REFERENCES

Albert, A. 1985. **Selective toxicity**. London: Cambridge Press.

Albright, L. J., Wentworth, J. W. and Wilson, E. M. 1972. Technique for measuring metallic salt effects upon the indigenous heterotrophic microflora of a natural water. **Water Res**. 6: 1589 – 1596.

Ashida, J., Higashi, N. and Kikuchi, T. 1963. An electron microscopic study on copper Precipitation by copper – resistant yeast cells. **Protoplasma**. 57: 27 – 32.

Azad, H. S. and king, D. L. 1965. **Evaluating the Effect of Industrial Wastes on Lagoon Biota**. 20th Industrial Waste Conference, Purdue University, Lafayette.

Baker, D. E. 1990. Copper. **In** B. J. Alloway (ed.), **Heavy metal in soils**. New York : John Wiley & Sons.

Beliles, R. P. 1975. Metals. **In** L. J. Casarett and J. Doull (ed.), **Toxicology : the basic science of poison**. New York: Macmillan Publishing Co., Inc.

Bendell, G. W. and Darnall, D. W. 1990. Immobilization of nonviable, biosorbent algal Biomass for the recovery of metal ions. **In** B. Volesky (ed.), **Biosorption of Heavy Metals**. Boca Raton: CRC Press.

Beveridge, T. J. and Koval, S. F. 1981. Binding of metals to cell envelope of *Escherichia coli* K-12. **Appl. Environ. Microbiol**. 42: 325.

Beveridge, T. J. and Murray, R. G. E. 1976. Uptake and retention of metal by cell walls of *Bacillus subtilis*. **J. Bacteriol**. 127: 1502.

Bird, N. P., Chambers, J. G., Leech, R. W., and Cummins, D. 1985. A note on the use of metal species in microbiological tests involving growth media. **J. Appl. Bateriol.** 59: 353-355.

Bishop, D. F. and Jaworski, N. A. 1988. Biological treatment of toxics in wastewater : the Problems and opportunities. **In** R. J. Scholze (ed.), **Biotechnology for degradation of Toxic chemicals in hazardous wastes**. America: Noyes Data Corporation.

Blundell, M. R. and Wild, D. G. 1969. Inhibition of bacterial growth by metal salts. **J. Biochem**. 115: 207.

Borst – Pauwels, G. W. F. H. 1981. Ion transport in yeast. **Biochem. Biophys. Acta**. 650 : 88 – 127.

Boughton, J. B. and Hardy, W. T. 1934. **The Metals**, pp. 1624. New York : John Wiley & Sons.

Boyden, R., Potter, V. R. and Elvehjem, C. A. 1938. **The Metals**. pp. 1623. New York : John Wiley & Sons.

Bremer, P. J. and Loutit. The effect of Cr (III) on the form and degradability of a Polysaccharide produced by a bacterium isolated from a marine sediment. **Mar. Environ. Res.** 20: 249.

Bremner, J. 1974. Heavy metal toxicities. **Q. Rev. Biophys**. 7: 75 – 124.

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

Brierley, C. L., Kelly, D. P., Seal, K. J. and Best, D. J. 1985. Material and biotechnology. **In** I. J. Higgins, D. J. Best and J. Jones (ed.), **Biotechnology Principles and Applications**. Oxford: Blackwell Scientific Publication.

Brown, M. J. and Lester, J. N. 1982. Role of bacteria extracellular polymers in metal uptake in pure bacterial cultures and activated sludge – I Effect of metal concentration. **Water Res**. 16: 1539.

Brown N. L., Barrett, S. R., Camakaris, J., Lee, B.T.O., and Rouch, D. A. 1995. Molecular genetics transport analysis of the copper-resistance determinant (pco) from *Escherichia coli* plasmid pRJ 1004. **Mol. Microbiol**. 17: 1153-1166.

Brown N. L., Lee, B.T.O., and Silver, S. 1994. Bacterial transport of and resistance to copper. **In** H. Sigel and A. Sigel (ed.), **Metal ion in biological systems**. New York: Dekker.

Buchanan, R. E., and Gibbons, N. E., (eds.). 1974. **Bergey 's manual of determinative Bacteriology**. 8th Edition. Baltimore: The Williams & Wilkins Company.

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

Cassity, T. R. and Kolodziej, B. J. 1984. Role of the capsuled by *Bacillus megaterium* ATCC 19213 in the accumulation of metallic cations. **Microbios**. 41: 117.

Cooksey, D. A. 1993. Copper uptake and resistance in bacteria. **Mol. Microbiol.** 7: 1-5.

Cooksey, D. A. 1994. Molecular mechanisms of copper resistance and accumulation in bacteria. **FEMS. Microbiol. Rev**. 14: **381-386.**

Cookson, J. T. 1995. **Bioremediation engineering design and application.** New York : McGraw Hill.

Crist, R. H., Oberhosler, K., Shank, N. and Naygen, M. 1981. Nature of bonding between metallic ions and algal cell walls. **Environ. Sci. Technol**. 15: 1212 – 1217.

Darnall, D. W., Greene, B. and Gardea – Torresdey, J. 1988. Gold binding by algae. **In** P. R. Norris and D. P. Kelly (ed.), **Biohydrometallurgy**. Kew : Science and Technology Letters.

Darnall, D. W., Greene, B., Henzl, M. T., Hosea, J. M., McPherson, R. A., Sneddon, J. and Alexander, M. D. 1986. Selective recovery of gold and other metal ions from an algal biomass. **Env. Science Technol**. 20: 206 – 208.

Davis, M. L., and Cornwell, D. A. 1991. **Introduction to environmental engineering**. Singapore: McGraw Hill.

Drbal, K., Veber, K. and Zahradnik. 1985. Toxicity and accumulation of copper and cadmium In the alga *Scenedesmus obliqnus* LH. **Bull. Environ. Contam. Toxicol**. 34: 904.

Dugan, P. R. 1972. **Biochemical Ecology of Water Pollution**. New York: Plenum Press.

Eagon, R. G. 1956. Studies on polysaccharide formation by *Pseudomonas fluorescens*. **Can. J. Microbiol.** 2: 673-676.

Easson, D. D., Peoples, O. P., and Sinskey, A. J. 1990. *Zoogloea* Transformation Using Exopolysaccharide Non-Capsule Producing Strains. **US. Patent No. 4**, 948,733.

Echarti, C.E.B., Hirschel, B., Boulnois, G. J., Varley, J. M., Waldvogel, F., and Timmis, K. N. 1983. Cloning and analysis of the K1 capsule biosynthesis genes of *Escherichia coli* : lack of homology with *Neisseria meningitidis* group B DNA sequence. **Infection and Immunity.** 41: 54-60.

Eckenfelder, W. W. 1970. **Water Quality Engineering for Practicing Engineers**. New York : Barnes & Noble, Inc.

Ehrlich, H. L. 1984. **Geomicrobiology**. New York: Dekker.

Ensley, B. D. 1994. Genetic strategies for strain improvement. **In** D. L. Stoner. (ed.), **Biotechnology for the Treatment of Hazardous Waste.** Boca Raton : Lewis Publishers.

Esmond, S. E. and Petrasek A. C. 1974. Trace Metal Removal. **Ind. Water Eng**. May / June : 14 – 17.

Ferris, F. G. and Beveridge T. J. 1986. Physicochemical roles of soluble metal cations in the outer membrane of *Escherichia coli* K-12. **Can. J. Microbiol**. 32: 594.

Ferroni, G. D. and Boadi, K. N. 1990. Physiology of exopolymer production by a psychrotrophic bacterium. **J. Gen. Appl. Microbiol**. 36: 93 – 103.

Gadd, G. M. and Giffiths, A. J. 1980. Influence of pH on toxicity and uptake of copper in *Aureobasidium pullulans*. **Trans. Br. Mycol. Soc**. 75: 91 – 96.

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

Gadd, G. M. 1986. Fungal responses towards heavy metals. **In** R. A. Herbert and G. A. Codd (ed.), **Microbes in Extreme Environments**. London: Academic Press.

Gadd, G. M. 1986. The uptake of heavy metals by fungi and yeasts : The chemistry and physiology of the process and applications for biotechnology. **In** H. Eccles and S. Hunt (ed.), **Immobilization of Ions by Bio – Sorption**. U.K.: Ellis Hardwood.

Gadd, G. M. 1990. Metal tolerance. **In** C. Edwards (ed.), **Microbiology of extreme Environment**. U.S.A.: McGraw – Hill.

Gadd, G. M. 1992. Microbial control of heavy metal pollution. **In** J. C. Fry, G. M. Gadd, R. A. Herbert, C. W. Jones and I. A. Watson – Craik (ed.), **Microbial Control of Pollution**. Cambridge Press.

Geesey, G. G. and Jang, L. 1989. Interaction between metal ions and capsule polymer. **In** T. J. Beveridge and R. J. Doyle (ed.), **Metal ions and bacteria**. New York : John Wiley & Sons.

Geesey, G. G. and Jang, L. 1990. Extracellular polymers for metal binding. **In** H. L. Ehrlich and C. L. Brierley (ed.), **Microbial Mineral Recovery**. New York: McGraw – Hill.

Hancock, I., and Poxton, I. 1988. **Bacterial Cell Surface Techniques**. New York : John Wiley & Sons.

Heliovaara, K. and Vaisanen, R. 1993. **Insects and Pollution**. United States: CRC Press.

Hollo, J., Toth, J., Tengerdy, R. P. and Johnson, J. E. 1979. Denitrification and removal of heavy metals from wastewater by immobilized microorganisms. **In** K. Venkatsubramanian (ed.), **Immobilized Microbial Cells**. Washington : American Chemical Society.

Horitsu, H., Takagi, M. and Tomoyeda, M. 1978. Isolation of a mercuric chloride – tolerant Bacterium and uptake of mercury by the bacterium. **Eur. J. Appl. Microbiol. Biotechnol**. 5: 279 – 290.

Kallquist, T. and Meadows, B. S. 1978. The toxic effect of copper ion on algae and rotifers from a soda lake (Lake Nukuru, East Africa). **Water Res**. 12: 771.

Kaplan, D., Christiaen, D. and Arad, S. 1987. Chelating properties of extracellular polysaccharide from *Chlorella* spp. **Appl. Microbiol. Biotechnol**. 53: 2953 – 2956.

Kauffman, J. W., Langhlin, W. C. and Baldwin, R. A. 1986. Microbiological treatment of uranium mine water. **Environ. Sci. Technol**. 20: 243 – 248.

Kelly, D. P., Norris, P. R. and Brierley C. L. 1979. **In** A. T. Bull, D.C. Ellwood and C. Ratledge (ed.), **Microbial Technology,** Current State, Future Prospects. Cambridge University Press.

Kendrick, M. J., May, M. T., Plishka, M. J. and Robinson, K. D. 1992. **Metal in biological systems**. England: Ellis Horwood Ltd.

Kiff, R. J. and Little, D. R. 1986. **In** H. Eccles and S. Hunt (ed.), **Immobilization of Ions by Biosorption**. Chichester: Ellis Horwood.

Kuyucak, N. 1990. Feasibility of biosorbents application. **In** B. Volesky (ed.), **Biosorption of heavy metals**. Boca Raton: CRC Press.

Laube, V. M., McKenzie, C. N. and Kushner, D. J. 1980. Strategies of response to copper, Cadmium and lead by a blue – green and a green algae. **Can. J. Microbiol**. 26 : 1306-1311.

Lee, Y. A., Hendson, M., Panopoulus, N. J., and Schroth, M. N. 1994. Molecular cloning, Chromosomal mapping and sequence analysis of copper resistance gene from *Xanthomonas campestris pv. Juglandis* : homologous with blue copper proteins and multicopper oxidase. **J. Bacteriol.** 176: 173-188.

MacLeod, R. A., Kuo, S. C. and Gelinas, R. 1967. Metabolic injury to bacteria II Metabolic injury induced by distilled water of copper in the plating diluent. **J. Bacteriol.** 93 : 317-324.

Manzini, G., Cesaro, A., Delben, F., Paoletti, S. and Reisenhofer, E. 1984. Copper (II) binding by natural ionic polysaccharides. Part I. Potentiometric and spectroscopic data. **Bioelectronchem. Bioenerg**. 12: 443 – 454.

Martell, A. E. 1971. Principles of complex formation. **In** S. J. Faust and J. V. Hunter (ed.), **Organic Compounds in Aquatic Environments**. New York: Dekker.

McLean, R. J., and T. J. Beveridge. Metal-Binding Capacity of Bacterial Surfaces and Their Abilty to Form Mineralized Aggregates. **In** H. L. Ehrlich and C. L. Brierley (ed.), **Microbial Mineral Recovery.** New York: McGraw Hill Publishing.

Minney, S. F. and Quirk, A. V. 1985. Growth and adaptation of *Saccharomyces cerevisiae* at different cadmium concentrations. **Microbios**. 42: 37 – 44.

Mittleman, M. w. and Geesey, G. G. 1985. Copper – binding characterization of exopolymers from a freshwater sediment bacterium. **Appl. Environ. Microbiol**. 49: 846.

Moat, A. G., and Foster, J. W. 1995. **Microbial Physiology.** New York: Wiley-Liss.

Munger, K., Germann, N. A. and Lerch, K. 1985. Isolation and structural organization of the *Neurospora* copper metallothionein gene. **EMBO J**. 4: 1459 – 1462.

Murphy, R. J., and Levy, J. F. 1983. Production of copper oxalate by some copper tolerant Fungi. **Br. Mycol. Soc**. 81; 165 – 168.

Nakajima, A., Horikoshi, T. and Sakaguchi, T. 1982. Recovery of uranium by immobilized microorganisms. **Eur. J. Appl. Microbiol. Biotechnol**. 16: 88 – 91.

Nakajima, A. and Sakaguchi, T. 1986. Selective accumulation of metals by microorganisms. **Appl. Microbiol. Biotechnol**. 24: 59 – 64.

Norberg, A. and Rydin, S. 1984. Development of a continuous process for metal accumulation by *Zoogloea ramigera*. **Biotechnol. Bioeng**. 26: 265 – 268.

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

Norris, P. R. and Kelly, D. P. 1979. Accumulation of bacteria and yeasts. **Dev. Ind. Microbiol**. 20: 299 – 308.

Odermatt, A., Suter, H., Krapf, R., and Solioz, M. 1993. Primary structure of two P-type ATPase involved in copper homeostasis in *Enterococcus hirae.* **J. Biol. Chem.** 268 : 12775-79.

Oliver, B. G. and Cosgrove, E. G. 1974. The Efficiency of Heavy Metal Removal by a Conventional Activated Sludge Treatment Plant. **Water Res**. 10: 157 – 163.

Paker A. J. 1981. Copper. **In** J. F. Loneragan, A. D. Robson and R. D. Graham (ed.), **Copper In Soils and Plants**. New York: John Wiley & Sons.

Poolvey, F. E. 1982. **Nature**. 296: 642 – 643.

Roane, T. M., Pepper, I. L. and Miller, R. M. 1996. Microbial remediation of metals. **In** R. L. Crawford and D. L. Crawford (ed.), **Bioremediation Principles and Applications**. Cambridge University Press.

Roberts, I. S., Mountford, R., Hodge, R., Jann, K., and Bouluosis, G. J. 1988. Common Organization of gene clusters for production of different capsular polysaccharides (K antigens) in *Escherichia coli*. **J. Bacteriol.** 170: 1305-1310.

Rudd, T., Sterritt, R. m. and Lester, J. N. 1983. Mass balance of heavy metal uptake by encapsulated culture of *Klebsiella aerogenus*. **Microb. Ecol**. 9: 261.

Saiz – Jimenez, C. and Shafizadeh, F. 1984. Iron and copper binding by fungal phenolic polymers. **Curr. Microbiol**. 10: 281 – 286.

Sakaguchi, T. and Nakajima, A. 1982. A recovery of uranium by chitin phosphate and chitosan phosphate. **In** S. Mirano and S. Tokura (ed.), **Chitin and Chitosan**. Japan : The Japanese Society of Chitin and Chitosan.

Schoot, H. and Young, C. Y. 1973. Electrokinetic studies of bacteria III : Effect of polyvalent metal ions on electrophoretic mobility and growth of *Streptococcus faecalis*. **J. Pharm. Aci.** 62 : 1797.

Shatzman, A. R. and Kosman, D. J. 1979. Characterization of two copper – binding component of the fungus *Daetylium dendroides*. **Arch. Biochem. Biophys**. 19 : 226 – 235.

Shorrocks, V. M. and Alloway, B. J. 1987. Copper in Plant, Animals and Human Nutrition. Copper Development Assn., Potters Bar, cited in Baker, D. E. 1990. **In** B. J. Alloway (ed.), **Heavy metal in soils**. New York: John Wiley & Sons.

Silver, S. 1981. Mechanism of plasmid-determined heavy metal resistance. **In** S. B. levy, R. C. Clowes and E. L. Koenig (ed.), **Molecular Biology, Pathogenecity and Ecology of Bacterial Plasmids**. New York: Plenum.

Silver, S., Misra, T. K. 1984. Bacterial transformations of and resistances to heavy metals. **In** G. S. Omenn and A. Hollaender (ed.), **Genetic Control of Environmental Pollutants.** New York: Plenum.

Silver S. and Phung, L. T. 1996. Bacterial heavy metal resistance: new surprises. **Annu. Rev. Microbiol.** 14: 381-386.

Sittig, M. 1977. **How to remove pollutant and toxic materials from air and water.** USA : Noyes data corporation.

Smithson. G. R. 1971. **An investigation of techniques for the removal of chromium from electroplating wastes**. U.S.A.: U.S. E.P.A. Press.

Solioz, M., Odermatt, A., and Krapf, R. 1994. Copper pumping ATPase : common concepts in bacteria and man. **FEBS. Lett.** 346: 44-47.

Spear, P. A. and Pierce, R. C. 1979. Copper in the aquatic environment : chemistry, distribution and toxicology. **National Research Council of Canada 16454**.

Starodub, M. E., Wong, P. T. S. and Mayfield, C. I. 1987. Short term and long term studies on individual and combined toxicities of copper, zinc and lead to *Scenedesmus quadricanda.* **Sci. Tot. Environ**. 63: 101.

Steiner, A. E., McLaren, D. A. and Forster, C. F. 1976. The Nature of Activated Sludge Flocs. **Water Res**. 10: 25 – 30.

Sterritt, R. M. and Lester, J. N. 1986. Heavy metal immobilization by bacterial extracellular polymers. **In** H. Eccles and S. Hunt (ed.), **Immobilization of ion by bio – sorption**. Chichester: Ellis Horwood.

Stojkovski, S., Magee, R. A. and Leisegang, J. 1986. Molybdenum binding by *Pseudomonas Aeruginosa*. **Aust. J. Chem**. 39: 1205.

Stokinger, H. E. 1986. **The metals**. New York: John Wiley & Sons.

Stoner, D. L. 1994. **Biotechnology for the Treatment of Hazardous Waste.** Boca Raton : Lewis Publishers.

Summer, A. O. 1985. Bacterial resistance to toxic elements. **Trends Biotechnol.** 40: 607-634.

Sutherland, I. W. 1980. Polysaccharide in the adhesion of marine and freshwater bacteria. **In** R. C. W. Berkeley, J. M. Lynch, J. Melling and B. Vincent (ed.), **Microbial Adhesion To Surfaces**. U.K.: Ellis Horwood.

Sutherland, I. W. 1990. **Biotechnology of microbial exopolysaccharide.** Cambridge : Cambridge Press.

Sutter, H. P., Jone, E. B. G. and Walchli, O. 1983. The mechanisms of copper tolerance in *Poria placenta* (FR.) Cke. and *Poria vaillanti* (Pers.) Fr. **Mater. Org**. 18: 243 – 263.

Tan, E. L. and Loutit, M. W. 1976. Concentration of molybdenum by extracellular material produced by rhizosphere bacteria. **Soil Biol. Biochem**. 8: 461.

Taylor, E. W., Beaumont, M. W., Butler, P. J., Mair, J. and Mujallid, M. S. I. 1996. Lethal and sub – lethal effects of copper upon fish : a role for ammonia toxicity?. **In** E. W. Taylor (ed.), **Toxicity of Aquatic Pollution Physiological, Molecular and Cellular Approaches**. Cambridge University Press.

Tchobanoglous, G., Theisen. H., and Vigil, S. 1993. **Integrated solid waste management.** New York: McGraw Hill.

Tobin, J. M., Cooper, D. G. and Neufeld, R. J. 1987. Influence of anions on metal adsorption by *Rhizopus arrhizus* biomass. **Biotechnol. Bioeng**. 30: 882 – 886.

Tobin, J. M., Cooper, D. G. and Neufeld, R. J. 1987. The effect of cation competition on metal adsorption by *Rhizopus arrhizus* biomass. **Biotechnol Bioeng**. 31: 282 –286.

Townsley, C. C. and Ross, I. S. 1985. Copper uptake by *Penicillium spinulosum*. **Microbios**. 44: 125 – 132.

Townsley, C. C. and Ross, I. S. 1986. Copper uptake in *Aspergillus niger* during batch growth and in non – growing mycelial suspensions. **Exp. Mycol**. 10: 281 – 288.

Tsezos, M. 1984. Recovery of uranium from biological adsorbents – desorption equilibrium. **Biotechnol. Bioeng**. 26: 973 – 981.

Tsezos, M., Baird, M. H. I. And Shemit, L. W. 1987. The elution of radium adsorbed by microbial biomass. **The Chemical Engineering J**. 34: 57 – 64.

Tsezos, M., McCready, R. G. L. and Bell, J. P. 1989. The continuous recovery of uranium from biologically leached solution using immobilized biomass. **Biotecnol. Bioeng**. 34: 10 – 17.

Tsezos, M. 1990. Engineering aspect of metal binding by biomass. **In** H. L. Ehrlich and C. L. Brierley (ed.), **Microbial Mineral Recovery**. New York : McGraw – Hill Publishing Company.

Unz, R. F. and Farrah, S. R. 1976. Exopolymer production and flocculation by *Zoogloea* MP6. **Appl. Environ. Microbiol.** 31: 623-626.

Voleskey, B. 1990. **Biosorption of heavy metals**. Boca Raton : CRC Press.

Wakutsuki, T., Imahara, H., Kitamura, T. and Tanaka, H. 1979. On the absorption of copper into yeast cell. **Agric. Biol. Chem**. 43: 1687 – 1692.

Washington, J. A. and Sutter, V. L. 1980. Dilution susceptibility test: agar and macro-broth dilution procedures. **In** E. H. Lennette, A. Balows, W. T. Hausler, Jr. and J. P. Truant (ed.) **Manual of clinical microbiology**, 3rd ed. American Society for Microbiology, Washington D.C.

Wentz, C. A. 1995. **Hazardous Waste Management**. Second edition. Singapore: McGraw – Hill.

Wilkinson, J. F. 1958. Extracellular bacterial polysaccharides. **Bacteriological Reviews.** 22: 46-69.

Wilkinson, J. F. and Stark, G. H. 1956. The synthesis of polysaccharide by washed suspensions of *Klebsiella aerogenes*. **Proc. Roy. Physical. Soc., Edinburgh.** 25: 35.

Williams, A. G. and Wimpenny, J. W. T. 1977. Exopolysaccharide production by *Pseudomonas* NCIB 11264 grown in batch culture. **J. Gen. Microbiol.** 102: 13-21.

Zunino, H. and Martin, J. P. 1977. Metal binding organic macromolecules in soil. **Soil Sci**. 123: 65 – 76.

Zunino, H. and Martin, J. P. 1977. Metal - binding organic macromolecules in soil 2. Characterization of the maximum binding ability of the macromolecules. **Soil Sci**. 123: 188.

APPENDIX A

BACTERIAL SOURCES

In this present study, 50 samples were chosen as bacterial source. They were collected during February 1997 to December 1997, and were categorized into various groups as follows :

Soil

The soil samples were collected from:

- Thai Copper Rods industry, Bang Phe, Samut Prakarn
- Copper plating, Bangkhen, Bangkok
- Zip industry, Samutsakorn
- Copper plating, Nonthaburi
- Yinguan plating industry, BangPhe, Samut Prakarn
- Yongsin plating, Ratchaburana, Bangkok
- Suthichai plating, Thonburi
- GENCO, Bang Khun Tain, Bangkok
- Faculty of science, Thammasat University
- Faculty of science, Chulalongkorn University
- Faculty of science, Kasetsat University
- Rice field, Uttradit
- Rice field, AmPhoe Sena, Ayuddaya
- Orange orchard, Nonthaburi
- Duck farm (1), Ban Prew, Nakornprathom
- Duck farm (2), Ban Prew, Nakornprathom

- Chicken farm (1), Ban Prew, Nakornprathom
- Chicken farm (2), Ban Prew, Nakornprathom
- Pig farm (1), Ban Prew, Nakornprathom
- Pig farm (2), Ban Prew, Nakornprathom
- Pop farm, ban Prew, Nakornprathom
- CP farm, Ban Prew, Nakornprathom
- ICI, Laksi, Bangkok
- Garbage heap, Faculty of Science, Thammasat University
- Garbage heap, Faculty of Science, Chulalongkorn University
- Chaopraya River, Bangkok
- Chaopraya River, Thammasat University, Bangkok
- Klong Taweewattana Nongkam, Bangkok
- Chemical industry, Bangkok
- Industrial Sector, Ayuttaya
- Fertilizer, Bangkok

Wastewater

The samples were collected from:

- Thai Copper Rods industry, Bang Phe, Samut Prakarn
- Zip industry, Samutsakorn
- Municipal sewer, Ayuttaya Industrial Sector
- Water drainage, Soi Naksathaporn 2, Phetkasem 69, Nongkam, Bangkok
- Yinguan plating industry, BangPhe, Samut Prakarn
- Yongsin plating, Ratchaburana, Bangkok
- Suthichai plating, Thonburi

- GENCO, Bang Khun Tain, Bangkok
- ICI, Laksi, Bangkok
- Industrial Sector, Ayuttaya

Sludge

The samples were collected from:

- Thai Copper Rods industry, Bang Phe, Samut Prakarn
- Zip industry, Samutsakorn
- Municipal sewer, Ayuttaya Industrial Sector
- Municipal sewer, World Trade Center, Bangkok
- GENCO, Bang Khun Tain, Bangkok

Natural Water

The samples were collected from:

- Chaopraya River, Bangkok
- Chaopraya River, Thammasart University, Bangkok
- Klong Taweewattana, Nongkam, Bangkok
- Meklong River, Samutsongkarm

APPENDIX B

CULTURE MEDIA

Formula

1. Tryptic Soy Agar (TSA) (Difco laboratories, Detroit, Michigan, U.S.A.)

Formula in gram per 1 liter

- Bacto Tryptone Pancreatic Digest of Casein	17
- Bacto Soytone Papaic Digest of Soybean Meal	3
- Bacto Dextrose	2.5
- Sodium Chloride	5
- Dipotassium Phosphate	2.5
- Agar	15

Final pH 7.1

2. Tryptic Soy Broth (TSB) (Difco)

Formula in gram per 1 liter

- Bacto Tryptone Pancreatic Digest of Casein	17
- Bacto Soytone Papaic Digest of Soybean Meal	3
- Bacto Dextrose	2.5
- Sodium Chloride	5
- Dipotassium Phosphate	2.5

Final pH 7.1

The TSB medium was prepared by suspending 30 gram of TSB in 1 L of distilled water and added 15 gram of agar when prepare TSA medium and warm slightly to dissolve completely. After, the medium was autoclaved at 121^{o}C for 15 min. All media were dispend in plates and before used, plate was incubated over night.

3. Pseudomonas Selective Isolation Agar (PSIA)

(adapted from Krulger and Sheikh, 1986)

Formula in milliliter and gram per 1 liter

- Nitrofurantoin (5% solution)	7
- Crystal violet (0.1 % solution)	2
- TSB	30
- Agar	15
- Distilled Water	990

Pseudomonas selective isolation agar (PSIA) was prepared as follows. A stock solution of 5 % (wt/vol) nitrofurantoin (Sigma, Steinheim, Germany), was prepared in N,N-dimethyformamide (Merck, Darmsatadt, Germany). A stock solution of 0.1 % (wt/vol) crystal violet (Merck, Darmsatadt, Germany) was prepared in deionized water. The stock solution were stored at room temperature, and nitrofurantoin solution was protected from exposure to light. The medium (PSIA) was prepared by suspending 30 gram of TSB and 15 gram of agar in 990 ml distilled water and added 2 ml of crystal violet stock solution. After the mixture was autoclaved at 121 ^{o} C for 15 min and then cooled to 50^{o}C 7 ml of nitrofurantoin stock solution were added (adapted from Krulger and Sheikh, 1986). All media were dispended in plates and before used plates was incubated over night.

4. MacConkey-inositol-potassium tellurite (MCIK) agar
(adapted from Toman, Cirerana and Jofre, 1986)

Formula in milliliter and gram per 1 liter

- MacConkey Agar 40
- Myo-inositol 10 mM
- Potassium tellurite 0.003

The medium (MCIK) was prepared by suspending 40 gram of MacCongey agar in 1 L of distilled water. After the mixture was autoclaved at 121 ^{o} C for 15 min and then cooled to 50 ^{o} C, myo-inositol (Fluka, Messerschmittstr, Switzerland), final concentration 10 mM. and potassium tellulite (Merck, Darmsatadt, Germany), final concentration, 3 μg/ml were added (adapted from Toman, Cirerana and Jofre, 1986). All media were dispended in plates and before used plates was incubated over night.

5. Shigella and Salmonella (SS) Agar (Difco)

Formula in gram per 1 liter

- Bacto Beef Extract	5
- Bacto Proteose Peptone	5
- Bacto Lactose	10
- Bacto Bile Salt No. 3	8.5
- Sodium Citrate	8.5
- Sodium Thiosulfate	8.5
- Ferric Citrate	1
- Bacto Agar	13.5
- Brilliant Green	0.33 mg
- Neutral Red	0.025

Final pH 7.0 +/- 0.2 at 25°C

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

6. MacConkey Agar (Difco)

Formula in gram per 1 liter

- Bacto Peptone	17
- Bacto Proteose Peptone	3
- Bacto Lactose	10
- Bacto Bile Salts No. 3	1.5
- Sodium Chloride	5
- Bacto Agar	13.5
- Neutral Red	0.03
- Bacto Crystal Violet	0.001

The medium was prepared by suspending 50 gram of MacCongey agar in 1 L of distilled water and boil to dissolve completely. After, the medium was autoclaved at 121 ^{o}C for 15 min. Avoid overheating. All media were dispended in plates and before used plates was incubated over night.

APPENDIX C

SOME BIOCHEMICAL TEST OF SELECTED BACTERIAL STRAIN

Tests	Bacterial Strain	
	CuR-38	CuR-40
Gram Stain Reaction	-	+
EPS Production	+	+
Endospore Forming	-	+
Catalase	+	ND
Oxidase	+	ND
SS Agar	-	-
Indole	ND	-
Glucose	-	+
MCIK	-	-
Urea	-	ND

ND = Not Done

APPENDIX D

METALS BY ATOMIC ABSORPTION SPECTROPHOTOMETER

Reagents

- Copper : Dissolve 1.00g copper metal in 15 ml of 1+1 HNO_3 and dilute to 1,000 ml with deionized distilled water; 1.00 ml = 1.00 mg Cu
- Zinc : Dissolve 1.00g zinc metal in 20 ml of 1+1 HCl and dilute to 1,000 ml with deionized distilled water; 1.00 ml = 1.00 mg Zn
- Cadmium : Dissolve 1.00g cadmium metal in a minimum volume of 1+1 HCl. Dilute to 1,000 ml with deionized distilled water; 1.00 ml = 1.00 mg Cd
- Manganese : Dissolve 3.07g manganese sulfate monohydrate $MnSO_4.H_2O$, in about 200 ml deionized distilled water; add 1.5 ml conc. HNO_3, and make up to 1,000 ml with deionized water; 1.00 ml = 1.00 mg Mn

Wavelengths and Sensitivities for metal analyses

Metal	Wavelength (nm)	Sensitivity for 1% Absorption (μg/ml)
Copper	324.7	100
Zinc	213.9	15
Cadmium	228.8	25
Manganese	279.5	50

Reference : Rand, M.C., Greenberg, A.E. and Taras, M.J., 1976. **Standard Methods for the Examination of Water and Wastewater**, 14th ed., Baltimore, American Public Health Association-American Water Works Association Water Pollution Control Federation, p. 144-161.

RELATIONSHIP BETWEEN COPPER CONCENTRATION AND THE pH VALUES OF GROWTH MEDIUM

Copper concentration (μg/ml)	pH values		
	TSB	TSA	Distilled Water
0	7.1	7.1	7.1
100	5.0	5.0	5.1
200	4.2	4.3	4.2
300	4.1	4.2	4.1
400	4.0	4.0	4.0
500	3.9	4.0	4.0
600	3.9	4.0	4.0
700	3.9	4.0	4.0
800	3.9	3.9	4.0
900	3.9	3.9	4.0
1,000	3.9	3.9	4.0

APPENDIX E

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) Readed 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.

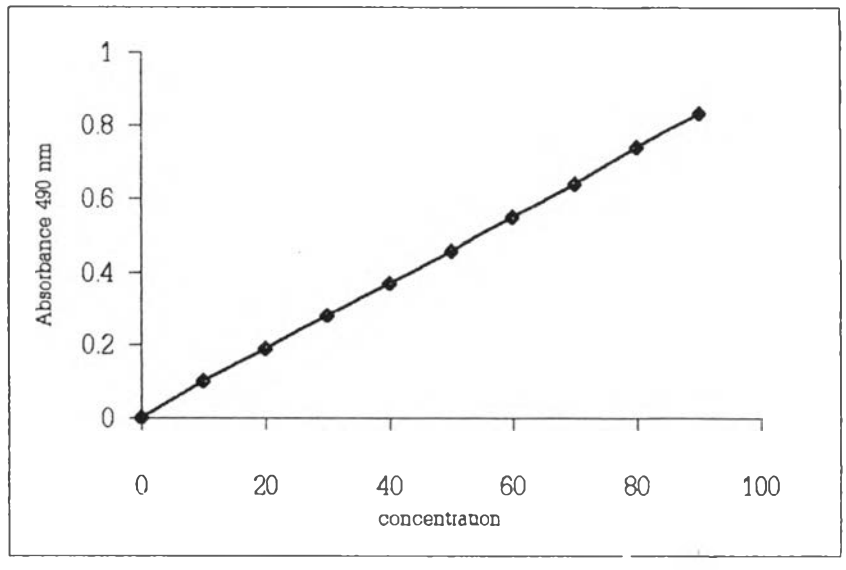

Figure E-1 A linear standard curve of glucose detected by this method

Calculation Method

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

Where slope constant equals to 0.0092

APPENDIX F

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

Prepared 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)

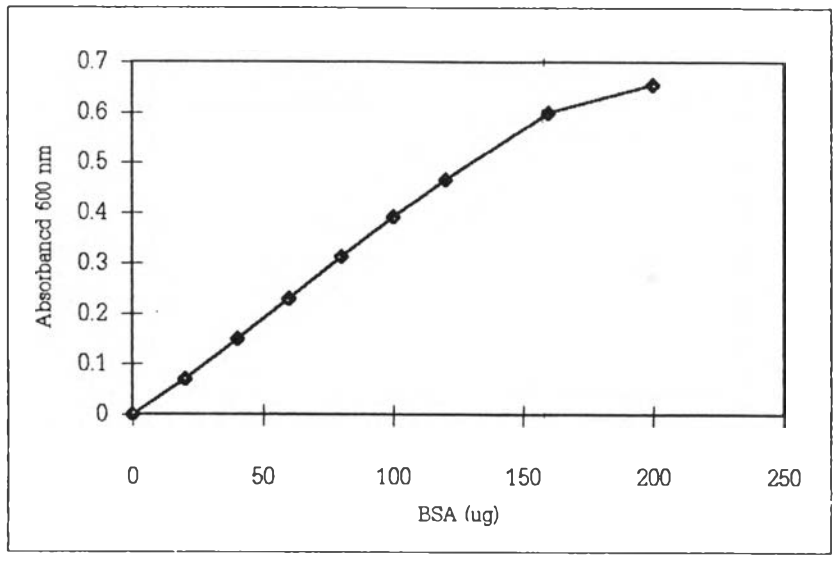

Figure F-1 A linear standard curve of Bovine Serum Albumin detected by this method

Calculation Method

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

Where slope constant equals to 0.00346

BIOGRAPHY

Mr. Torpow Channarong was born in Bangkok on the 18 February 1972. He entered Thammasat University in June 1989 and graduated a Bachelor of Science (Environmental Science) in February 1994. In 1994-1995, he worked at Siam-DHV Ltd. (Bangkok). He furthered his education at the inter-department of Environmental Science, Graduate School of Chulalongkorn University, in 1996.