BIBLIOGRAPHY

LIST OF REFERENCES

1. ACGIH (American Conference of Governmental Industrial Hygienists), 2004, Threshold limit values for chemical substances and physical agents and biological exposure indices. ACGIH, Cincinati, OH, USA.
2. Ackerley, D.F., Gonzalez, C.F., Keyhan, M., Blake, R., and Matin, A., 2004, Mechanism of chromate reduction by the *Escherichia coli* protein, NfsA, and the role of different chromate reductases in minimizing oxidative stress during chromate reduction. *Environmental Microbiology*, 6 (8), 851-860.
3. Ackerley, D.F., Barak, Y., Lynch, S.V., Curtin, J. & Matin, A., 2006, Effect of chromate stress on *Escherichia coli* K-12. *Journal of Bacteriology*, 188, 3371–338
4. Amann, R.I., Ludwig, W., Schleifer, K.-H., 1995, Phylogenetic identification and in situ detection of individual microbial cells without cultivation. *Microbiology Reviews*, 59, 143– 169.
5. APHA, 2005, *Standard Methods for the Examination of Water and Wastewater*. 21st Edition (Centennial Edition). By Eaton, A.D., Clesceri, L.S., Rice, E.W., Greenberg, A.E., Franson, M.A.H., (Eds.). American Public Health Association, American Water Works Association, Water Environment Federation, USA.
6. Baker, M.J., Blowes, D.W., and Ptacek, C.J., 1997, Phosphorous adsorption and precipitation in a permeable reactive wall: applications for wastewater disposal systems. *Land Containment Reclamation*, 5, 189-193.
7. Baldi, F., Vaughan A.M., Olson, G.J., 1990, Chromium (VI)-resistant yeast isolated from a sewage treatment plant receiving tannery wastes. *Applied and Environmental Microbiology*, 56 (4), 913-918.
8. Baral, A., and Engelken, R.D., 2002, Chromium-based regulations and greening in metal finishing industries in the USA. *Environmental Science and Policy*, 5 (2), 121–133.

9. Beceiro-Gonzalez, E,, Barciela-Garcia, J,, Bermejo-Barrera, P., Bermejo-Barrera, A, Fresenius, J., 1992. *Journal of Analytical Chemistry*, 344, p. 301.

10. Benner, S.G., Blowes, D.W., and Ptacek, C.J., 1997, A full-scale porous reactive wall for prevention of acid mine drainage. *Groundwater Monitoring Retention*, 17 (4), 99-107

11. Beszedits, S. ,1988, "Chromium removal from industrial wastewaters," p. 232-263, in O. Nriagu and E. Nieboer (eds.), *Chromium in the Natural and Human Environments*, John Wiley, New York.

12. Blackall, L.L., Burrell, P.C., Bradford, H.D., Bond, P.L., and Hugenholtz, P., 1998, The use of 16S rDNA clone libraries to describe the microbial diversity of activated sludge communities. *Water Science and Technology*, 37 (4-5), 451-454.

13. Blowes, D.W. and Ptacek, C.J., 1992, Geochemical remediation of groundwater by permeable reactive walls: Removal of chromate by reaction with iron-bearing solids. In: *Proc. Subsurface Restoration Conference* (*3rd Int. Conference on groundwater Quality research*, Dallas, Texas, June 1992), 214- 216.

14. Blowes, D.W., Ptacek, C.J.S., Benner, G.C., Mcra, W.T., 1998, Treatment of dissolved metals using permeable reactive barriers, Remediation and Protection. *Proceedings of the GQ'98 Conference* held at 4g3, Tubingen, Germany, IAHS Publ. no. 250.

15. Blowes, D.W., Ptacek, C.J., Waybrant, K.R., Bain, J.D., and Robertson W.D., 1995, In situ treatment of mine drainage water using porous reactive walls. *Proceedings of Ontario Environment and Energy Conference - The new Economy*". Green needs and opportunities, Toronto, Ontario.

16. Borden, R.C., Goin, R.T., Kao, C.M., 1997, Control of BTEX migration using a biologically enhanced permeable barrier. *Ground Water Monitoring and Remediation*, 17, 70-80.

17. Brown, S.D., Thompson, M.R., Verberkmoes, N.C., Chourey, K., Shah, M., Zhou, J.Z., Hettich, R.L. and Thompson, D.K., 2006, Molecular dynamics of the *Shewanella oneidensis* response to chromate stress. *Molecular Cell Proteomics*, 5, 1054-1071.

18. Brock, T.D., and Madigan, M.T., 1991, *Biology of Microorganisms*. 6th Edition. Prentice Hall, New Jersey.

19. Bush, M.B., 2003, *Ecology of a Changing Planet*, 3rd Edition, Prentice Hall, New Jersey, USA.

20. Carsten, V., Albin, A., Helmut, L., Doreen, H., Lothar, W., and Wolfgang, B., 2004, Bioremediation of chlorobenzene-contaminated ground water in an in situ reactor mediated by hydrogen peroxide. *Journal of Contaminant Hydrology*, 68, 121–141.

21. Camargo F.A.O., Bento F.M., Okeke B.C. and Frankenberger W.T., 2003, Chromate Reduction by Chromium-Resistant Bacteria Isolated from Soils Contaminated with Dichromate. *Journal of Environmental Quality*, 32, 1228-1233.

22. Cervantes, C., Campos-Garcia, J., Devars, S., Gutierrez-Corona, F., Loza-Tavera, H., Torres-Guzman, J.C., Moreno-Sanchez, R., 2001, Interactions of chromium with microorganisms and plants. *FEMS Microbiology Review,* 25(3), 335-47.

23. Chirwa, E.M.N., and Wang, Y.T., 1997a, Hexavalent chromium reduction by *Bacillus sp*. in a packed-bed bioreactor. *Environmental Science and Technology*, 31 (5), 1446-1451.

24. Chirwa, E.M.N., 2001, Modelling Chromium (VI) Reduction in Pure and Coculture Biofilm Reactors. Doctoral Thesis, Department of Civil Engineering, University of Kentucky, Lexington, Kentucky, USA.

25. Chirwa, E.M.N., 2005, Uncoupling Cr(VI) reduction in a dual species bacterial culture system electron flow pathway analysis. *Chemical Engineering Transactions*, vol 7, AIDIC, *Proc 8th Processing and Control Conference*,14-18 May 2005, Gardini di Naxos, Sicily, Italy.

26. Chirwa, E.M.N., and Wang, Y.T., 1997a, Hexavalent chromium reduction by *Bacillus sp.* in a packed-bed bioreactor. *Environmental Science and Technology*, 31 (5), 1446–1451.

27. Chirwa, E.M.N., and Wang, Y.T., 1997b, Chromium(VI) reduction by *Pseudomonas fluorescens* LB300 in fixed-film bioreactor. *Journal of*

Environmental Engineering, 123 (8), 760–766.

28. Chuan, M. and Liu, J., 1996, Release Behavior of Chromium from Tannery Sludge. *Water Research*, 30, 932.
29. Cifuentes, F., Lindemann, W., Barton, L., 1996, Chromium Sorption and Reduction in Soil with Implications to Bioremediation. *Soil Science*, 161, 233.
30. Coenye, T., Falsen, E., Vancanneyt, M., Hoste, B., Govan, J.R.W., Kersters, K., Vandamme, P., 1999, Classification of *Alcaligenes faecalis*-like isolates from the environment and human clinical samples as *Ralstonia gilardii* sp. nov. *International Journal of Systematic Bacteriology*, 49, 405–413.
31. Cooke, V. M.; Hughes, M. N.; Poole, R. K., 1995, Reduction of chromate by bacteria isolated from the cooling water of electricity generating station. *Journal of Industrial Microbiology*, 14, 323−328.
32. Cotton, F.A., and Wilkinson, G., 1980, *Advanced Inorganic Chemistry*, A Comprehensive Textt. John Wiley & Sons, New York.
33. Dakiky, M., Khamis, M., Manassra, A., and Mer'eb, M., 2002, Selective adsorption of Cr(VI) in industrial waste water using low-cost abundantly available adsorbents, *Advances in Environmental Research,* 6, 533–540.
34. De Flora, S., 2000, Threshold mechanisms and site specificity in chromium (VI) carcinogenesis. *Carcinogenesis*, 21, 533–541.
35. De Flora, S., Bagnasco, M., Serra, D., and Zanacchi, P., 1990, Genotoxicity of chromium compounds. A review. *Mutation Research*, 238, 99-172.
36. Doherty, R., Phillips, D.H., McGeough, K.L., Walsh, K.P., and Kalin R.M., 2006, Development of modified flyash as a permeable reactive barrier medium for a former manufactured gas plant site, Northern Ireland. *Environmental Geology*, 50, 37–46.
37. Donat, E., Oliver, C., Guruchet, G., 2003, Jan./Mar, Reduction of chromium (VI) by the indirect action of *Thiobacillus thioparus*. *Brazilian Journal of Chemical Engineering*, 20 (1), São Paulo, doi: 10.1590/S0104-66322003000100013.
38. Dries Bastiaens, L., Vos, J., Simons, Q., De Smet, M., and Diels, L., 2004, Comparison of different multi-barrier concepts designed for treatment of

groundwater containing mixed pollutants, in: A. Boshoff, B. Bone, eds., Permeable Reactive Barriers. *International Symposium on Permeable Reactive Barriers*, March 14, 2004, Queens University Belfast Northern Ireland, 298 (2005), 45-51.

39. DWAF, 2005, December 23, Pollution of chrome-6 in the Crocodile River between Brits and the Roodekopjies Dam. Press Release by the Department of Water Affairs and Forestry, Pretoria, South Africa.

40. Eary, L.E., and Rai, D., 1988, Chromate removal from aqueous wastes by reduction with ferrous ion. *Environmental Science and Technology*, 22(8), 972-977.

41. Ehrlich, H.L.,1996, *GeoMicrobiology*, 3rd ed.; Marcel Dekker: Inc.: New York, USA.

42. EC-Official Journal of the European Communities, L330/32, 1998, December 12.

43. Endo, G., Narita, M., Huang, C-.C., and Sliver, S., 2002, Microbial heavy metal resistance transposons and plasmids: potential use for environmental biotechnology. *Journal of Environmental Biotechnology*, 2 (2), 71-82.

44. Ercolini, D., 2004, PCR-DGGE fingerprinting: novel strategies for detection of microbes in food. *Journal of Microbiological Methods*, 314 56 , 297–314.

45. Ehrlich, H. L., 1996, *GeoMicrobiology*, 3rd ed.; Marcel Dekker: Inc.: New York.

46. Evanko, C.R., and Dzombak, D.A., 1997, Remediation of Metals-Contaminated Soils and Groundwater Carnegie, Mellon University Department of Civil and Environmental Engineering Pittsburgh, PA.

47. Faisal, M., and Hasnain, S., 2006, Detoxification of Cr(VI) by *Bacillus cereus*. *Research Journal of Microbiology*, 1 (1), 45-50.

48. Federal Register, 2004, Occupational Safety and Health Administration. Occupational Exposure to Hexavalent Chromium. *69 Federal Register 59404*. October 4, 2004.

49. Fendorf, S.; Wielinga, B. W.; Hansel,C. M., 2000, Chromium transformations in natural environments: the role of biological and abiological processes in

chromium (VI) reduction. *International Journal of Geology Reviews*, 42, 691−701.

50. Ferris M.J., Muyzer G., Ward D.M, 1996, Denaturing gradient gel electrophoresis profiles of 16S rRNA-defined populations inhabiting a hot spring microbial community. *Applied and Environmental Microbiology*, 62, 340-346.

51. Fisher, S.G., Lerman, L.S., 1983, DNA fragments differing by single base pair substitutions are separated in denaturing gradient gels: correspondence with melting theory. *Proceedings of the National Academy fo Science*, *U.S.A*, 80, 1579-1583.

52. Flemming, C.A., Ferris, F.G., Beveridge, T.J., and Bailey, G.W., 1990, Remobilization of toxic heavy-metals adsorbed to bacterial wall-clay composites. *Applied Environmental Microbiology*, 56, 3191–3203

53. Flessel, C.P., 1979, *Trace Metals in Health and Disease*. Pp. 109-122, Raven Press, New York.

54. Flores, A., Pérez, J.M., 1999, Cytotoxicity, apoptosis, and in vitro DNA damage induced by potassium chromate. *Toxicology and Applied Pharmacology*, 161, 75-81.

55. Francis, C.A., Obraztsova, A.Y., and Tebo, B.M., 2000, Dissimilatory metal reduction by the facultative anaerobe *Pantoea agglomerans* SP1. *Applied and Environmental Microbiology*, 66, 543−548.

56. Francisco, R., Alpoim, M.C., and Morais, P.V., 2002, Diversity of chromium-resistant and -reducing bacteria in a chromium-contaminated activated sludge. *Journal of Applied Microbiology*, 92, 837−843 .

57. Fredrickso, J.K., Kostandarithes H. M., Li S.W., Plymale, A.E., Daly M.J., 2000, Reduction of Fe(III), Cr(VI), U(VI), and Tc(VII) by *Deinococcus radiodurans* R1. *Applied and Environmental Microbiology*, 66, 2006−2011.

58. Garrels, R.M. and Christ, C.L., 1965, In *Solutions, Minerals and Equilibria*, pp. 403-435. Harper and Row Publishers, New York.

59. Ganguli, A. and Tripathi, A.K., 2002, Bioremediation of toxic chromium from electroplating effluent by chromate-reducing *Pseudomonas aeruginosa* A2 Chr in two bioreactors. *Applied Microbiology and Biotechnology*, 58, 416-420

60. Garbisu, C., Alkorta, I., Llama, M.J., and Serra, J.L., 1998, Aerobic chromate reduction by *Bacillus subtilis*. *Biodegradation*, 9, 133-141.

61. Gavaskar, A., Gupta, N., Sass, B., Janosy, R., and Hicks, J., 2000, Design Guidelines for Applications of Permeable Reactive Barriers for Groundwater Remediation, Battelle, Columbus, OH, Report No. AFRL-ML-WP-TR-2000-4546, NTIS: ADA380005, pp. 399.

62. Glaze, W.H., 1990, Chemical precipitation. In *Water Quality and Treatment*, ed. Pontius, F. W., pp. 747-779. McGraw-Hill, Inc., NY.

63. Hintze, C., 1930, In *Handbook of Mineralogy*, vol. 1 III/2, p. 4012-4030, Berlin, Leipzig, DeGryter, Germany.

64. Giovannoni S.J., Britschgi T.B., Moyer C.L., Field K.G., 1990, Genetic diversity in Sargasso Sea bacterioplankton. Nature (London) 345, 60– 63.

65. Golder Associates, 2006,Contamination Assessment at Envirochrome – *Brits*. Golder Associates Report to the Industrial Development Corporation. Sandton, South Africa.

66. Hao O.J., Huang, L Chen, J.M., and Buglass R.L., 1994, Effects of metal additions on sulfate reduction activity in wastewaters. *Toxicological and Environmental Chemistry*, 46(2), 197.

67. Head, I.M., Saunders, J.R., and Pickup, R.W., 1998, Microbial evolution,diversity, and ecology: a decade of ribosomal analysis of uncultivated microorganisms. *Microbial Ecology*, 35, 1– 21.

68. Heuer, H., Krsek, M., Baker, P., Smalla, K., and Wellington, E.M.H., 1997, Analysis of actinomycete communities by specific amplification of genes encoding 16S rRNA and gel electrophoretic separation in denaturing gradients. *Applied and Environmental Microbiology*, 63, 3233-3241.

69. Horitsu, H., Futo, S., Miyazawa, Y., Ogai, S., and Kawai, K., 1987, Enzymatic reduction of hexavalent chromium by hexavalent tolerant *Pseudomonas ambigua* G-1. *Agricultural and Biological Chemistry*, 51 (9), 2417-2420.

70. Hu, P., Brodie, E. L., Suzuki, Y., McAdams, H.H., and Andersen, G. L. ,2005,. Whole-genome transcriptional analysis of heavy metal stresses in *Caulobacter crescentus*. *Journal of Bacteriology*, 187, 8437–8449.

71. Imai, A., and Gloyna, E.F., 1990, Effects of pH and oxidation state of chromium on the behavior of chromium in the activated sludge process. *Water Research*, 24, 1143-1150.

72. Ishibashi, Y., Cervantes, C., and Silver, S., 1990, Chromium reduction in *Pseudomonas putida*. *Applied and Environmental Microbiology*, 56, 2268-2270.

73. International Agency for Research on Cancer and World Health Organization, 1990, Chromium, nickel and welding. Lyon: International Agency for Research on Cancer: distributed for the International Agency for Research on Cancer by the Secretariat of the World Health Organization; p. 677.

74. Jianlong, W., Xiangchun, Q., Libo, W., Yi, Q., and Hegemann, W., 2002 December 31, Bioaugmentation as a tool to enhance the removal of refractory compound in coke plant wastewater. *Process Biochemistry*, 38 (5), 777-781.

75. Kotas, Â.J., Stasicka, Z., 2000, Chromium occurrence in the environment and methods of its speciation. *Environmental Pollution*, 107 (2000), 263-283.

76. Kashefi, K., and Lovley, D.R., 2000, Reduction of Fe(III), Mn(IV), and toxic metals at 100 °C by *Pyrobaculum islandicum*. *Applied and Environmental Microbiology*, 66, 1050-1056.

77. Kieft, T.L., Fredrickson, J.K., Onstott, T.C., Gorby, Y.A., Kostandarithes, H.M., Bailey, T.J., Kennedy, D.W., Li, S. W., Plymale, A.E., Spadoni, C.M., and Gray, M.S., 1999, Dissimilatory reduction of Fe(III) and other electron acceptors by a *Thermus* isolate. *Applied and Environmental Microbiology*, 65, 1214-1221.

78. Kiilunen, M., 1994, Occupational exposure to chromium and nickel in Finland and its estimation by biological monitoring. Doctoral thesis, Kuopio University Publications C, Natural and Environmental Sciences, 17.

79. Krishna, K.R and Philip, L., 2005, Bioremediation of Cr(VI) in contaminated soils. *Journal of Hazardous Materials B*, 121, 109-117.

80. Langand, S., 1983, The carcinogenicity of chromium compounds in man and mammals. In D. Burrows (ed.), *Metabolism and Toxicity*, pp. 13-30. CRC Press, Inc., Boca Rotan, FL .

81. Llagostera, M., Gariddo, S., Guerrero, R., and Barbé, J.,1986,. Induction of SOS genes of *Escherichia coli* by chromium compounds. *Environmental Mutagenesis*, 8, 571-577.

82. Llovera, S., Bonet, R., Simon-Pujol, M. D., and Congregado, F., 1993, Chromate reduction by resting cells of *Agrobacterium radiobacter* EPS-916. *Applied and Environmental Microbiology*, 59, 3516-3518.

83. Lovley, D.R., Giovannoni, S.J., White, D.C., Champine, J.E., Phillips, E.J.P., Gorby, Y. A., and Goodwin, S., 1993, Geobacter metal lireducens gen. nov. sp. nov., a microorganism capable of coupling the complete oxidation of organic compounds to the reduction of iron and other metals. *Archives of Microbiology*, 159, 336-344.

84. Lovley, D.R., and Phillips, E.J., 1994, Reduction of chromate by *Desulfovibrio vulgaris* and its c_3 cytochrome. *Applied and Environmental Microbiology*, 60, 726-728.

85. Lu, Y.L., and Yang, J.L., 1995, Long-term exposure to chromium (VI) oxide leads to defects in sulfate transport system in *Chinese hamster ovary* cells. *Journal of Cellular Biochemistry*, 57, 655-665.

86. Ludwig, W., Schleifer, K.H., 1994, Bacterial phylogeny based on 16S and 23S rRNA sequence analysis. *FEMS Microbiology Reviews*, 15, 155-173.

87. Mazierski, J., 1994, Effect of chromium (VI) on the growth of denitrifying bacteria. *Water Research*, 28(9), 1981-1985.

88. Mel Lytle, C., Lytle, F., Yang, N., Qian, J.-H., Hansen, D., Zayed, A., and Terry, N., 1998, Reduction of Cr(VI) to Cr(III) by Wetland Plants: Potential for in situ Heavy Metal Detoxification. *Environmental Science and Technology*, 32, 3087.

89. Merian, E., 1984, Introduction on environmental chemistry and global cycles of arsenic, beryllium, cadmium, chromium, cobalt, nickel, selenium, and their derivatives. *Toxicological and Environmental Chemistry*, 8, 9-38.

90. McLean, R.J.C., Beauchemin, D., Clapham, L. and Beveridge, T.J., 1990, Metal-binding characteristics of the gamma-glutamyl capsular polymer of *Bacillus licheniformis* ATCC 9945. *Applied and Environmental Microbiology*,56, 3671-3677

91. McRae C.W., Blowes, D.W. and Ptacek, C.J., 1997, Laboratory-scale investigation of remediation of As and Se using iron oxides. *Proc. Sixth Symposium and Exhibition on Groundwater and Soil Remediation*, March 18-21, Montreal, Quebec, 167-168.

92. McMurty, D., and Elton, R.O., 1985, New approach to *in situ* treatment of contaminated groundwaters. *Environmental Progress*, 4, 168-170.

93. Miranda, A.T., Gonzalez, M.V., Gonzalez, G., Vargas, E., Campos-Garcia, J. and Cervantes, C., 2005, Involvement of DNA helicases in chromate resistance by *Pseudomonas aeruginosa* PAO1. *Mutation Research*, 578, 202-209.

94. Mohan, D. and Pittman, C.U., Jr., 2006, Activated carbons and low cost adsorbents for remediation of tri- and hexavalent chromium from water. *Journal of Hazardous Materials*, B137, 762-811.

95. Morel, F.M.M, and Hering, J.G., 1993. *Principles and Applications of Aquatic Chemistry*. John Wiley & Sons, Inc., New York, NY, USA.

96. Morrison, S.J, Metzler, D.R, and Carpenter, C.E, 2001, Uranium Precipitation in a Permeable Reactive Barrier by Progressive Irreversible Dissolution of Zerovalent Iron. *Environmental Science and Technology*, 35 (2), 385-390.

97. Myers, C.R.; Carstens, B.P.; Antholine, W. E.; and Myers, J. M., 2000, Chromium(VI) reductase activity is associated with the cytoplasmic membrane of anaerobically grown *Shewanella putrefaciens* MR-1. *Journal of Applied Microbiology*, 88, 98-106.

98. Mertz W., 1981, The essential trace elements. *Science,* 213, 1332–1338.

99. Metfies K. and Medlin L., 2005, Ribosomal RNA Probes and Microarrays: Their Potential Use in Assessing Microbial Biodiversity. *Methods in Enzymology*, 395, 258-278.

100. Molokwane, P.E., and Chirwa, E.M.N., 2008, Bioremediation of a Cr(VI) contaminated site: a conceptual and feasibility study for a site in Brits. *Proc.*

11th Conference on Process Integration, Modelling and Optimisation for Energy Saving and Pollution Reduction, 2008 PRES, 24-28 August 2008, Prague, Czech Republic.

101. Molokwane, P.E., Meli, C.K. and Chirwa, E.M.N., 2008, Chromium (VI) reduction in activated sludge bacteria exposed to high chromium loading. *Water Science and Technology*, 58 (2), 399-405.

102. Molokwane, P.E., Meli, K.C., and Nkhalambayausi-Chirwa, E.M.,2008, Chromium (VI) reduction in activated sludge bacteria exposed to high chromium loading: Brits culture (South Africa). Water Research, 42 (17), 4538-4548.

103. Molokwane, P.E., and Chirwa, E.M.N., 2009, Microbial culture dynamics and chromium (VI) removal in packed-column microcosm reactors. *Water Science and Technology*, 60 (2), 381-388.

104. Morel, F. M. M., and Hering, J. G.,1993, In *Principles and Applications of Aquatic Chemistry*, chap. 6, Wiley & Sons, Inc., New York.

105. Mukhopadhyay, B., Sundquist, J., and Schmidt, J.R., 2007, Removal of Cr(VI) from Cr-contaminated groundwater through electrochemical addition of Fe(II). *Journal of Environmental Management*, 82 (1), 66-76.

106. Muyzer, G., de Waal, E.C., Uitterlinden, A.G., 1993, Profiling of complex microbial populations by denaturing gradient gel electrophoresis analysis of polymerase chain reaction-amplified genes coding for 16S rRNA. *Applied and Environmental Microbiology*, 59:695-700.

107. Muyzer, G., Smalla, K., 1995, Application of denaturing gradient gel electrophoresis (DGGE) and temperature gradient gel electrophoresis (TGGE) in microbial ecology. *Antonie van Leeuwenhoek*, 73**,** 127-141, 1998.

108. Namasivayam, C. and Yamuna, R.T., 1995, Adsorption of chromium (VI) by a low-cost adsorbent: biogas residual slurry, *Chemospher*, 30, 561-578.

109. NAS, (National Academy of Science), 1974, In Chromium, National Research Council, Committee on Biological Effects of Atmospheric Pollutants. National Academy of Sciences, Washington, DC. page 155.

110. Nelson, Y. M., Lion, L. W., Shuler, M. L., and Ghiorse, W. C.,1996, "Modeling oligotrophic biofilm formation and lead adsorption to biofilm components." *Environmental Science and Technology*, 30, (6), 2027-2035.

111. Nieboer, E., Jusys, A.A., 1988, Biologic chemistry of chromium in the Natural and Human Environments. Nriagu, F.O. Nieboer, E., Eds., John Wiley, New York, 21.

112. Nkhalambayausi-Chirwa, E.M., Wang, Y.T., 2001, Simultaneous chromium(VI) reduction and phenol degradation in a fixed-film coculture bioreactor: reactor performance. *Water Research*, 35(8), 1921-1932.

113. Nriagu, J. O.; Nieboer, E., Eds.1998, *Chromium in the Natural and Human Environments*; John Wiley and Sons: New York, .

114. Nriagu, J.O., Robins, T., Gary, L., Liggans, G., Davila, R., Supuwood, K., Harvey, C., Jinabhai, C.C., and Naidoo, R., 1999, Prevalence of asthma and respiratory symptoms in south-central Durban,South Africa, *European Journal of Epidemiology*, 15: 747-755.

115. Nies, D.H., 1995, Microbial heavy-metal resistance. *Applied Microbiology and Biotechnology*, 51, 730–750.

116. Øvreås, L., Forney, L., Daae, F.L., and Torsvik, V., 1997, Distribution of bacterioplankton in meromictic Lake Saelenvannet, as determined by denaturing gradient gel electrophoresis of PCR-amplified gene fragments coding for 16S rRNA. *Applied Environmental Microbiology*, 63, 3367-3373.

117. Ohtake, H., Fujii, E., and Toda, K., 1990, Reduction of toxic Cr(VI) in an industrial effluent by use of a Cr(VI)-reducing strain *Enterabacter cloacae* HO1. *Environmental Technology Letters*, 11, 663-668.

118. Pal, A., Sumana Dutta, S., and Paul, A.K., 2005, Reduction of hexavalent chromium by cell-free extract of *Bacillus sphaericus* AND 303 Isolated from serpentine soil. *Current Microbiology*, 51 (5), 327-330.

119. Papp, J.F., 2006, Chromium. U.S. Geological Survey Minerals Year Book. http://minerals.usgs.gov/minerals/pubs/commodity/chromium/myb1-2006-chrom.xls 2006/10/14.

120. Park, C. H., Keyhan, M., Wielinga, B., Fendorf, S., Matin, 2000, Purification to homogeneity and characterization of a novel Pseudomonas putida chromate reductase. *Applied Environmental Microbiology*, 66, 1788-1795.

121. Patterson, R.R., Fendorf, S., and Fendorf, M., 1997, Reduction of hexavalent chromium by amorphous iron sulphide. *Environmental Science and Technology*, 3 (7), 2039-2044.

122. Reichert P, 1998, Swiss Federal Institute for Environmental Science and Technology (EAWAG), Switzerland, ISBN: 3-906484-16-5.

123. Petrilli, F.L., and De Flora, S., 1977, Toxicity and mutagenicity of hexavalent chromium compounds in *Salmonella typhimurium*. *Applied Environmental Microbiology*, 33, 805-809.

124. Phillips, D.H., 2009, Permeable reactive barriers: A sustainable technology for cleaning contaminated groundwater in developing countries. *Desalination*, 248, 352-359.

125. Powell, R.M., Puls, R.W., Hightower, S.K., and Sabatini, D.A., 1995, Coupled iron corrosion and chromate reduction: Mechanisms for subsurface remediation. *Environmental Science and Technology*, 29, 1913.

126. Prat, AR, Blowes, D., W, and Ptacek, C.J., 1997, Products of chromate reduction on proposed remediations material. *Environmental Science and Technology*, 31, 2492-2498.

127. Quintana, M., Curutchet, G., and Donati, E., 2001, Factors Affecting the Chromium(VI) Reduction by *Thiobacillus ferrooxidans*. *Biochemical Engineering Journal*, 9, 11.

128. Rajwade, J. M., Paknikar, K. M.,1997, Microbiological Detoxification of Chromate from Chrome-plating Effluents. *In Proceedings of International Biohydrometallurgy Symposium*. Sydney, Australia, pp. 221.

129. Rasmussen, G., Fremmersvik, G., Olsen, R.A., 2002, Treatment of creosote-contaminated groundwater in a peat/sand permeable barrier—a column study. *Journal of Hazardous Materials*, B 93, 285-306.

130. Rege, M. A., Petersen, J. N., Johnstone, D. L., Turick, C. E., Yonge, D. R., Apel, W. A. ,1997, Bacterial Reduction of Hexavalent Chromium by *Enterobacter cloacae* Strain HO1 Grown on Sucrose. *Biotechnology Letters*, 19, 691.

131. Ramirez-Diaz, M.I., Diaz-Perez, C., Vargas, E., Riveros-Rosas, H., Campos-Garcia, J., and Cervantes, C., 2008, Mechanisms of bacterial resistance to chromium compounds. *Biometals*, 21, 321-332.

132. Ramírez-Ramírez, R., Calvo-Méndez, C., Ávila-Rodríguez, M., Lappe, P., Ulloa, M., Vázquez-Juárez, R., Gutiérrez-Corona, J.F., 2004, Cr(VI) reduction in a chromate-resistant strain of *Candida maltosa* isolated from the leather industry. *Journal Antonie van Leeuwenhoek*, 85 (1), 63-68

133. Reichert, P., Swiss Federal Institute for Environmental Science and Technology (EAWAG) CH Dubendorf, Switzerland, September 1998, ISBN 3906484-16-5

134. Reid, V.M., Wyatt, K.W., and Horn, J.A. ,1994, A new angle on groundwater remediation. *Civil Engineering*, 64 (4), 56-58.

135. Richard, F.C., and Bourg, A.C. M., 1991, Aqueous geochemistry of chromium: A review, *Water Research*, 25(7): 807-816.

136. Robertson, R.D. & Cherry, J.A., 1995, *In situ* denitrification of septic system nitrate using reactive porous medium barriers: field trials. *Ground Water*, 33, 99-111.

137. Robertson, F.N., 1975, Hexavalent chromium in the ground water in Paradise Valley, Arizona, *Ground Wate*r, 13(6): 516-527.

138. Romanenko, V.I., and Koren'kov, V.N., 1977, A pure culture of bacteria utilizing chromate and dichromate as hydrogen acceptors in growth under anaerobic conditions. *Mikrobiologiya*, 46, 414-417.

139. Rosko, J.J., Rachlin, J.W., 1977, Effect of cadmium, copper, mercury, zinc and lead on cell- division, growth, and chlorophyll-a content of *chlorophyte Chlorella vulgaris*. *Bulletin of the Torrey Botanical Club*, 104, 226-233.

140. Salunkhe, P.B., Dhakephalkar, P.K., and Paknikar, K. M., 1998, Bioremediation of hexavalent chromium in soil microcosms. *Biotechnology Letters*, 20, 749.

141. Sani, R. K.; Peyton, B. M.; Smith, W. A.; Apel, W. A.; Petersen, J. N.,2002, Dissimilatory reduction of Cr(VI), Fe(III), and U(VI) by *Cellulomonas* isolates.

Applied Microbiology and Biotechnology, 60, 192-199.

142. Stearns, D.M., Kennedy, L.J., Courtney, K.D., Giangrande, P.H., Phieffer, L.S., and Wetterhahn, K.E., 1995, Reduction of chromium (VI) by ascorbate leads to chromium-DNA binding and DNA strandbreaks *in vitro*. *Biochemistry*, 34, 910-919

143. Shen, H., Pritchard, P.H., and Sewell, G.W., 1996. Kinetics of chromate reduction during naphthalene degradation in a mixed culture. *Biotechnology and Bioengineering*, 52 (3), 357-363.

144. Shen H., and Wang, Y.T., 1993, Characterization of enzymatic reduction of hexavalent chromium by *Escherichia coli* ATCC 33456. *Applied Environmental Microbiology*, 59 (11), 3771-3777.

145. Shen, H., and Wang Y T., 1994a, Modeling hexavalent chromium reduction in *Escherichia coli* ATCC 33456. *Biotechnology and Bioengineering*, 43 (4), 293-300.

146. Shen, H., and Wang, Y.T., 1994b, Biological reduction of chromium by *E. coli*. *Journal of Environmental Engineering*, 120, 60-572.

147. Shen H. and Wang Y.T., 1995, Simultaneous Chromium Reduction and Phenol Degradation in a Coculture of *Escherichia coli* ATCC 33456 and *Pseudomonas putida* DMP-1. *Applied Environmental Microbiology*, 61 (7), 2754–2758.

148. Shi, X.L., and Dalal, N.S., 1990, Evidence for a Fenton-type mechanism for the generation of ·OH radicals in the reduction of Cr(VI) in cellular media. *Archives of Biochemistry and Biophysics*, 281, 90-95.

149. Silverberg, B.A., Wong, P.T.S., and Chau, Y.K., 1977, Effect of tetramethyl lead on freshwater *green-algae*. *Archives of Environmental Contamination and Toxicology*, 5, 305-313.

150. Stern, R.M., 1982, Chromium compounds: production and occupational exposure," p. 5-47. In S. Langard (ed.), *Biological and Environmental Aspects of Chromium*, Elsevier Publishers, Amsterdam, New York, Oxford.

151. Snyder, S.L., Walker, R.I., MacVittie, T.J., and Sheil, J.M., 1978, Biologic properties of bacterial lipopolysaccharides treated with chromium chloride. *Canadian Journal of Microbiology*, 24, 495–501.

152. Suzuki, T., Miyata, N., Horitsu, H., Kawai, K., Takamizawa, K., Tai, Y., and Okazaki, M., 1992, NAD(P)H-dependent chromium (VI) reductase of *Pseudomonas ambigua* G-1: a Cr(V) intermediate is formed during the reduction of Cr(VI) to Cr(III). *Journal of Bacteriology*, 174(16), 5340-5345.

153. Tebo, B.M., Obraztsova, A., Y., 1998, Sulfate-reducing bacterium grows with Cr(VI), U(VI), Mn(IV), and Fe(III) as electron acceptors. *FEMS Microbiology Letters*, 162, 193-198.

154. Teske, A., Wawer, C., Muyzer, G., Ramsing, N.B., 1996, Distribution of sulfate-reducing bacteria in a stratified fjord (Mariager Fjord, Denmark) as evaluated by most-probable-number counts and denaturing gradient gel electrophoresis of PCR-amplified ribosomal DNA fragments. *Applied Environmental Microbiology*, 62, 1405-1415.

155. Thompson, M.R., Verberkmoes, N.C., Chourey, K., Shah, M., Thompson, D.K., and Hettich, R.L., 2007, Dosage-dependent proteome response of *Shewanella oneidensis* MR-1 to acute chromate challenge. *Journal of Proteome Research*, 6, 1745-1757.

156. Top, E.M., Springael, D., and Boon, N., 2006, Catabolic mobile genetic elements and their potential use in bioaugmentation of polluted soils and waters. *Microbiology Ecology*, 42 (2), 199-208.

157. U.S.EPA, 1978, Reviews of the environmental effects of pollutants - III. Chromium, EPA 600/1-78-023, Washington, District of Columbia.

158. U.S. EPA, 1997, Permeable Reactive Subsurface Barriers for the Interception and Remediation of Chlorinated Hydrocarbon and Chromium (VI) Plumes in Ground Water, EPA/600/F-97/008, Ada, OK.

159. U.S. EPA, 2001, Chromite ore from the Transvaal Region of South Africa; toxic chemical release reporting; community right-to-know, 40 CFR Part 372.

160. Vidic, R.D. and Pohland, F.G.,1996, “Treatment Walls,” Technology Evaluation Report TE-96-01, Ground-Water Remediation Technologies Analysis Center, Pittsburgh, PA.

161. Viti, C., Pace, A., and Giovannetti, L.,2003, Characterization of Cr(VI)-resistant bacteria isolated from chromium-contaminated soil by tannery activity. *Current*

Microbiology, 46, 1-5.

162. Viti, C., and Giovannetti, L., 2007, Bioremediation of soils polluted with hexavalent chromium using bacteria – the challenge. In *Environmental Bioremediation Technologies*, pp. 57-76. Edited by S. N. Singh & R. D. Tripathi. Berlin: Springer.
163. Wang, P., T. Mori, K. Toda, and H. Ohtake.,1990, Membrane associated chromate reductase activity from Enterobacter cloacae. *Journal of Bacteriology*, 172, 1670-1672.
164. Ward, D.M., Weller, R., and Bateson, M.M., 1990, 16S rRNA sequences reveal numerous uncultured microorganisms in a natural community. *Nature*, 345, 63–65.
165. Wang, M., Chen, J.K., and Li, B., 2007, Characterization of bacterial community structure and diversity in rhizosphere soils of three plants in papidly changing salt marshes using 16S rDNA. *Pedosphere*, 17 (5), 545-556.
166. Wang, Y.T., and Shen, H., 1995, Bacterial reduction of hexavalent chromium. *Journal of Industrial Microbiology*. 14, 159-163.
167. Wang, Y.T., and Shen, H., 1997, Modelling Cr(VI) reduction by pure bacterial cultures. *Water Research*, 41 (4), 727-732.
168. Wang, Y-.T., Chirwa E.N., and Shen H., 2000, Cr(VI) reduction in a continuous-flow coculture reactor. *Journal of Environmental Engineering*. 126, (4), 300-306.
169. Wang, Y-.T., Chirwa, E.N., and Shen H., 2000, Cr(VI) reduction in a continuous-flow coculture reactor. *Journal of Environmental Engineering*. 126, (4), 300-306.
170. Wetterhahn, K.E., Hamilton, J.W., Aiyar, J., Borges, K.M., and Floyd, R., 1989, Mechanism of chromium(VI) carcinogenesis. Reactive intermediates and effect on gene expression. *Biological Trace Element Research*, 21, 405-411.
171. Wilkin, R.T., Puls, R.W., and Sewell, G.W., 2003, Long-term performance of permeable reactive barriers using zero-valent iron: geochemical and microbiological effects. *Ground Water*, 41 (4), 493–503.

172. Williams, J.W., and S. Silver., 1984, Bacterial resistance and detoxification of heavy metals. *Enzyme Microbial Technology*, 6, 530-537.

173. Wybrant, R.D., and Cherry, J.A., 1995, *In situ* denitrification of septic system nitrate using reactive porous medium barriers: field trials. *Ground Water*, 33, 99-111.

174. Xing, L. and Okrent., D., 1993, Future risk from a hypothesized RCRA site disposing of carcinogenic metals should a loss of societal memory loss occur. *Journal of Harzadous Materials*, 38, 363-384.

175. Zayed, A.M., and Terry N., 2003, Chromium in the environment: factors affecting biological remediation, *Plant Soil*, 259, 139-156.

176. Zhao, M. and Duncan, J.R., 1997, Batch removal of hexavalent chromium by *Azolla filiculoides*. *Biotechnology and Applied Biochemistry*, 26,179-182.

177. Zakaria, Z.A., Zakaria, Z., Surif, S., and Ahmad, W.A., 2007, Biological detoxification of Cr(VI) using wood-husk immobilized *Acinetobacter haemolyticus*. *Journal of Hazardous Materials*, 148 (1-2), 164-171.

APPENDIX A

AQUASIM 2.0

Variables

A:	Description:	Cross-sectional area
	Type:	Constant Variable
	Unit:	m^2
	Value:	0.00046495435
	Standard Deviation:	1
	Minimum:	0
	Maximum:	1000
	Sensitivity Analysis:	active
	Parameter Estimation:	inactive

----

a:	Description:	
	Type:	Constant Variable
	Unit:	
	Value:	-66
	Standard Deviation:	1
	Minimum:	-100
	Maximum:	10000
	Sensitivity Analysis:	active
	Parameter Estimation:	inactive

----

alpha:	Description:	
	Type:	Formula Variable
	Unit:	
	Expression:	0.5

----

b:	Description:	
	Type:	Constant Variable
	Unit:	days
	Value:	3.030879
	Standard Deviation:	1
	Minimum:	0
	Maximum:	1000
	Sensitivity Analysis:	active
	Parameter Estimation:	inactive

C:	Description:	Dissolved concentration
	Type:	Dyn. Volume State Var.
	Unit:	mg/m^3
	Relative Accuracy:	1e-006
	Absolute Accuracy:	1e-006

C5:	Description:	
	Type:	Constant Variable

Unit:	mg/L
Value:	4.02255
Standard Deviation:	1
Minimum:	0
Maximum:	55
Sensitivity Analysis:	active
Parameter Estimation:	inactive

----

calcnum: Description:

Type:	Program Variable
Unit:	
Reference to:	Calculation Number

Cmeas: Description:

Type:	Real List Variable
Unit:	mg/L
Argument:	t
Standard Deviations:	global
Rel. Stand. Deviat.:	0
Abs. Stand. Deviat.:	1
Minimum:	0
Maximum:	1e+009
Interpolation Method:	linear interpolation
Sensitivity Analysis:	inactive

Real Data Pairs (65 pairs):

0	0
0.0938	36.6697
0.8438	34.4415
1.0208	35.0144
1.1146	35.651
38.0063	5.2203
39.9646	4.3927
42.1417	5.1567
43.1	3.2468
45.1	3.1195

Co: Description: Initial added added chromium

Type:	Formula Variable
Unit:	
Expression:	50

C_crit: Description:

Type:	Formula Variable
Unit:	mg/m^3
Expression:	0.01

C_in: Description:

Type:	Formula Variable
Unit:	mg/L
Expression:	50

C_in_meas:	Description:	
	Type:	Real List Variable
	Unit:	mg/L
	Argument:	t
	Standard Deviations:	global
	Rel. Stand. Deviat.:	0
	Abs. Stand. Deviat.:	1
	Minimum:	0
	Maximum:	1e+009
	Interpolation Method:	linear interpolation
	Sensitivity Analysis:	inactive
	Real Data Pairs (65 pairs):	

0	47.937929
0.09375	47.937929
0.84375	47.746941
1.0208333	48.383567
1.1145833	45.837064
38.00625	50.102457
39.964583	45.773401
42.141667	50.038794
43.1	48.95653
45.1	48.383567

D:	Description:	Dispersion coefficient
	Type:	Constant Variable
	Unit:	m^2/h
	Value:	4.0990701
	Standard Deviation:	1
	Minimum:	0
	Maximum:	10
	Sensitivity Analysis:	active
	Parameter Estimation:	inactive

K:	Description:	
	Type:	Formula Variable
	Unit:	mg/m^3
	Expression:	0.5

----

k:	Description:	Relaxation rate constant for sorption of B
	Type:	Formula Variable
	Unit:	1/h
	Expression:	10000

Kc:	Description:	half velocity
	Type:	Constant Variable
	Unit:	
	Value:	2.452503
	Standard Deviation:	1
	Minimum:	0.0005

	Maximum:	1e+009
	Sensitivity Analysis:	inactive
	Parameter Estimation:	inactive

Kd:	Description:	cell death coefficient
	Type:	Constant Variable
	Unit:	m^3/kg
	Value:	0.00058
	Standard Deviation:	1
	Minimum:	0
	Maximum:	10000
	Sensitivity Analysis:	active
	Parameter Estimation:	inactive

KF:	Description:	
	Type:	Formula Variable
	Unit:	
	Expression:	0.00025

----

kmc:	Description:	Maximum specific Cr(VI) reduction rate coefficient
	Type:	Constant Variable
	Unit:	
	Value:	1.53
	Standard Deviation:	1
	Minimum:	0
	Maximum:	100000
	Sensitivity Analysis:	active
	Parameter Estimation:	active

Qin:	Description:	
	Type:	Formula Variable
	Unit:	m^3/h
	Expression:	0.001

Rc:	Description:	Inactivation capacity
	Type:	Constant Variable
	Unit:	mg/mg
	Value:	0.533764
	Standard Deviation:	1
	Minimum:	0
	Maximum:	100
	Sensitivity Analysis:	active
	Parameter Estimation:	inactive

----

rho_s:	Description:	Density of solid material
	Type:	Formula Variable
	Unit:	kg/m^3
	Expression:	2300

S: Description: Adsorbed concentration
Type: Dyn. Surface State Var.
Unit: mg/kg
Relative Accuracy: 1e-006
Absolute Accuracy: 1e-009

Smax: Description:
Type: Formula Variable
Unit: mg/kg
Expression: 0.00029

S_eq: Description: Isotherm
Type: Variable List Variable
Unit: mg/kg
Argument: calcnum
Interpolation Method: linear interpolation
Real-Variable Data Pairs (1 pairs):
0 S_eq_0

S_eq_0: Description: Isotherm for no sorption
Type: Formula Variable
Unit: mg/kg
Expression: Kd*C

S_eq_Freundlich:
Description: Freundlich isotherm
Type: Formula Variable
Unit: mg/kg
Expression: if C>C_crit then KF*C^alpha else K
F*C_crit^alpha*C/C_crit endif

S_eq_Langmuir: Description: Langmuir isotherm
Type: Formula Variable
Unit: mg/kg
Expression: Smax*C/(K+C)

S_eq_lin:
Description: Linear isotherm
Type: Formula Variable
Unit: mg/kg
Expression: Kd*C

----

t: Description: Time
Type: Program Variable
Unit: d
Reference to: Time

----

theta: Description: Porosity
Type: Formula Variable
Unit:

Expression: 0.4

---

to:	Description:	initial time
	Type:	Constant Variable
	Unit:	days
	Value:	20.356
	Standard Deviation:	1
	Minimum:	0
	Maximum:	1000
	Sensitivity Analysis:	active
	Parameter Estimation:	inactive

X:	Description:	Biomass
	Type:	Formula Variable
	Unit:	mg/L
	Expression:	Xo+a/(1+(t/to) ^{b})

Xo:	Description:	Concntration of viable cells at time t
	Type:	Constant Variable
	Unit:	mg/L
	Value:	70.456994
	Standard Deviation:	1
	Minimum:	0
	Maximum:	100000
	Sensitivity Analysis:	inactive
	Parameter Estimation:	inactive

Processes

Reduction:Description: Chromium(VI) Reduction
Type: Dynamic Process
Rate:
(K^(-1*(Co-C5)/Co))*kmc*C*(X)/(Kc+C)
Stoichiometry:
Variable : Stoichiometric Coefficient
C : -1

Sorption: Description:
Type: Dynamic Process
Rate: k*(S_eq-S)
Stoichiometry:
Variable : Stoichiometric Coefficient
C : -rho_s*(1-theta)/theta
S : 1

Compartments

column: Description:
Type: Soil Column Compartment

Compartment Index:	0
Active Variables:	C, S
Active Processes:	Sorption, Reduction
Initial Conditions:	
Variable(Zone) :	Initial Condition
C(Advective Zone) :	0
Inflow:	Qin
Loadings:	
Variable :	Loading
C :	Qin*C_in
Lateral Inflow:	0
Start Coordinate:	0
End Coordinate:	1
Cross Section:	A
Adv. Vol. Fract.:	theta
Dispersion:	D
Parallel Zones:	
Num. of Grid Pts:	52 (high resolution)
Accuracies:	
Rel. Acc. Q:	0.0001
Abs. Acc. Q:	1e-006
Rel. Acc. D:	1e-006
Abs. Acc. D:	1e-006

Definitions of Calculations

calc_0: Description:

Calculation Number:	0
Initial Time:	0
Initial State:	given, made consistent
Step Size:	0.02
Num. Steps:	2300
Status:	active for simulation inactive for sensitivity analysis

Definitions of Parameter Estimation Calculations

fit1: Description:

Calculation Number:	0
Initial Time:	0
Initial State:	given, made consistent
Status:	active
Fit Targets:	
Data :	Variable (Compartment,Zone,Time/Space)
Cmeas :	C (column,Advective Zone,0)

Plot Definitions

plot: Description:

Abscissa:	Time
Title:	Break through curves
Abscissa Label:	t [d]
Ordinate Label:	C [mg/L)
Curves:	
Type :	Variable [CalcNum,Comp.,Zone,Time/Space]
Value :	C [0,column,Advective Zone,1]
Value :	Cmeas [0,column,Advective Zone,0]
Value :	C_in_meas [0,column,Advective Zone,0]

X: Description:

Abscissa:	Time
Title:	Biomass
Abscissa Label:	
Ordinate Label:	
Curves:	
Type :	Variable [CalcNum,Comp.,Zone,Time/Space]
Value :	X [0,column,Advective Zone,0]

Calculation Parameters

Numerical Parameters: Maximum Int. Step Size: 1

Maximum Integrat. Order: 5

Number of Codiagonals: 8

Maximum Number of Steps: 1000

Fit Method: simplex

Max. Number of Iterat.: 100

Calculated States

Calc. Num.	Num. States	Comments
0	2301	Range of Times: 0 - 46

APPENDIX B

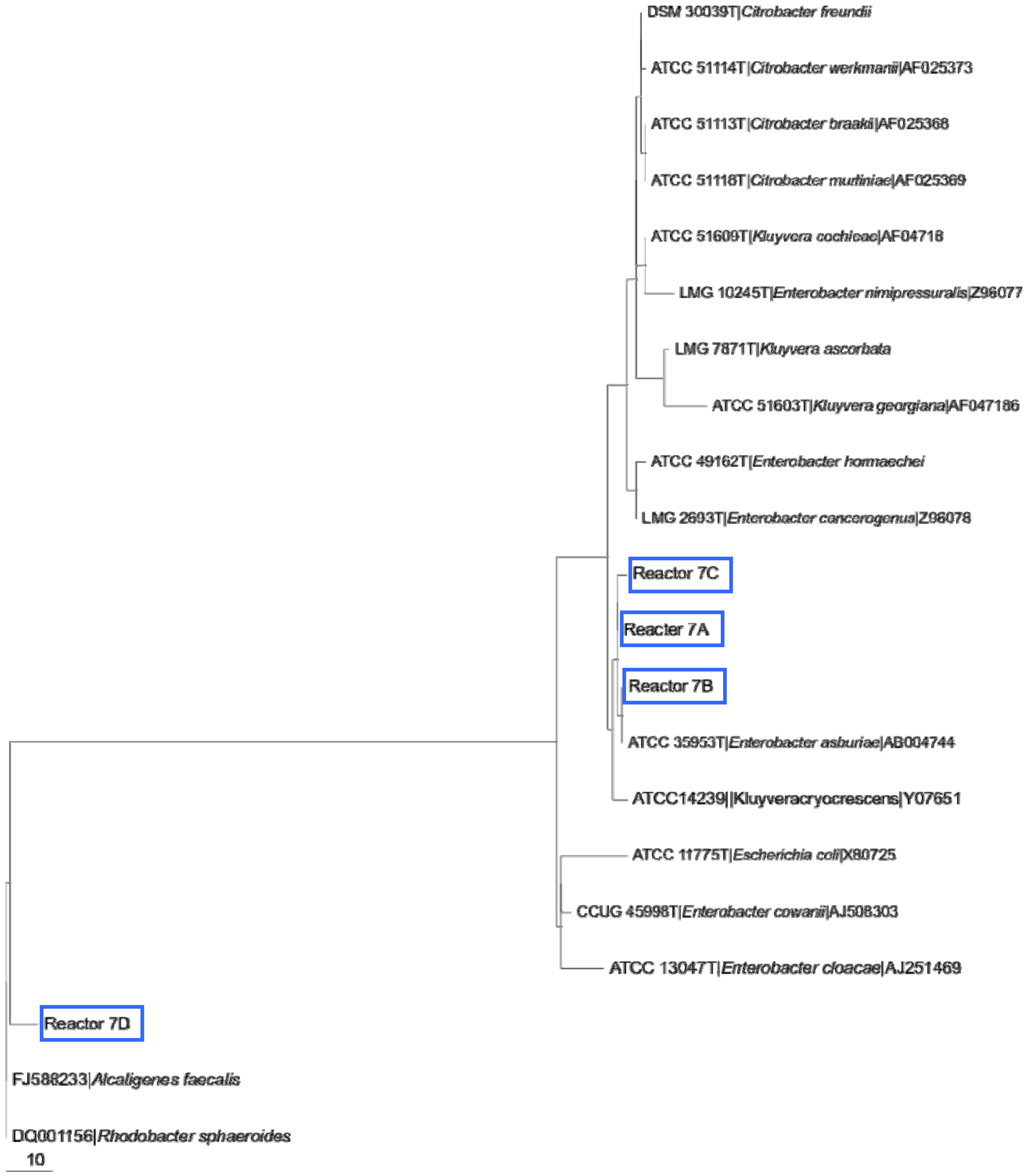

Figure B-1: Phylogenetic analysis of Gram-negative species of bacteria in the HR7 reactors at day 45. Possible Cr(VI) reducers were detected including Enterobacteriaceae, *Escherichia coli*, and *Citrobacter spp.* Bacteria originating from soil was detected including *Rhodobacter spp.* and *Alcalegenes spp*.

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