New York, John Wiley & Sons. p.228-237.

Nielands, J.B. 1989. Siderophore systems of bacteria and fungi. In T.J. Beveridge and R.J. Doyle (eds.), **Metal Ions and Bacteria.** pp.141-164. New York:John Wiley & Sons, Inc.

Nies,D.H. 1995. The cobalt,zinc,and cadmium efflux system CzcABC from *Alcaligenes eutrophus* Function as a Cation-Proton Antiporter in *Escherichia coli.* **J.Bacteriol.** 177(10):2707-2712.

Nieto, J.J., Fernandez-Castillo, R. Marquez, M.C., Ventosa, A. Quesada, E. and Ruiz-Berraquero, F. 1989. Survey of metal tolerance in moderately halophilic eubacteria. **Appl. Environ. Microbiol.** 55(9):2385-2390.

Norberg,A.B. and Enfors,S-O. 1982. Production of extracellular polysaccharide by *Zoogloea ramigera.* **Appl.Environ.Microbiol.** 44(5):1231-1237.

Norris,P.R. and Kelly,D.P. 1977. Accumulation of cadmium and cobalt by *Saccharomyces cerevisiae.* **J.Gen. Microbiol.** 99:317-324.

Norberg, A.B. and Persson, H. 1984. Accumulation of heavy-metal ions by *Zoogloea ramigera.* **Biotechnol.Bioeng.** 26:239-246.

O'neill, P., ed. 1993. **Environmental chemistry.** 2 nd ed., pp. 215-221. New Delhi : Chapman & Hall.

Orskov, F. and Orskov, I. 1982. Gram-negative rods : Enterobacteriaceae. In A.I. Braude (ed.). **Microbiology.** pp. 341-352. Tokyo: W.B. Sauders Company.

Park, J.K., Jin, Y.B. and Chang, H.N. 1999. Reusable biosorbents in capsules from *Zoogleae ramigera* cells for cadmium removal. **Biotechnol. Bioeng.** 63(1) : 116-121.

Parsons, A.B. and Dugan, P.R. 1971. Production of extracellular polysaccharide matrix by *Zoogloea ramigera*. **Appl.Microbiol.** 21(4):657-661.

Perry,R.D. and Silver,S. 1982. Cadmium and manganese transport in *Staphylococcus aureus* membrane vesicles. **J. Bacteriol.** 150(2):973-976.

Pollution Control, Department. 1997. **Cadmium.** Bangkok: The national register of potentially toxin chemicals.

Puranik,P.R., Chabukswar,N.S. and Paknikar,K.M. 1995. Cadmium biosorption by *Streptomyces pimprina* waste biomass. **Appl. Microbiol. Biotechnol.**

Rand. M.C., Greenberg, A.E. and Taras,, M.J., eds. 1976. **Standard method for the exammination of water and wastewater,** 14 th ed.,pp. 144-161. Baltimore: American Public Health Association-American Water Works associatio Water Pollution Control Federation.

Rayner, M.H. and Sadler, P.J. 1989. Cadmium accumulation and resistance mechanisms in bacteria. In R.K. Poole and G.M. Gadd (eds.), **Metal microbe interactions.** pp. 39-63.

Reichardt, W. 1996. Ecotoxicity of certain heavy metals affecting bacteria-mediated biogeochemical pathways in sediments. In C.U. Forstner (ed.) **Sediments and toxic substances** pp. 159-178. Springer : New York.

Robert, I.S. 1996. The biochemistry and genetics of capsular polysaccharide production in bacteria. In L.N. Ornston (ed.) **Annu. Rev. Microbiol.** Vol.50, pp.285-315. California : Annual Reviews Inc.

Sakaguchi,T. and others. 1979. Accumulation of cadmium by green microalgae. **European J.Appl.Microbiol.** 8:207-215.

Sanglimsuwan,S. and others. 1993. Resistance to and uptake of heavy metals in mushrooms. **J. Ferment. Bioeng.** 75(2):112-114.

Scott.J.A. and Karanjkar,A.M. 1992. Repeated cadmium biosorption by regenerated *Enterobacter aerogenes* biofilm attached to activated carbon. **Biotechnol.Lett.** 14(8):737-740.

Scott.J.A. and Palmer,S.J. 1988. Cadmium Bio-sorption by bacterial exopolysaccharide. **Boitechnol.Lett.** 10(1):21-24.

Scott.J.A. and Palmer,S.J. 1990. Sites of cadmium uptake in bacteria used for biosorption. **Appl. Microbiol.Biotechnol.** 33:221-225.

Seguin,C. and Hamer,D.H. 1987. Regulation in vitro of metallothionein gene binding factors. **Science** , 235(March):1383-1386.

Shaikh, Z.A. and Tewari, P.C. 1990. Similarities between metallothionein and low molecular weight testicular cadmium-binding protein. **Experientia** 46:694-696.

Shumate,S.E. and Strandberg,G.W. 1985. Accumulation of metals by microbial cells. In C.W.Robinson and J.A.Howell (ed.). **Comprehensive Biotechnology.** Vol 4. p.235-247. Oxford, Pergamon Press Ltd.

Sidhu, M.S. and Olsen, I. 1997. S-layer of *Bacillus species*. **Microbiol.** 143:1039-1052.

Silver, S. 1994. Exploiting heavy metal resistance systems in bioremediation. **Res. Microbiol.** 145(1): 61-66.

Silver, S. 1996. Bacterial resistances to toxic metal ion: a review. **Gene.** 179:9-19.

Silver, S. and Misra, T.K. 1988. Plasmid-Mediated heavy metal resistances. In L.N. Ornston,A. Balows and P. Baumann (ed.), **Ann. Rev.Microbiol.** pp.717-743. california,Annual Reviews Inc.

Silver, S., Misra, T.K. and Laddaga, R.A. 1989. Bacterial resistance to toxic heavy metals. In T.J. Beveridge and R.J. Doyle (eds.). **Metal Ions and Bacteria**, pp.121-140. New York: John Wiley & Son, Inc.

Silver,S. and Phung,L.T. 1996. Bacterial heavy metal resistance: new surprises. **Annu.Rev.Microbiol.** 50:753-789.

Silver, S. and Walderhaug, M. 1992. Gene regulation of plasmid-and chromosome-determined inorganic ion transport in bacteria. **Microbiol.Rev.** 56(1):195-228.

Sitting, M., ed. 1976. Toxic metals pollution control and water protection, pp.73-96. New Jersey: Noyes Data.

Sleytr, U.B., Messner, P., Minnikin, D.E., Hecklels, J.E., Virji, M. and Russell, R.B.B. 1988. Surface of bacteria and their envelopes. In I. Hancock and I. Poxton (eds.), pp. 17. **Bacterial cell surface techniques.** Chichester : John Wiley & Sons.

Stoepple, M., ed. 1992. **Hazardous metals in the environment**, pp.177-194. Amsterdam:Elsevier science Publishers.

Sutherland, I.W. 1985. Biosynthesis and composition of gram-negative bacterial extracellular and well polysaccharides. **Annu. Rev. Microbiol.** 39: 243-270.

Sutherland, I.W. 1990. **Biotechnology of microbial exopoly-saccharides.** Cambridge, Cambridge University Press.

Taylor, W.H. and Juni, E. 1961. Pathway for biosynthesis of a bacterial capsular polysaccharide. **J. Bacteriol.** 81: 688-693.

Ting,Y.P., Lawson,F. and Prince,I.G. 1989. Uptake of cadmium and zinc by the alga *Chlorella vulgaris*:part 1.Individual ion species. **Biotechnol. Bioeng.** 34:990-999.

Tobin,J.M.,Cooper,D.G. and Neufeld,R.J. 1984. Uptake of metal ion by *Rhizopus arrhizus* biomass. **Appl.Microbiol.Biotechnol.** 47:821-824.

Tomas, J.M., Ciurana, B. and Jofre, J.T. 1986. New, simple medium for selective, differential recovery of *Klebsiella* spp. **Appl. Environ. Microbiol.** 51(6):1361-1363.

Trevors,J.T., Stratton,G.W. and Gadd,G.M. 1986. Cadmium transport, resistance and toxicity in bacteria, algae and fungi. **Can. J. Microbiol.** 32:447-464.

Tyneaka,Z., Gos,Z. and Zajac,J. 1981. Reduced cadmium transport determined by a resistance plasmid in *Staphylococcus aureus*. **J. Bacteriol.** 147(2):305-312.

Volesky,B. and Prasetyo,I. 1994. Cadmium removal in a biosorption column. **Biotechnol. Bioeng.** 43:1010-1015.

Volesky,B., May,H. and Holan,Z.R. 1993. Cadmium biosorption by *Saccharomyces cerevisiae*. **Biotechnol.Bioeng.** 41:826-829.

Wang,C.L. and others. 1997. Cadmium removal by a new strain of *Pseudomonas aeruginosa* in aerobic culture. **Appl.Environ. Microbiol.** 63(10):4075-4078.

Webb, J.S., McGinness, S. and Lappin-Scott, H.M. 1998. Metal removal by sulphate reducing bacteria from natural and constructed wetlands. **J.Appl.Microbiol.** 64(7):2743-2747.

Wehrheim, B. and Wettern,M. 1994. Biosorption of cadmium, copper and lead by isolated mother cell walls and whole cells of *Chlorella fusca*. **Appl.Microbiol.Biotechnol.** 41:725-728.

Williams,A.G. and Wimpenny,J.W.T. 1977. Exopolysaccharide production by *Pseudomonas* NCIB 11264 grown in batch culture. **J.Gen.Microbiol.**

Wood,J.M. and Wang,H-K. 1983. Microbial resistance to heavy metals. **Environ.Sci.Technol.** 17(12):582A-590A.

Xue,H-B., Stumm,W. and Sigg,L. 1988. The binding of heavy metals to algal surfaces. **Wat.Res.** 22(7):917-926.

Yong,P. and Macaskie,L.E. 1997. Effect of substrate concentration and nitrate inhibition on product release and heavy metal removal by a *Citrobacter* sp. **Biotechnol.Bioeng.** 55(6):821-830.

Yoshida,N., Morinaga,T. and Murooka,Y. 1993. Isolation and characterization of a heavy metal-binding protein from a heavy matal-resistant strain of *Thiobacllus* sp. **J. Ferment. Bioeng.** 76(1):25-28.

APPENDIX A : THE DETAIL OF ALL SAMPLES

Sample no.	Characteristics of sample	Sampling Site	Date
	Soil		
1.	Rough gray	around of the chemistry II building	28 Jan. 97
3.	Black, wet	In village	30 Jan. 97
5.	Gray, dry	Mining plant	30 Jan. 97
7.	Black, wet	Sewage treatment plant, Hauy Kwang	4 Mar. 97
18.	Blue, dry	Mining plant	28 Jun. 97
23.	Mud, brown	Farm in province of Pratumthanee	7 Apr.98
24.	Dry, soil	Farm in Thonburi	9 Apr. 98
26.	Rough, brown	Mining plant	10 Apr. 98
27.	Mud, brown	Chemical plant	10 Apr. 98
28.	Black, wet	Mining plant	10 Apr. 98
29.	Brown, wet	Bang-pre industry	10 Apr. 98
31.	Brown, wet	Chicken farm in Samut-Songkarm	20 Apr. 98
32.	Brown, wet	Duck farm	20 Apr. 98
33.	Black, wet	Industrial plant	20 Apr.98
34.	Black, wet	Industrial plant	20 Apr.98
	Water		
10.	White, turbidity	ICI paint plant, Co.	19 Mar. 97
13.	Black	Nawanakorn Industrial community	27 Jun.97
25.	Turbidity	Canal in Bangkok	7 Apr. 98
	Sediment		
2.	Mud with duck weed	Pool front General Science building	28 Jan. 97
4.	Turbidity	Canal at Victory Monument	30 Jan. 97
9.	Black, putrid smell	Thai-ping industry, Co.	19 Mar. 97
11.	Black, mixed oils	Side Vipawadee Rangsit road	19 Mar. 97
12.	Rough	Nawanakorn Industrial community	27 Jun. 97
14.	Brown	Paint plant	27 Jun. 97
15.	Brown	Ladkrabung Industrial community	27 Jun. 97

Sample no.	Characteristics of sample	Sampling Site	Date
	Sediment		
17.	Brown	Ladkrabung Industrial community	27 Jun. 97
19.	Brown	Canal in Bangkok	15 Nov. 97
20.	Black	Canal in Bangkok	15 Nov. 97
21.	Brown	Canal in Bangkok	16 Nov. 97
30.	Black	Oil industrial plant	20 Apr. 98
	Activated Sludge		
6.	Brown	Sewage treatment plant, Hauy Kwang	4 Mar. 97
8.	Brown	Sewage treatment plant, Si-Phya	4 Mar. 97
16.	Black	Ladkrabung Industrial Community	27 Jun. 97

APPENDIX B : MEDIA

1. MacConkey agar

For isolating and differentiating lactose-fermenting from lactose-non fermenting gram negative enteric bacilli.

Formula : ingredient per liter

Bacto Peptone	17	g
Bacto Proteose Peptone	3	g
Bacto Lactose	10	g
Bacto Bile Salt No.3	1.5	g
Sodium Chloride	5	g
Bacto Agar	13.5	g
Neutral Red	30	mg
Bacto Crystal Violet	1	mg

Final pH 7.1 $\pm$ 0.2 at 25 °C

Direction : suspend 50 grams in 1 liter, distilled or deionize water and boil to dissolve completely. Sterilize in the autoclave for 15 minutes at 15 pounds pressure. Avoid overheating.

2. MacConkey-Inositol-Potassium Tellurite (MCIK)

Formula : ingredient per liter

MacConkey agar	40	g
Myo-inositol	1.8	g
Potassium tellurite	0.003	g

Direction : Suspend MacConkey and warm to dissolve the medium completely. Autoclaved at 121 °C for 15 min and then cooled to

50 °C, filter-sterilized myo-inositol and potassium tellurite were added. After mixing well, the medium was poured into sterile petri plates.

3. Minimal Medium

Formula : ingredient per liter

$(NH_4)_2SO_4$	2	g
KH_2PO_4	13.6	g
$FeSO_4$ $7H_2O$	0.5	mg
1 M $MgSO_4$ $7H_2O$	1	ml
20% Glucose	10	ml
Vitamin B	0.1	ml
20% cas amino acid	5	ml

The glucose, $MgSO_4$ $7H_2O$, and cas amino acid were separated autoclave at 110 °C, 10 min. The another was normal sterilize at 121°C for 15 min.

4. Motility test medium

Formula : ingredient per liter

Beef extract	3	g
Peptone	10	g
NaCl	5	g
Agar	4	g

Final pH = 7.3

5. MR/VP broth

Formula : ingredient per liter

Polypeptone	7	g

Glucose	5	g
Dipotassium phosphate	5	g

Final pH = 6.9 ± 0.2

6. Pseudomonas Selective Isolation Agar (PSIA)

Formula : ingredient per liter

Tryptic Soy	30	g
5% (w/v) nitrofurantoin	7	ml in N,N-dimethylformamide
0.1%(w/v) crystal violet	2	ml in deionized water
Agar	15	g

Two ml of crystal violet were added in 990 ml of Tryptic Soy Agar (TSA). After, autoclaving and cooling the TSA to 50 °C adding 7 ml nitrofurantoin.

7. Salmonella-Shigella Agar (SS)

Formula : ingredient per liter

Bacto Beef Extract	5	g
Bacto Proteose Peptone	5	g
Bacto Lactose	10	g
Bacto Bile Salt No.3	8.5	g
Sodium Citrate	8.5	g
Sodium Thiosulfate	8.5	g
Ferric Citrate	1	g
Bacto Agar	13.5	g
Brilliant Green	0.33	mg
Neutral Red	25	mg

Final pH 7.0 ± 0.2 at 25 °C

Direction : Suspend 60 grams in 1 liter distilled or deionized water and boil carefully for no more than 2-3 min to dissolve completely. Avoid overheating. Do not autoclave.

8. Simmons Citrate Agar

Formula : ingredient per liter

Magnesium Sulfate	0.2	g
Ammonium Dihydrogen Phosphate	1	g
Dipotassium Phosphate	1	g
Sodium Citrate	2	g
Sodium Chloride	5	g
Bacto Agar	15	g
Bacto Brom Thymol Blue	0.08	g

Final pH 6.8 at 25 °C

Direction : To rehydrate the medium, suspend 24.2 grams in 1L, cold freshly distilled water and heat to boiling to dissolve the medium completely. Sterilize in the autoclave for 15 minutes at 15 pounds pressure (121 °C).

9. Triple Sugar Iron Agar (TSI)

Formula : ingredient per liter

Bacto Beef Extract	3	g
Bacto Yeast Extract	3	g
Bacto Peptone	15	g
Proteose Peptone	5	g
Bacto Dextrose	1	g
Bacto Lactose	10	g

Saccharose	10	g
Ferrous Sulfate	0.2	g
Sodium Chloride	5	g
Sodium Thiosulfate	0.3	g
Bacto Agar	12	g
Bacto Phenol Red	24	mg

Final pH 7.4 at 25 °C

Direction : To rehydrate the medium, suspend 65 grams in 1000 ml, cold freshly distilled water and heat to boiling to dissolve the medium completely. Sterilize in the autoclave for 15 minutes at 15 pounds pressure. Allow the tubes to solidify in a slanting position in a manner which will give a generous butt.

10. Tryptic Soy Broth (TSB)

Formula : ingredient per liter

Bacto Tryptone	17	g
Bacto Soytone	3	g
Bacto Dextrose	2.5	g
Sodium Chloride	5	g
Dipotassium Phosphate	2.5	g
(Bacto Agar	15 g; TSA)	

Final pH 7.3 $\pm$ 0.2 at 25 °C

Direction : Suspend 30 grams in 1 liter distilled or deionized water and warm slightly to dissolve completely. Sterilize at 121-124 °C for 15 min.

APPENDIX C : PHENOL-SULFURIC ACID METHOD

Reagent :

(i) 67% conc. (V/V) Sulfuric acid

(ii) Phenol reagent : Added 5 grams reagent-graded phenol to 100 ml distilled water

Procedure

(i) To prepare the stock standard, dissolved 100 mg glucose in 100 ml distilled water (conc. 1 mg/ml). Diluted 1:10 in distilled water just before use to give a solution containing 100 μg glucose per ml. Prepared standards (10-100 μg/ml) from the diluted solution.

(ii) 1.0 ml glucose solution added 1.0 ml of the phenol reagent; mixed rapidly and thoroughly

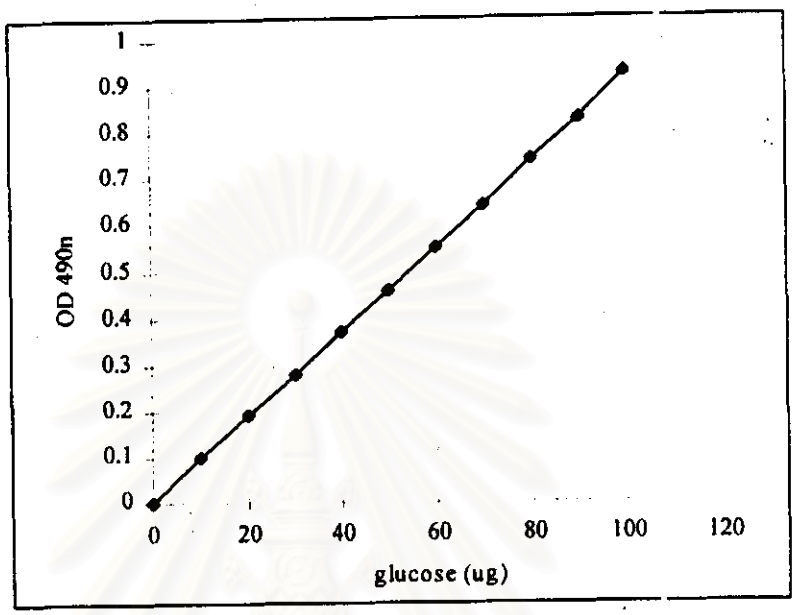
(iii) Added 5.0 ml of concentrated sulfuric acid, mixed rapidly, and let stand for 10 min.

(iv) Placed the tubes in a water bath at 25 C for 15 min.

(v) Read the absorbance of each tube at 490 nm against the blank without glucose using the spectrophotometer.

(vi) Determined the concentration of carbohydrate in the samples from a standard curve prepared by plotting the absorbances of the standards versus the concentration of glucose.

Figure C-1 A linear standard curve of glucose detected by this method



Calculation Method

$$\text{Glucose } (\mu g) = \frac{\text{Absorbance read}}{\text{Slope constant}}$$

Where slope constant equals to 0.0092

APPENDIX D : LOWRY'S METHOD

Reagent :

(i) 2 mg/ml BSA (Bovine Serum Albumin)

(ii) Folin-Ciocalteau reagent (lowry's reagent) composite with:

Reagent A

a. 10 ml of 2.0% (w/v) $NaKC_4H_4O*4H_2O$

b. 10 ml of 1.0% (w/v) $CuSO_4*5H_2O$

c. 200 ml of 2.0%(w/v) Na_2CO_3 in 0.1N NaOH

For reagent A, mix 2 ml of (a), 2 ml of (b) and 196 ml of (c). Reagent A must be freshly prepared.

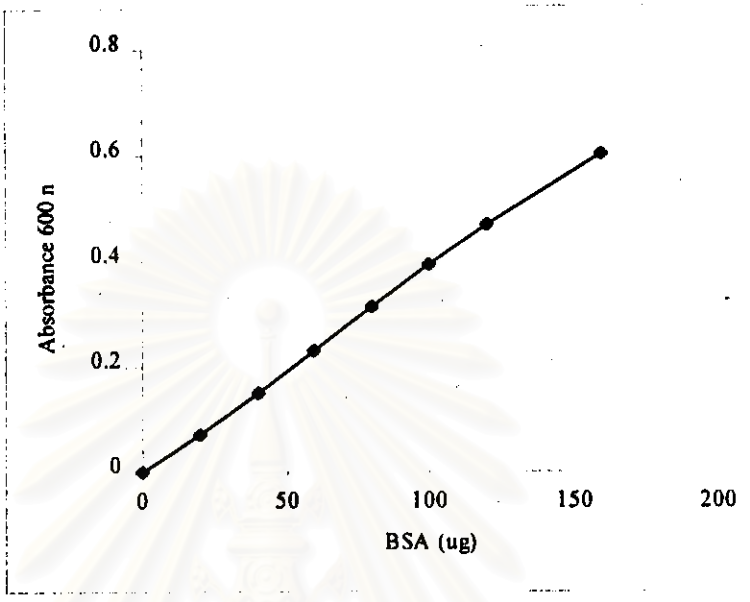
Reagent B (Phenol reagent)

Make 1:3 dilution before used.

Serial dilution standard technique

Prepare a set of 5 serial dilutions (1:2) of standard BSA in the following manner. Pipet 0.5 ml of distilled water into each of five test tube (no.1-5). Pipet 0.5 ml of stock BSA solution (2.0 mg/ml) into tube no.1. Mix gently, and then transfer 0.5 ml of this diluted solution to tube no.2. Continue this dilution to tube no.5. From each tube in this serial dilution set, pipet 0.1 ml solution to another set of 5 test tubes. Add reagent A 3.0 ml, mix well and wait 10 minutes before adding 0.3 ml of reagent B. After 30 minutes, measure the absorbance at 600 nm of every tube. Plot the BSA standard calibration curve (OD vs μg BSA).

Figure D-1 A linear standard curve of Bovine Serum Albumin detected by this method



Calculation Method

$$\text{BSA } (\mu g) = \frac{\text{Absorbance read}}{\text{Slope constant}}$$

Where slope constant equals to 0.00346

APPENDIX E : INFLUENCE OF pH, TEMPERATURE, TIME AND CAMIUM CONCENTRATION TO EPS PRODUCTION

Table E-1 Influence of pH factor on EPS production of each strain.

Strains	pH	Dried weight EPS (mg)	Dried weight cells (mg)	Proportion of EPS (mg) per cell (mg)
87	5	8.46	8.8	0.96
	6	10.68	9.9	1.08
	7	15.41	13.3	1.16
	8	24.70	14.95	**1.65**
	9	18.64	13.0	1.43
98	5	10.85	11.25	0.96
	6	9.50	10.15	0.94
	7	16.29	10.9	**1.49**
	8	17.15	13.0	1.32
	9	18.06	12.75	1.42
205	5	7.19	8.35	0.86
	6	13.45	9.75	1.38
	7	13.92	9.75	1.43
	8	24.70	11.05	2.23
	9	28.91	12.2	**2.37**
207	5	5.25	8.8	0.60
	6	7.40	10.45	0.71
	7	7.73	11.1	0.70
	8	18.90	13.05	1.45
	9	23.55	10.15	**2.32**

Table E-1 (continuous)

Strains	pH	Dried weight EPS (mg)	Dried weight cells (mg)	Proportion of EPS (mg) per cell (mg)
273	5	4.45	16.35	0.31
	6	14.26	16.45	0.87
	7	16.40	14.4	1.00
	8	14.80	12.0	**1.23**
	9	6.70	11.05	0.61

To duplicates, temperature 37 °C, for 24 hr.

Table E-2 Influence of temperature factor on EPS production of each strain.

Strains	Temp.	Dried weight EPS (mg)	Dried weight cells (mg)	Proportion of EPS (mg) per cell (mg)
87	30	14.26	14.4	0.99
	37	19.77	18.65	1.06
	40	11.25	9.87	**1.14**
	45	6.12	7.95	0.77
	50	0	8.95	0
98	30	12.36	12.00	1.03
	37	12.67	12.30	1.03
	40	17.39	12.70	**1.37**
	45	12.77	12.40	1.03
	50	0	7.00	0
205	30	17.47	10.85	**1.61**
	37	15.63	11.75	1.33
	40	20.77	13.40	1.55
	45	18.41	13.95	1.32
	50	0	6.05	0
207	30	9.55	10.85	0.88
	37	9.80	12.10	0.81
	40	16.58	14.80	**1.12**
	45	5.98	6.95	0.86
	50	0	6.50	0
273	30	12.58	13.10	0.96
	37	13.75	12.50	**1.10**
	40	14.61	13.65	1.07
	45	10.88	11.33	0.96
	50	0	7.50	0

To duplicates, adjust pH 7.0, 24 hr.

Table E-3 Influence of time factor on EPS production of each strain.

Strains	Time (hr)	Dried weight EPS (mg)	Dried weight cells (mg)	Proportion of EPS (mg) per cell (mg)
87	24	72.80	62.8	1.16
	48	156.20	62.6	2.49
	72	274.80	55.9	**4.92**
98	24	76.60	52.5	1.46
	48	117.50	61.0	1.93
	72	246.10	77.3	**3.18**
205	24	104.70	42.8	2.45
	48	206.60	57.4	3.56
	72	252.10	61.2	**4.12**
207	24	70.90	41.8	1.70
	48	115.90	49.6	2.34
	72	243.50	62.8	**3.88**
273	24	82.18	53.5	1.93
	48	158.86	58.0	2.74
	72	229.04	63.8	**3.59**

To duplicates, adjust pH 7.0, 37 °C.

Table E-4 Influence of Cd concentration factor on EPS production of each strain.

Strains	Cd conc. (mg/l)	Dried weight EPS (mg)	Dried weight cells (mg)	Proportion of EPS (mg) per cell (mg)
87	0	6.29	4.6	**1.37**
	10	3.84	7.2	0.53
	20	6.23	12.8	0.49
	100	6.07	10.7	0.57
98	0	9.43	6.0	**1.57**
	10	10.18	10.0	1.02
	20	1.05	8.6	0.12
	100	0.40	7.7	0.05
205	0	12.52	8.9	**1.41**
	10	5.13	7.3	0.70
	20	9.00	8.7	1.03
	100	9.77	11.7	0.83
207	0	5.28	7.1	**0.74**
	10	3.26	6.9	0.47
	20	5.32	9.7	0.55
	100	0.74	9.2	0.08
273	0	7.21	6.1	**1.18**
	10	8.83	7.7	1.15
	20	8.44	8.0	1.05
	100	0.81	9.2	0.09

To duplicates, adjust pH 6.0, 37 °C, for 24 hr.

APPENDIX F : COMPARISION OF UPTAKE AND ADSORPTION CADMIUM BY VIABLE CELLS AT DIFFERENT CONCENTRATION

Strains	Initial Cd conc.(mg/l)	Amount of Cd adsorption (mg/l)	%adsorption	Uptake (nM/mg)
CdR-87	10.39	8.56	82.4	75.79
	50.12	30.225	60.3	269.15
	102.50	35.4	34.1	314.92
CdR-98	10.39	8.987	86.5	79.95
	50.12	36.366	72.55	323.51
	102.50	29.50	28.39	262.43
CdR-205	10.39	8.353	80.4	74.31
	50.12	37.49	74.79	333.51
	102.50	23.40	22.52	20.817
CdR-207	10.39	8.826	84.95	78.52
	50.12	38.20	76.21	339.83
	102.50	27.95	26.9	248.64

$$\%\text{adsorption} = \frac{\text{amount of adsorption}}{\text{initial concentration}} \times 100$$

Uptake value ; $Q = V(c_i - c_f)/1000m$

Where Q is the Cd content (mg/g biomass), V the volume of metal solution (ml), c_i the initial concentration of Cd in solution, c_f the final concentration of Cd in solution and m is the mass of biomass (g).

(Puranik, Chabukswar and Paknikar, 1995)

APPENDIX G : CADMIUM AND OTHER METALS BY VIABLE CELLS, DEAD CELLS AND EPS.

Table G-1 Comparison the adsorption of cadmium by viable cells, dead cells and EPS

Strains	Initial Cd conc.(mg/l)	Amount of Cd adsorption (mg/l)		
		Viable cells	Dead cells	EPS
CdR-87	10.39	8.56±0.52 (82.40%)	8.30±0.43 (79.90%)	8.65±0.47 (83.25%)
CdR-98	10.39	8.99±0.57 (86.50%)	8.49±0.43 (81.70%)	9.19±0.46 (88.45%)
CdR-205	10.39	8.35±0.41 (80.40%)	7.57±0.51 (72.90%)	7.70±0.61 (74.15%)
CdR-207	10.39	8.83±0.50 (84.95%)	8.20±0.49 (78.95%)	8.30±0.48 (79.90%)
CdR-273	10.39	8.26±0.50 (79.55%)	7.59±0.51 (73.07%)	8.03±0.48 (77.25%)

Table G-2 Comparison the adsorption of copper by viable cells, dead cells and EPS

Strains	Initial Cu conc.(mg/l)	Amount of Cu adsorption (mg/l)		
		Viable cells	Dead cells	EPS
CdR-87	10.49	1.22±0.47 (11.64%)	3.93±0.60 (37.48%)	3.62±0.78 (34.57%)
CdR-98	10.49	2.81±0.42 (26.78%)	5.56±0.43 (53.06%)	2.83±0.51 (27.03%)
CdR-205	10.49	3.94±0.60 (37.60%)	6.39±0.51 (60.74%)	2.89±0.45 (27.52%)
CdR-207	10.49	4.10±0.39 (39.11%)	6.59±0.42 (62.84%)	3.38±0.58 (32.21%)
CdR-273	10.49	6.196±0.61 (59.09%)	9.48±0.53 (90.45%)	5.11±0.53 (48.76%)

Table G-3 Comparison the adsorption of manganese by viable cells, dead cells and EPS

Strains	Initial Mn conc.(mg/l)	Amount of Mn adsorption (mg/l)		
		Viable cells	Dead cells	EPS
CdR-87	10.09	3.91±0.43 (38.73%)	3.31±0.39 (32.76%)	0.68±0.48 (6.71%)
CdR-98	10.09	4.12±0.55 (40.86%)	3.56±0.52 (35.28%)	3.12±0.41 (30.88%)
CdR-205	10.09	7.89± 0.74 (78.16%)	3.24±0.51 (32.11%)	7.87±0.48 (78.00%)
CdR-207	10.09	6.27±0.38 (62.13%)	4.09±0.45 (40.55%)	3.79±0.48 (37.65%)
CdR-273	10.09	3.76±0.43 (37.26%)	5.84±0.47 (57.86%)	3.12±0.52 (30.95%)

APPENDIX H : EFFECT OF CADMIUM CONCENTRATION TO pH OF MEDIA

Cd conc.(mg/l)	pH in media*	PH in distilled water	pH at soluble Cd in media
0	7.3	8.2	-
100	7.3	5.6	5.5
200	7.2	6.0	5.2
300	7.2	6.0	5.1
400	7.1	6.1	5.0
500	7.1	6.1	5.0
600	7.1	6.1	4.9
700	7.0	6.1	4.8
800	6.8	6.1	4.8
900	6.8	6.1	4.8
1000	6.5	6.1	4.5

* Tryptic Soy Broth

BIOGRAPHY

Miss Anicha Luengchaichawang was born in Ratchaburi on the 11 th of November, 1973. She was graduated with Bachelor of Science (Microbiology) in 1994 from Burapha University, Bangsan, Chonburi. A year later, 1995, she was started study in Biotechnology, Faculty of Science, Chulalongkorn University.