BIBLIOGRAPHY

Abbasi, S.A., Abbasi N., and Soni, R., (1998). Heavy Metals in the Environment Mittal Publications, New Delhi.

Acton, D. F., and Gregorich, L. J., (1995). The Health of our Soils: Toward Sustainable Agriculture in Canada. Agric. Agri-food Can.,CDR Unit, 960 Carling Ave, Ottawa, ON K1A 0C6.

Aitken, R.L., Moody, P.W., and McKinley, P.G., (1990). Lime requirement of acidic Queensland soils.I. Relationships between soil properties and pH buffer capacity. Australian Journal of Soil Research.28: p.695-701.

Allison, F.E., (1973). Soil organic matter and its role in crop production. Developments in Soil Science no. 3. Elsevier.

Alloway, B.J., (1990). Soil processes and the behaviour of heavy metals. Ch 2 in B.J. Alloway (ed.) Heavy Metals In Soils. John Wiley and Sons: New York.

Amman, A. A., Michalke, B., Schramel, P., (2002). Speciation of heavy metals in environmental water by ion chromatography coupled to ICP-MS. Anal. Biochem., 372, p.448-452.

Anderson, D.W., and Gregorich, E.G., (1984). Effect of soil erosion on soil quality and productivity. p. 105-113. Soil Erosion and Degradation. Proceedings of 2nd ann. western provincial conf.rationalisation of water and soil research and management, Saskatoon, Saskatchewan.

Angus, J. F., (1992). Soil N contributions to wheat yield and protein in south eastern Australia. p. 109-116. Proceedings Of The Workshop "Transfer Of Biologically Fixed Nitrogen To Wheat". Adelaide 1991. Grains Research and Development Corporation, Canberra, ACT.

A.O.A.C., (1950). Official and Tentative Methods of Analysis of The Association of Official Agricultural Chemists, 7th Ed., Washington, p. 910.

Aowal, A.F.S.A., (1981). Design of an Iron eliminator for hand tube wells. Journal of I.W.W.A., XIII (1), 65.

APHA, AWWA, WPCF, (1985). Standard method for the examination of water and waste water (16th Edition), American public Health Association, Wasington D.C.

A.P.H.A, (1989). Standard Methods for the Examination of Water and Wastewater, 17th ed. American Public Health Association, Washington DC. p. 1550.

APHA, AWWA, WPCF, (1995). Standard method for the examination of water and waste water (19th Edition), American public Health Association, Wasington D.C

Arshad, M. A., Lowery, B., Grossman, B., (1996). Physical Tests for Monitoring Soil Quality. In: JWDoran; AJ Jones (ed.) Methods for assessing soil quality. Madison, WI. 1996, p.123-41.

ATSDR, (2000). Toxicological profile for manganese. Atlanta, GA, US Department of Health and Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry.

Balaji, S. and Sharma, M. P., (2007). 'Water quality assessment and conservation of river Bhavani', Eco. Env. & Cons., 13(3):p.593-600.

Baldock ,J.A; Skjemstad, J.O., (1999). Soil organic carbon/soil organic matter, In: K.I. Peverill *et al.,* (ed.) Soil analysis: An interpretation manual, CSIRO Publishing, Melbourne, Australia,, p. 159–170.

Ball, R. C., (1994). Fertilization of lake, Good or Bad, Michigen, Conserv. p. 7-14.

Barbarick, K.A., J.A. Ippolito, and D.G. Westfall., (1997). Sewage biosolids cumulative effects on extractable-soil and grain elemental concentrations. J. Environ. Qual. 26: p.1696–1702

Bardsley, C.E., Lancaster, J.D., (1960). Determination of reserve sulphur and soluble sulphates in soils. Soil Sc.Soc. Amer.Proc.24: p.265-268

Barry, G.A., Chudek, P.J., Best, E.K., and Moody, P.W., (1995). Estimating sludge application rates to land based on heavy metal and phosphorus sorption characteristics of soil. Water Research 29: p.2031-4.

Baruah, A., Sharma, R. N., Chowdhary, P. K., *et al.*, (1995). Assessment of ground water quality around oil installations of Rudrasagar, Assam, India. Ecology Environment and Conservation, 1(1-4), p.43-45.

Baruah T.C.C. & Borthakur, H.P., (1997). In: A Text Book of Soil Chemical Analysis, Vikash Publishing, New Delhi.

Bavinck, H.F., Roels, J.M., and Vetger, J.J., (1988). The importance of measurement procedures in curative and preventative soil protection. p. 125-133 in K. Wolf *et al.*, (eds.) Contaminated Soil '88, Kluwer Academic Publishers, Dordrecht.

Begum A., Ramaiah M., Harikrishna, Khan I. and Veena K., (2009). Heavy Metal Pollution and Chemical Profile of Cauvery River water, E J Chem., 6(1) pp. 47-52.

Bhatia, R., and Deve, J. M., (1980). 'Study of water quality of an urban village in Delhi', Indian Journal of Water Works, Asson. 12 (4), p. 337-349.

Bhattacharjee, S., Chakravarty, S., Maity, S., Dureja, S. And Gupta, K.K., (2005). Metal contents in the groundwater of Sahebgunj district, Jharkhand, India, with special reference to arsenic, Chemosphere, 2005, 58, p.1203–1217.

Bhuyan, B., Kakati, S., and Sarma, H. P., (2006). 'Chemical Quality of Water and Health Effects of Drinking water Contaminants in and around the Tea Gardens of Lakhimpur District, Assam', Pollution Research, 25(3): p. 571-575.

Bhuyan, B. and Sarma, H. P., (2006). "Evaluation of Soil Fertility Status and Chemical Indicators of Soil Quality in Tea Gardens of Lakhimpur District, Assam", Ecol. Env. & Cons., 12(1), p. 75-79.

Black, C.A., (1965). Methods of Soil Analysis, Vol.1. Am.Soc.Agron., Madison, Wisconsin, USA.

Bolsa analytical : State Certified Laboratory No. 1326, 2337 Technology Parkway, Suite K, Hollister, CA 95023

Bower, C.A. and Wilcox, L.V., (1965). Soluble salts In Agronomy No. 9. Methods of soil analysis, Part 2, Black, C.A. ed., p. 933-951.

Brady, N.C.,and Weil, R.R., (1999). The nature and properties of soils, 12th Edition, Prentice Hall, Upper Saddle River, New Jersey, U.S.A

Bray, R.H. and Kurtz, L.T., (1945). Determination of total, organic and available forms of phosphorus in soils, Soil Sci. 59: 39 – 45.

Bremner, J. M. and Mulvaney, C. S., (1982). In: A. L. Page *et al.,* (ed.) Methods of soil analysis: Part 2. Chemical and microbiological properties. ASA Monograph Number 9. Nitrogen-total. p. 595-624.

Bruins, M.R., Kapil, S., Oehme, F.W., (2000). Microbial resistance to metals in the environment. Ecotoxicol. Environ. Saf. 45, p. 198–207.

Bruvold W.H, Ongerth, H.J., (1969). Taste quality of mineralized water. Journal of the American Water Works Association, 61: p. 170.

Cameron, K.C., (1995). Soil Quality Indicators For Sustainable Agriculture. Proceedings of the Environmental Indicators Seminar, Palmerston North, .

Camp T. R., (1963). Water and its impurities, 2nd ed, Reinhold publishing Corp., London

Cess Act, (1977). The water (prevention and control of pollution), The Gazette of India, Extraodinary, Part II, Section 1, dated 7th December, 1977

CGWB (2010), Ministry of Water Resources, Govt. of India, Faridabad, (2010). Ground Water quality in shallow aquifers of India

Chakraborti, D., Rahman, M.M., Paul, K., Choudhury, U.K., Sengupta, M.K., Lodh, D., Chanda, C.R., Saha, K.C., Mukherjee, S.C., (2002). 'Arsenic calamity in the Indian subcontinent What lessons have been learned?' Talanta 58, p. 3–22.

Cheng, K.L. and Bray, R.H., (1951). Determination of calcium and magnesium in soil and plant material, Soil. Sci. 72: 449-458.

Chatterjee, A., Das, D., Mandal, B. K., Roy Chowdhury, T., Samanta, G. and Chakraborti, D., (1995). "Arsenic in ground water in six districts of West Bengal, India: the biggest arsenic calamity in the world. Part I. Arsenic species in drinking water and urine of the affected people". Analyst 120:p. 643–651. doi:10.1039/AN9952000643.

Chakravarti, D., Chanda, C. R., Samanta, G., Chowdhury, U.K, Mukherjee, S.C., Pal, A.B. *et al.*, (2000). Fluorosis in Assam, India. Current Science,78,p. 1421-3.

Chi-Man, L. and Jiu J.J., (2006). Heavy metal and trace element distributions in groundwater in natural slopes and highly urbanized spaces in Mid-Levels area, Hong Kong, Water Research, 40 (4),p. 753-767.

Clesceri *et.al.*, (1992), Standard Methods for the Examination of Water and Wastewater (18^{th} ed.). APHA-AWWA-WPCF, Washington DC.

Cole, C. V., Innis, G. S., and Stewart, J. W. B., (1977). Simulation of phosphorus cycling in semi-arid grassland. Ecology 58, p. 1-15.

CPCB, (2007). Annual report: 2006-2007, CPCB, Ministry of Environment and Forest, Govt. of India. Delhi: Central Pollution Control Board.

Das, S., Behera, S. C., Kar, A., Narendra, P. & Guha,S.,(1997). Hydrogeomorphological mapping in ground water exploration using remotely sensed data – A case study in Keonjhar District, Orissa. Journal of the Indian Society of Remote Sensing 25: p.247-250

Das S. K., (2007). Water vision to avoid water wars in India-Key note address, published in the proceedings of Integrated water resource management (IWRM), p. 9-14.

Dang, H. S., Wadwani, C. N., Jaiswal, D. D. and Somasundram, S., (1984). 'Drinking water-important sources of trace element intake', Indian Journal of Environmental Health, 26(2), p.151.

Das, H. B., (1989). 'Potability of waters of Arunachal Pradesh', Indian Journal of Water Works Asson, (April-June), p. 191-196.

Dash, J. R., Patra, H. K., Mohanty, S. K., (2007). 'Bacteriological quality of the ground and Surface water in the rural areas around Angul - Talcher Industrial Zone , Orissa', International Journal of Ecology, Environment & Conservation , 13(1), p. 43-46.

Datta, D.V., Kaul, M.K., (1976). 'Arsenic content of drinking water in villages in northern India, A concept of arsenicosis', J. Assoc. Phys. India, 24, p.599–604.

De, A.K.,(2000). Environmental Chemistry 4th Edition , New Age International (P) limited publishers, New Delhi., P.239-240

Demirel Z., (2007). Monitoring of Heavy Metal Pollution of Groundwater in a Phreatic Aquifer in Mersin-Turkey, Environ Monit Assess., 132 (1-3), p. 15-23.

Diehl, H. *et. al.*, 1950, The versenate titration for total hardness, Amer. Water Works Jour. 42: 42-48.

Diersing, Nancy., (May 2009) . http://floridakeys.noaa.gov/pdfs/wqfaq.pdf. Water Quality: Frequently asked questions, Florida Keys National marine Sanctuary

Dixit R.C., Varma S.R., Notnaware V. and Thacker, N.P., (2004). Heavy metals contamination in surface and groundwater supply of an urban city, Indian Journal of Environmental Health, 45, p. 107–112

Doran, J.W., Sarrantonio, M., Liebig, M.A, (1998). "Soil health and sustainability", In: Sparks, D.L. (Ed.), Advances in Agronomy, Vol. 56, Academic Press, San Diego, CA, USA, p. 1–54.

Doran, J.W., and Parkin, T.B., (1994). Defining and assessing soil quality. P. 3-21 in J.W. Doran,*et al.*, (eds.) Defining Soil Quality For A Sustainable Environment. Soil Sci Soc. Am. Spec. Pub. No.15, Am. Soc. Agron., Madison, Wisconsin.

Doran, J.W., Sarrantonio, M., and Lieberg, M.A., (1996). Soil health and sustainability. Adv. Agronomy 56 (In press).

Doran, J.W., Zeiss, M.R., (2000). Soil health and sustainability: managing the biotic component of soil quality. Applied Soil Ecology 15, p. 3–11.

Dutta, J., Bhuyan, B., and Misra, A. K., (2009). "A Case Study on Soil Acidity and Metal Contents in and around the Tea Gardens of Sonitpur District, Assam, (India)", Journal of Environmental Research and Development, 3(4), p.1108-1113.

Dutta, J, Bhuyan, B., and Misra, A. K., (2008). "Chemical Estimation of Soil Fertility Status in and around the Tea Gardens of Gahpur Sub-Division, Assam", International Journal of Chemical Sciences, 6(2), p.1099-1105.

Esrey, S.A., Potash, J.B., Roberts, L. & Shiff, C., (1991). 'Effects of improved water supply and sanitation on ascariasis, diarrhoea, dracunculiasis, hookworm infection, schistosomiasis, and trachoma', Bulletin of the World Health Organization, 69 (5) p. 609-621.

Evans, L. J., (1989). 'Chemistry of Metal Retention by Soils', Environmental Science & Technology, 23, p.1046-1056.

Eckert, D.J., (1987). "Soil Test Interpretation - Basic Cation Saturation Ratios and Sufficiency Levels". In: Soil Testing, Sampling, Correlation, Calibration and Interpretation, SSSA Special Publication No. 21, Soil Sc. Soc. of America, Madison, Wisconsin, USA, p. 53-64

Elinder, C.G. Zinc. In: Friberg L, Nordberg G.F, Vouk V.B., (1986). eds. Handbook on the toxicology of metals, 2nd ed. Amsterdam, Elsevier Science Publishers,:p 664-679.

Evans, K.J., Mitchell, I.G. and Salau, B., (1978). Heavy Metal Accumulation In Soils Irrigated By Sewage And Effect In The Plant-Animal System. Melbourne and Metropolitan Board of Works (now Melbourne Water).

Farrimond, M. S., (1980). 'Impact of man in Catchments (111) Domestic and Industrial wastes in Water Quality in Catchment eco-system', Gower A M ed., John Wiley and Sons, Chichesterch, 4, p. 113-144.

Garai, R., Chakraborti, A.K., Dey, S.B., Saha, K.C., (1984). 'Chronic arsenic poisoning from tubewell water', J. Ind. Med. Assoc. 82, p. 34–35.

Garg. V.K., Deepshikha; Dahiya, S., Choudhury, A., (1998). ground water quality in rural areas of Jind district, Haryana, J. env. & poll. 5 (4) p. 285-290.

Das S. K., (2007). Water Vision to avoid water wars in India- key note address, published in the proceedings of Integrated Water Resource Management (IWRM), P. 9-14

Garg, D. K., Pant, A. B., Agarwala, M. R., and Gayal, B. N., (1990). Indian Journal of Environmental Protection, 10, p. 673.

Gauthreaux, K., Hardway, C., Falgoust, T., Noble C.O., Sneddon, J., Beck, M.J and Gopal, R. and Ghosh, P. K., (1985). 'Fluoride drinking water: its effects and removal', Def. Sc. J, 35 (I), p.81-88.

Ghosh, S., Vass, K. K., (1997). Role of sewage treatment plant in Environmental mitigation. K. K. Vass and M. Sinha (Eds.), Proceedings of the national seminar on changing perspectives of inland fisheries, Inland Fisheries Society of India, Barrackpore, p. 36-40.

Gupta, M. K., Singh, V., Rajwanshi, P., Srivastava, S. and Das, S., (1994). 'Fluoride in ground water at Agra', Indian Journal of Environmental Health, 36, p.43-46.

Gupta, S. C., (1991). 'Chemical character of ground waters in Nagpur District, Rajasthan', Indian Journal of Environmental Health, 33, p.341-349.

Gupta, S. C., (1981). 'Evaluation of quality of well waters in Udaipur District', Indian Journal of Environmental Health, 23 (3), p.195-202

Gupta, S. C., Rathore, G. S. and Doshi, C. S., (1993). 'Fluoride distribution in ground waters of Southern Rajasthan', Indian Journal of Environmental Health, 37 (2), p.97.

Gupta, A., Mall, R.K.; Singh ,R.; Rathore ,L. S., Singh R. S., (2006). Water resources and climate change: An Indian Perspective; Current Science, VOL. 90, NO. 12,

Glanz, J.T., (1995). "Saving Our Soil: Solutions for Sustaining Earth's Vital Resource", Boulder, Colorado: Johnson Books, p. 182.

Gregorich, E.G., Carter, M.R., Angers, D.A., Monreal, C.M., and Ellert, B.H., (1994). Towards a minimum data set to assess soil organic matter quality in agricultural soils. Can. J. Soil.Sci. 74: p. 367-385.

Haberern, John., (1992). Viewpoint: A soil health index. J. Soil Water Conserv. 47:6.

Hodges L., (1973). Environmental pollution (1st ed) Holt, Rinshert and Winston Inc. USA, p. 125-170

http://pib.myiris.com/facts/article.php3?fl=D3509, Drinking water quality in rural India: Issues and approaches, Water Aid

ICAR, (2005). Hand Book of Agriculture, 3rd Edition, Indian Council of Agricultural Research, New Delhi, P. 61

ICAR, (2005). Hand Book of Agriculture, 3rd Edition, Indian Council of Agricultural Research, New Delhi, P. 71

Interdepartmental Committee on the Redevelopment of Contaminated Land (ICRCL)., (1987). Guidance on Assessment and Redevelopment of Contaminated Land. 2nd Edition. ICRCL Central Directorate on Environmental protection, Department of the Environment , London, Circular 59/83.

IPCS, (2002). Principles and methods for the assessment of risk from essential trace elements. Geneva, World Health Organization, International Programme on Chemical Safety (Environmental Health Criteria 228).

ISI, (1989). Quality Criteria of Drinking Water, Prescribed by Indian Standards Institution and Indian Council of Medical Research, Prescribed by ISI (IS:10500-1989).

IWMI: Internationa water Management Institute, Head quarter in Sri Lanka.

Jackson, M. L., (1958). Soil Chemical Analysis Prentice-Hall of India, Private Limited, New Delhi (1973), p. 227-255.

Jackson, M. L., (1973). Soil Chemical Analysis, Prentice-Hall of India Private Limited, NewDelhi, pp. 214-255.

Järup, J., (2003). Hazards of heavy metal contamination. British Medical Bulletin, 68, p. 167-182.

Jenny, Hans., (1980). The Soil Resource: Origin and Behavior. Ecological studies 37. Springer-Verlag, New York.

Johnson, R.D., Jones, R.L., Hinesly, T.D., and David, D.J., (1974). Selected Chemical Characteristics of Soils, Forages, And Drainage Water From The Sewage Farm Serving Melbourne, Australia. U.S. Dept. of the Army, Corps of Engineers.

Johnson F. M., (1998). The genetic effects of environmental lead., Mutat. Res., 410, p.123-140.

Kakati, S. S., Sarma, H.P., (2008). A thesis "A study on quality of drinking water in Lakhimpur district of Assam with reference to Health Hazard" submitted to Gauhati University for the degree of Ph.D

Kataria, H.C., and Jain, O.P., (1995). 'Physico-chemical Analysis of river Ajnar', Ind. J. Env .Prot. 15(8) p.569-571.

Kaushik A, Kuashik C. P., (2004). 'Perspectives in Enviromental studies', New Age International Publishers, New Delhi, p. 14-15.

Karlen, D. L., Andrews, S. S. and Doran, J. W., (2001). Soil quality: Current concepts and applications. Advances in Agronomy 74:p. 1-40.

Kotoky, P., Barooah, P. K., Goswami, A. , Borah, G. C., Gogoi, H. M., Ahmed, F., Gogoi, A., Paul, A. B. *et. al.*, (2008). Fluoride and endemic fluorosis in the Karbianglong District, Assam, India. Fluoride, 41(1) p.42–45

Kumar, S. P., Pamteke, W., Srivastava, R. and Gnng, N., (1990). 'Indian Journal of Environmental Protection', 10, p. 763.

Kharat, S. J., Pagar, D., Sanjay., (2009). 'Determination of Phosphate in water samples of Nashik district (Maharashtra State, India) Rivers by UV- visible Spectoscopy' E-Journal of Chemistry 6 (S1), p S515-S521

Kumar, Kaushic, A., Kanchan T., and Sharma, R.H., (2002). J. Environ. Biol., 23 (3), p. 325-333.

Kumar, S., (2004). Pollution level and chemistry of drinking water in Hojai Sub-division, Nowgaon , Assam, India, Ph.D Thesis Gauhati University

Lal, R., (1987). Effects of soil erosion on crop productivity. CRC Critical Reviews in Plant Sciences. 5(4):p.303-367.

Larson, W.E., and Pierce, F.J., (1994). The dynamics of soil quality as a measure of sustainable management. P 37-51 in J.W. Doran *et al.*, (eds.) Defining Soil Quality For A Sustainable Environment. Soil Sci Soc. Am. Spec. Pub. No. 15, Am. Soc. Agron., Madison, Wisconsin.

Lantzy, R. J., Mackenzie, F. T., (1979). Atmospheric trace metals: global cycles and assessment of man's impact, Geochim. Cosmochim. Acta., 43, p. 511- 525.

Laxen, D. P.H and Harrison, R. M., (1981). Sc. Tot. Envir. 19 p. 59-82

Lereh, R.N., Barbarick, K.A., Westfall, D.G., Follett, R.H., McBride, T.M. and Owen, W.F., (1990). Sustainable rates of sewage sludge for dry land winter wheat production. I. Soil nitrogen and heavy metals. J. Prod. Agric. 3:p.60–65.

Mathias, A. J., Sumitha, B., Deepa, K. V., Ramya, C., Deepashree, G. H. M. and Smitha., (2007). 'Bacterial contamination of drinking water supplies to residential and work places of Bangalore', International Journal of Ecology, Environment and conservation ,13(1), p.123-128.

Marschner, H., (1995). Mineral nutrition of higher plants, Academic Press, London.

Mayback, M., Chapman, D.V. and Helmer, R., (eds.) (1989). 'Global Environment Monitoring System: Global Fresh Water Quality', Basil Blackwell Ltd., Oxford, p. 107-163.

McGowan, W., (2000). Water processing: residential, commercial, light-industrial, 3rd ed Lisle, IL, Water Quality Association.

Meenakshi, Arora, Garg, V.K., Kavita, Renuka and Malik, A., (2004). Ground water quality in some villages of Haryana, India: Focus on fluoride and fluorosis. J. Haz. Mater., 106 B:p. 85-97.

Meloun, M., Militky, J., and Forina, M., (1992). Chemometrics for Analytical Chemistry, Vol. 1: PC-Aided Statistical Data Analysis. Chichester, U.K.: Ellis Horwood.

Miller, T. G. J., (1991). 'Environment Science, sustaining the earth', Words Worth, Belment, California, p. 232.

Minaxi B. L., Amarika, S., Rupainwar, D.C., and Dhar, D. N., (2008). Seasonal variations of heavy metal contamination in river Gomti of Lucknow city region, Environ Monit Assess, 2008, 147, p.253–263.

Moen, J.E.T., Cornet, J.P., and Ewers, C.W.A., (1986). Soil protection and remedial actions: criteria for decision making and standardisation of requirements. p 441-448 in J.W. Assink and W.J. van den Brink (eds.) Contaminated Soil. Martinhus Nijhoff Publishers.

Moen, J.E.T., (1988). Soil protection in the Netherlands. p 1495-1503 in K. Wolf *et al.*, (eds.) Contaminated Soil '88, Kluwer Academic Publishers, Dordrecht.

Naik, S. and Purohit, K. M., (1996). 'Physico-Chemical analysis of some community ponds of Rourkela', Indian Journal of Environmental Protection. 16(9),p. 579-685.

National Academy of Science, (1977). In Drinking Water and Health, National Research Council (National Academy of Sciences), Washington D.C.

Nayak, M. S. and Sawant, A. D., (1996). 'Heavy Metal Content in drinking water of Mumbai City', Indian Journal of Environmental Health , 38(4), p.246-255.

Nganje, N., Edet, A. E., and Ekwere, S. J., (2007). Concentrations of heavy metals and hydrocarbons in groundwater near petrol stations and mechanic workshops in Calabar metropolis, southeastern Nigeria, Environmental Geosciences (DEG), 14 (1), p.15 – 29.

Nriagu, J. O., (1979). Global inventory of natural and anthropogenic emissions of trace metals to the atmosphere, Nature, 279, p.409-411.

Olaniya, M. S., (1969). 'Well water quality in Jaipur city', Indian Journal of Environmental Health, 11, p.378-391.

Olson, R.V., and Carlson, C.W., (1950). Iron chlorosis of sorghums and trees as related to extractable soil iron and manganese, Soil Sci. Soc. Amer. Proc., 14; p.109-112.

Parikh, Y., (2004). Planning for water in coming years, Chemical Engineering World (CEW), 40 (5), P. 61-66.

Park, K., (2005). Preventive and social medicine, (18th ed.) Bhanot publishers, p. 531-535.

Patel,M. K. and Tiwari, T. N., (1988). 'Physico-Chemical quality of dug well water in rural area of Rourkela', Indian Journal of Environmental Protection, 8(12) p.889-892.

Patel, S. V., Fudani, D. R., Patel, K. P., (2007). 'Physico-chemical characterization of under ground water used in Modasa and other villages of Modasa Taluka District

Peech, M., (1965). Hydrogen-ion Activity. In C. A. Black(ed). Methods of Soil Analysis, Part 2, Chemical and Microbiological Properties 9, Amer. Soc. Agron. Madison, Wisconsin., p 914-925.

Pierce, F. J., (1995). Soil quality in relation to value and sustainable management. *In* Proceedings of the conference Valuing Natural Capital In Planning For Sustainable Development, held at Woods Hole, MA,. National Research Council, Washington, D. C.

Pierce, F.J., and Larson, W.E., (1993). Developing criteria to evaluate sustainable land management.Pages 7-14 *in* J.M. Kimble (ed.) Proceedings Of The Eighth Intern. Soil Management Workshop:Utilization Of Soil Survey Information For Sustainable Land Use. USDA, Soil Conservation Service,National Soil Survey Center, Washington, D.C.

Pierce, F.J., Larson, W.E., Dowdy, R.H., and Graham, W.A.P., (1983). Productivity of soils: Assessing long-term changes due to erosion. Journal of Soil and Water Conservation. 38: p.39-44.

Pierce, F. J., and Nowak, P., (1994). Soil erosion and soil quality: Status and trends. Proceedings of the 1992 National Resources Inventory: Environmental and Resource Assessment Symposium, Georgetown University, Washington, D. C. USDA Soil Conservation Service, Washington, D. C.

Pierzynski, G. M., Sims, J. T., and Vance, G. F., (1994). Soils And Environmental Quality. Lewis Publishers, CRC Press, Boca Raton, FL.

Pierzynski, G. M., Sims, J. T., and Vance, G. F., (2000). "Soils and Environmental Quality," CRC press, Boca Raton, London, New York, Washington DC.

Radojevic, M. and Bashkin, V.N., (1999). Practical Environmental Analysis, Cambridge, U.K: Royal Society of Chemistry.

Raina, V., Shah, A. R. and Shakto, A. K., (1984). 'Pollution studies on water quality', Indian Journal of Environmental Health, 26, p. 187-201.

Devi, Rajeswari., Haobijam, R.K., Dhamendra, R. K., Gyaneshwari and Laishram Kosygin, (2007). 'Physico-chemical characteristics and aquatic bio-diversity of Potsangbam river, Manipur', Eco. Env. & Cons., 13(2) p.447-451.

Rai, M. M, (1995). Principles of Soil Science, 3rd Edition, Macmillan India Ltd., New Delhi, p. 213-217.

Rai, M. M., (1995). Principles of Soil Science, 3rd Edition, Macmillan India Ltd., New Delhi, p. 220.

Radojevic, M., Bashkin ,V.N., (1999). Practical Environmental Analysis. Paston Prepress Ltd. U.K p. 466.

Ram, P. and Singh, A.K., (2007). Studies on Distribution of Heavy Metals in Ganga Water and Its Bed Sediments along the Patna Stretch, Journal of Environmental Science and Engineering, 2007, 49 (3), p.211-214.

Rao, J. K., and Shantaram, M. V., (1994). 'Heavy metal pollution of agricultural solid due to application of garbage', Indian Journal of Environmental Health 36(I), p. 31-39.

Rao, S. K., (1989). Indian Journal of Environmental Protection, 9, p. 438.

Rao, S. K., (1993). 'Correlations among water quality parameters of ground waters of Nuzvid town and Nuzvid Mandalam', Indian Journal of Environmental Protection. 13 (4). p.261-266.

Rao, S. K., Rao, L. V., Padmavathy, D. and Rambabu, C., (1992). 'Ground water quality in Challapalli Mandalam', Indian Journal of Environmental Protection, 12 (5). p. 341-347.

Rao, S. K., Raju, V. A., Singshan, X., Someswara, B., Rao, P. V., Rao, S. and Chakravarty, K. P., (1994). 'Studies on the quality of water supplied by municipality of Kakinada and ground waters of Kakinada town', Indian Journal of Environmental Protection,14(3), p.167-169.

Reddy, M. C., Somasekhara., (1998). Indian J. Env. Health 40, p. 242-252.

Reginna, B. and Nabi, B., (2003). 'Physico-chemical spectrum of the Bhavani River water collected from the Kalingarayan Dam, Tamil Nadu', Indian J. Environ. & Ecoplan. 7(3) p.633-636.

Remya, L., Geetha, R., Chandramohana, Kumar, N. and Mathews, L., (2007). 'Impact on the Quality of water after Tsunami on the Dug wells in Chellanam: A Tsunami affected area in Southern India', Research Journal of Chemistry and Environment, 11(3), p.72-76.

Reid, K (ed)., (1998). "Soil Fertility Handbook", Ministry of Agriculture, Food and Rural Affairs, Queen's Printer for Ontario, Toronto.

Ross, D. S., (1994). Planning a Home Greenhouse. Fact Sheet 645. Cooperative Extension Service, University of Maryland System. p. 8 Reprinted 1996. (peer reviewed)

Ruehlmann, J. , Körschens. M., (2009) Soil Sci Soc Am J., *73*,p. 876-885.

Suma Latha, S., Ambika, S. R. and Prasad, S. J., (1999). Current Science, 76 (6), p. 25.

Saikia, S., (2008). Ph. D. Thesis 'A study on quality of drinking water in Lakhimpur district of Assam with reference to Health Hazard'

Sadiq, M., (1991). Solubility and speciation of zinc in calcareous soils. Water Air Soil Pollut. 57/58:p.411–421.

Santhi , D., Bhagan, U., Sarma ,L., (2002). Poll. Res. 21 (2), p. 203-207.

Santor, J. D, Boyd, G. B. and Agardy, F. J., (1974). Journal of Water Pollution and Control. Fed. 46, p.458-467.

Sarma, H. P., (1997). Quality of drinking water in the Darrang district with particular reference to Mangaldai Sub- division., Ph. D. thesis , G.U.

Sarma, H. P. and Bhattacharya, K. G., (1999). 'Nitrate and Fluoride content in drinking water of Darrang district, Assam', Journal of Assam Science Society, 40(4), p. 126-134.

Saxton, K.E., Rawls, W. L., Rosenberger, J.S., and Papendick, R. I., (1986). Estimating generalized soil-water characteristics from texture, Soil Sci. Soc. Am. J., 50:1031-1036.

Schofield, R.K., (1955). Can a precise meaning be given to "available" soil phosphorus? Soils and Fertilizers. 18: p.373-375.

Schofield, R. K. and A. W. Taylor., (1955). The Measurement of Soil pH. Soil Sci. Soc. Amer. Proc. 19:164-167.

Shamsh, P. and Pandey. G S., (1994). 'The Progressive formation of sulphate in the Textile Mill effluents', Indian Journal of Environmental Health, 36 (4), p.263-265.

Shah, C. M., Shilpkar, P.G, Acharya, P. B., (2008). 'Ground Water Quality of Gandhinagar Taluka, Gujarat, India' E-Journal of Chemistry, Vol. 5, No.3, p. 435-446,

Shepherd, S.C., Gaudet, G., Shepherd, M.I., Cureton, P.M., and Wong, M.P., (1992). The development of assessment and remediation guidelines for contaminated soil, a review of the science. Canadian Journal of Soil Science. 72:p.359-395.

Short, H.E., Robert, G.R.M., Bernard, T.W. and Mannadinayar, A.S., (1973). Endemic flurosis in Madras Presidency, Indian journal of medicinal research. 25: p.553-561

Sing, B.N. and Rai, S., (1999). 'Physico-chemical studies of Ganga river at Varanasi', J. Environ. Poll. 6(1) p.43-46.

Singh, A. P., Srivastava, P., C., and Singh S K, (2007). 'Seasonal variations in water quality of natural lakes of Nainital, India', International Journal of Ecology, Environment and Conservation ,13(1), p. 137-141.

Singh H., (2005). Effect of environmental pollution on water resources , Methods of rain water .harvesting and points of energy efficiency to water conservation, Proc. of International Congress of Chemistry and Environment (ICCE), P. 350-355.

Singh, R., (1988). 'Assessment of drinking water supplied to Jamalpur Town (Munger) Bihar', Indian Journal of Water Works, Asson, 24 (3) p.229-230.

Sing, R.K., Iqbal, S.A. mand Seth, P.C., (2000). Assessment of water quality of river Narmada at Hoshangabad, Orient J. Chem (Eng.) 16(3): p.499-502.

Singhananam, M. and Rao, K. S., (1996). 'Trace Element analysis of Rameswaram Island ground water', Indian Journal of Environmental Protection, 16(7), p. 485-487.

Soil and Plant Analysis Council, Inc, (2002). Soil Analysis: Hand Book of Reference Methods, CRC Press, Fourth Revision, P. 17-23.

Soil Science Society of America, (1995). Statement on soil quality. Agronomy News, June, 1995

Stehouwer, Richard, Ann, (1999). Quality of land applied biosolids in Pennsylvania, JG Press, Inc

Subba, R. N. and Rao, G. K., (1991). 'Ground water quality in Visakhapatanam urban area, Andhra Pradesh', Indian Journal of Environmental Health, 33 (I), p. 25-30.

Sunil Kumar, M. and Sailaja, R., (1998). Water studies: Methods for monitoring water quality, Centre for Environmental education, Bangalore.

Sushella, A. K., (2007). A treatise on Fluorosis (pp.15). Fluorosis Research and Rural Development Foundation, New Delhi

Susheela A. K., (1999). Fluorosis management programme in India.;*Curr. Sci.*, 1999, 77 **(10)**, p.1250-1256.

Susheela A. K., (1993). Prevention and control of fluorosis in India,Rajiv Gandhi National Drinking water Mission, Ministry of rural development , New Delhi Health aspect. Vol.-I

Taheruzzaman, Q. and Kushari, D. P., (1995). 'Study of some physico-chemical properties of the different water bodies in Burdwan with special reference to effluents resulting from Anthropogenic activities', Indian Journal of Environmental Protection, 15 (5), p. 344-349.

Takkar, P.N., (1988). Sulphur states of Indian soils pp S ½-1 to 31. In TSI-FAI Sulphur in Indian Agriculture, Sulphur Institute, Washington D.C. and FAI, New Delhi.)

Tambekar, D. H., and Charan, A. B., (2004). Nature Environment and pollution Technology, 3(3), p. 413-418.

Tandukar, N., Bhattacharya, P., Mukherjee, A.B., (2001). 'Preliminary assessment of arsenic contamination in groundwater in Nepal', In: Proceedings of the International Conference on Arsenic in the Asia-Pacific Region: Managing Arsenic for our Future, 20–23 November 2001, Adelaide, Australia, Glen Osmond, South Australia: CSIRO, Land and Water, p. 103–105.

Tata, S. N., (Chief ed.), (1987). Hand Book of Agriculture, I.C.A.R, New Delhi.

Thodore, B. Shelton., (2005). 'Interpreting Drinking Water Quality Analysis: What do the numbers mean?', Water Resources Management, Cook College-Rutgers University, New Brunswick NJ 08903.

Tiller, K.G., Honeysett, J.L., de Vries, M.P.C., (1972). Soil zinc and its uptake by plants. Aust. J. Soil Res. 10:p 165–182

Toth, S.J. and Prince, A.L., (1949). Estimation of cation exchange capacity and exchangeable Ca, K and Na content of soil by flame photometer technique, Soil Sci. 67: p 439 – 445.

Train, R. E. (1979). 'Quality criteria for water USEPA', Washington DC.

Tripathi, A. K., and Singh, R. C., (1996).'Fluoride level in ground water and ground water quality in rural area of District Alwar', Indian Journal of Environmental Protection, 16 (10), p. 748-755.

Tripathi, I. P., Srivastava, K. and Pandey, K. B., (1996). 'Analysis of trace element in water from hand pumps Rewa City', Indian Journal of Environmental Protection, 16 (5), p. 321-328.

Trivedy, R. K., (1990). 'Quality Criteria of Drinking water Prescribed by Indian Standard Institute (ISI)', In : Environmental Directory of India, Enviro Media, Karad, (India), p. 279- 281.

Trivedy, R. K., Goel, P.K., (1986). Chemical and Biological methods for water pollution studies, Environment pollution, Karad.

Tsuji, L. J. S. and Karagatzides, J. D., (2001). Chronic lead exposure, body condition and testis mass in wild Mallard Ducks, B. Environ. Contam. Tox., 67, p. 489-495.

Tucker, B.B and Kurtz, L.T., (1961). Calcium and magnesium determination by EDTA titration, Soil Sci. Soc. Amer. Proc. 25: p. 27-29.

US EPA ,(1994). Drinking water criteria document for manganese. Washington, DC, US Environmental Protection Agency, Office of Water (September 1993; updated March 1994).

Vijayalakshmi, I.B., (2007). Water quality and Health, Key note address, Proc. of International workshop on Integrated Water Resource Management (IWRM), p. 54-56.

Walkley, A., (1947). A Critical Examination of a Rapid Method for Determination of Organic Carbon in Soils - Effect of Variations in Digestion Conditions and of Inorganic Soil Constituents. Soil Sci. 63: p. 251-257.

Walsh, L.M. and Beaton, J.D., (1973). Soil testing and Plant analysis, Soil Sci. Soc.Am., Madison, WI, USA.

Warkentin, B.P., (1995). The changing concept of soil quality. J. Soil Water Conservation 50: p. 226-228.

Watson, S.B. and **Lawrence, J., (2003).** Drinking water quality and sustainability. Water Qual. Res. J. Canada 38(1) :p. 3-13.

Webb, T. H. and A. D. Wilson, (1995). A manual of land characteristics for evaluation of rural land. Landcare Research Science Series No.10. Manaaki Whenua Press, Lincoln, Canterbury, New Zealand

WHO, (1993). Guidelines for drinking water quality, Vol.1, Recommendations, Second edition.

WHO, (1994). Environmental Health Criteria Document No. 170 Assessing human health risks of chemicals: derivation of guidance values for health-based exposure limits. World Health Organization, Geneva.

WHO, (1999). Environmental Health Criteria Document No. 210. Principles for theassessment of risks to human health from exposure to chemicals. World Health Organization,Geneva.

WHO, (2001). Water health and human rights, World Water Day 2001. Available online at http://www.worldwaterday.org/thematic/hmnrights.html#n4

WHO, (2004). Guidelines for drinking-water quality, 3rd ed., World Health Organization, Geneva.

WHO, (2005). 'Guidelines for safe recreational waters', Volume 2 - Swimming pools, spas and similar recreational-water environments.

WHO, (2009). Potassium in drinking-water Background document for development of WHO Guidelines for Drinking-water Quality

Westerman, R.L. (ed.), (1990). Soil Testing and Plant Analysis, 3rd Ed. SSSA Book Series No.3, Medison, WI: Soil Science Society of American.

Wetzel, R. G. and Likens, G. E., (1991). Limnological Analysis. (2nd ed.) Springer-Verlag, Berlin. p.391.

Wilcox, L.V., (1950). Electrical Conductivity, Amer.Water Works Assoc, J. 42: p.775-776.

World Resources Institute (WRI), (1992). in Collaboration with UNEP and UNDP World Resouces 1992-93, Oxford University Press, New York, p. 328-329.

World Resources Institute (WRI), (1992). in Collaboration with UNEP and UNDP World Resouces 1992-93, Oxford University Press, New York, p.160.

Yasuhiro, S., Duong, V.T., Daigo S., Doan, C. and Yoshito, K., (2007). Arsenic and other Metal Contamination of Groundwater in the Mekong River Delta, Vietnam, J. Health Sci., 53,.p. 344-346.

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Lead, arsenic, fluoride, and iron contamination of drinking water in the tea garden belt of Darrang district, Assam, India

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Abstract Drinking water quality with respect to lead, iron, fluoride, and arsenic has been carried out in and around tea gardens of Darrang district of Assam, India. The district lies between 26°25′ and 26°55′ northern latitude and 91°45′ and 91°20′ east longitude and covers an area of 3,465.30 km^2. Twenty-five different sampling stations were selected for the study. Iron, lead, and arsenic were analyzed by using an atomic absorption spectrometer, Perkin Elmer AA 200, while fluoride was measured by the SPADNS method using a UV–VIS spectrometer, Shimadzu 1240 model. The study revealed that the water sources in the area are heavily polluted with lead. Statistical analysis of the data is presented to determine the distribution pattern, localization of data, and other related information. Statistical observations imply non-uniform distribution of the studied parameters with a long asymmetric tail either on the right or left side of the median.

Keywords Skewness · Quartile · Correlation · Kurtosis · Lead · Arsenic

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Introduction

India is currently facing critical water supply and drinking water quality problems. Water supplies in India are no longer unlimited. In many parts of the country, water supplies are threatened by contamination and future water supplies are uncertain. There is evidence of prevailing contamination of water resources in many areas of India. Although information on drinking water quality of Northeastern India is very little, results reported by various agencies have been alarming. The discovery that arsenic-contaminated groundwater is found in many tube wells in West Bengal has provided a major challenge to the efforts to provide safe drinking water (Chakraborti et al. 2002). Available literature shows that groundwater in Assam are highly contaminated with iron (Aowal 1981). The occurrence of fluoride contamination in Darrang, Karbi Anglong, and Nagoan

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districts of Assam in the form of fluorosis were already reported (Kotoky et al. 2008; Sushella 2007; Chakravarti et al. 2000). High level of fluoride and iron distribution in groundwater sources of certain districts of Assam has also been observed (Baruah et al. 1995; Das et al. 2003). The elevated lead level in drinking water is a new public concern in Assam. A critical step in assuring the quality of drinking water resources is to identify the cause of current or potential contamination problems. Testing of water quality on a regular basis is, therefore, an important part of maintaining a safe and reliable source. The World Health Organization (WHO) has given a set of guideline values for drinking water quality (WHO 2004). These guideline values, along with tolerance limits prescribed by the Indian Standard Institute (ISI; Trivedy 1990) and EPA standards of USA, are also important in determining water quality (Train 1979). If the people continue to use contaminated water, many will lose their health or die within a few decades. Those who will survive are in danger of carrying genetic and other diseases to the future generation. Unfortunately, the people in Darrang district are still unaware of water contamination and its hazardous effects. The efforts are much less than needed to mitigate the crisis. Hence, the immediate involvement of the research community is needed to combat the slow-onset disaster and save the poor people. For a rural and backward district like Darrang of Assam where the majority of the people live below the poverty line, the provision of safe drinking water is one of the prior conditions for overall social development. The present research has been carried out to study the drinking water quality parameters with respect to lead, arsenic, fluoride, and iron in and around some tea gardens of Darrang district, Assam to help users at the national or local level to establish which chemicals in a particular setting should be given priority in developing strategies for risk. The present work has been intended to provide unfaltering records of contamination of water for safe future use so that it is of value as an indicator of short-term improvement or deterioration in the environment when implementing remedial policies.

Materials and methodology

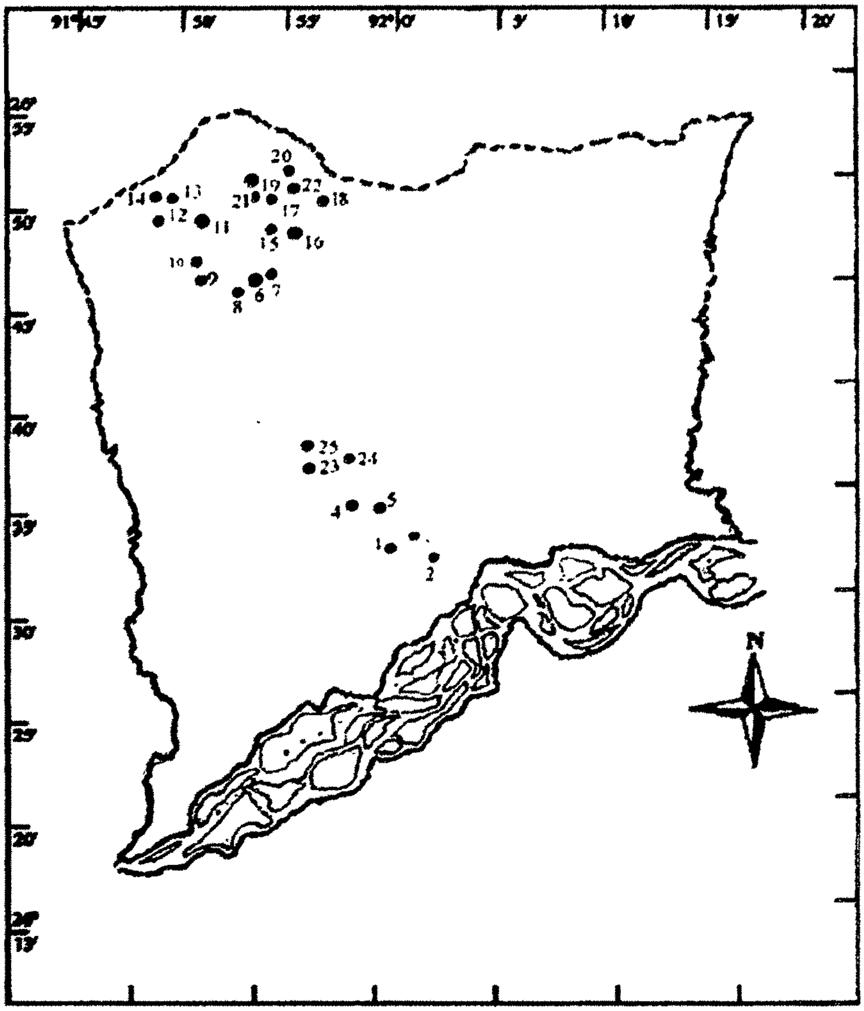
The study area, Darrang district, is situated in the eastern parts of India on the northeast corner of Assam. Located on the bank of the mighty river Brahmaputra, the district is largely plain. The district lies between 26°25′ and 26°55′ northern latitude and 91°45′ and 91°20′ eastern longitude. The district covers an area of 3,465.30 km^2 and falls in the subtropical climatic region and enjoys monsoon type of climate. For the present study, 25 water samples were collected in and around the five tea gardens of Darrang district during June to November 2008 (Fig. 1). Separate water samples were selected by random selection and compiled together in clean and sterile 1-L polythene cans rinsed with dilute HCl to set a representative sample and stored in an ice box. Samples were protected from direct sunlight during transportation to the laboratory and were analyzed as per the standard procedures (APHA 1998). Iron, lead, and arsenic were analyzed by using an atomic absorption spectrometer (Perkin Elmer AA 200). Fluoride was measured by the SPADNS method using a UV–VIS spectrometer (Shimadzu 1240).

Results and discussion

The experimental findings are summarized in Table 1. To look into the trend and distribution patterns of lead, iron, arsenic, and fluoride in drinking water, data were exposed to several statistical treatments. A conventional descriptive statistics based on normal distribution has been shown in Table 2. Correlations among the studied parameters are presented in Table 3.

Lead has no beneficial effect on humans or animals. Chronic exposure occurring over an extended period of time to even low levels of lead can have severe effects since lead is accumulated and stored in the bone. When the concentration is so high that storage in the bone is saturated, blood lead levels begin to affect nerve tissue. If drinking water is found to contain lead level exceeding the EPA guideline value of 0.015 ppm, it needs attention for lead contamination. In the present

Fig. 1 Sketch map of Darrang district showing the 25 sampling stations



study, the entire drinking water samples contain lead above the permissible limit. Lead above the permissible level in water can cause severe health problems among the people in the area. Large differences between mean and median, significant positive skewness, and kurtosis value indicate that the distribution of lead in the study area is widely off normal. The asymmetric nature of lead distribution is also evident from the width of the third quartile, which is much greater than the first and second quartiles.

Iron is one of the most disturbing constituents in water supplies throughout India. Water with high iron concentration causes most of the staining problems which appear around toilet bowls or on fixtures where water stands or drips. Although iron occurs naturally in groundwater, the higher concentration of iron in tube well waters with respect to other water sources in the area may be due to soil origin and age-old corroded iron pipes used. Iron content of some of the drinking water sources in the area exceeds the WHO guideline value of 0.3 mg/L. The iron content of the area may also promote the growth of iron bacteria, leaving a slimy coating in piping. A broad third quartile and positive skewness in case of iron represents a long asymmetric tail on the right of the median. The width of the third quartile is

Table 1 Average value of parameters of drinking water of Darrang district at 25 different stations

Sample no.	Sampling station	Source	Pb (in ppm)	Fe (in ppm)	As (in ppb)	F^- (in ppm)
1	Inside Tangoni Tea Garden	Tube well	0.07	0.36	1.70	0.62
2	Inside Tangoni Tea Garden	Tube well	0.08	0.35	1.08	0.54
3	Inside Tangoni Tea Garden	Tube well	0.08	0.29	1.33	0.31
4	Outside Tangoni Tea Garden	Tube well	0.10	0.27	BDL	0.97
5	Outside Tangoni Tea Garden	Tube well	0.09	0.31	0.32	0.61
6	Inside Paneri Tea Garden	Tube well	0.25	0.24	0.41	0.61
7	Inside Paneri Tea Garden	Tube well	0.07	0.13	BDL	0.58
8	Inside Paneri Tea Garden	Tube well	0.33	0.45	2.34	0.62
9	Outside Paneri Tea Garden	Tube well	0.35	0.87	0.41	0.58
10	Outside Paneri Tea Garden	Ring well	0.09	0.12	1.33	0.45
11	Inside Dimakusi Tea Garden	Tube well	0.05	0.25	BDL	0.51
12	Inside Dimakusi Tea Garden	Ring well	0.11	0.04	1.08	0.54
13	Outside Dimakusi Tea Garden	Tube well	0.09	0.01	BDL	0.42
14	Outside Dimakusi Tea Garden	Tube well	0.08	0.25	0.21	0.38
15	Inside GhagraparaTea Garden	Ring well	0.18	0.02	BDL	0.64
16	Inside Ghagrapara Tea Garden	Ring well	0.08	BDL	BDL	0.45
17	Outside Ghagrapara Tea Garden	Ring well	0.13	0.03	1.22	0.63
18	Outside Ghagrapara Tea Garden	Ring well	0.17	0.04	1.38	0.65
19	Inside Corramore Tea Garden	Stream	0.14	0.65	4.59	0.31
20	Inside Corramore Tea Garden	Stream	0.17	0.72	3.11	0.56
21	Outside Corramore Tea Garden	Ring well	0.16	0.53	2.89	0.43
22	Outside Corramore Tea Garden	Ring well	0.18	0.48	3.04	0.48
23	Inside Singrimari Tea Garden	Tube well	0.04	0.98	9.76	0.19
24	Inside Singrimari Tea Garden	Tube well	0.05	0.95	11.15	0.11
25	Outside Singrimari Tea Garden	Ring well	0.04	0.15	6.21	0.09

BDL below detection limit

Table 2 Descriptive statistics for water quality parameters

Descriptive statistics	Pb	Fe	As	F^-
Mean	0.1272	0.3396	2.1424	0.4912
Standard error	0.01654	0.05969	0.59139	0.03808
Median	0.0900	0.2700	1.2200	0.5400
Mode	0.08	0.04	0.00	0.31
Range	0.31	0.98	11.15	0.88
Standard deviation	0.08269	0.29843	2.95693	0.19042
Variance	0.00684	0.08906	8.74345	0.03626
Skewness	1.483	0.877	2.049	−0.21
Kurtosis	1.898	−0.143	3.892	1.176
First quartile	0.0750	0.0800	0.1050	0.4000
Second quartile	0.0900	0.2700	1.2200	0.5400
Third quartile	0.1700	0.5050	2.9650	0.6150

Table 3 Correlation table

		Fe	Pb	As	F^-
Pearson's correlation	Fe	1	−0.146	0.877**	−0.570**
Significance test (two-tailed)		–	0.486	0.000	0.003
Pearson's correlation	Pb	−0.146	1	−0.243	0.396*
Significance test (two-tailed)		0.486	–	0.241	0.050
Pearson's correlation	As	0.877**	−0.243	1	−0.717**
Significance test (two-tailed)		0.000	0.241	–	0.000
Pearson's correlation	F^-	−0.570**	0.396*	−0.717**	1
Significance test (two-tailed)		0.003	0.050	0.000	–

*$p = 0.05$ significant correlation (two-tailed)
**$p = 0.01$ significant correlation (two-tailed)

1.8 times greater than the second quartile, which for a symmetric distribution should be equal. Flat distribution for iron in the area is indicated by negative kurtosis value.

Natural fluoride in drinking water was not considered a health concern until just recently. The optimum level of fluorides in water for reducing dental cavities is about 1 mg/L. The distribution of fluoride in the drinking water of Darrang district was found to be within the permissible limit of the WHO with an average of 0.4912 mg/L. Fluoride with this average value in water may cause dental carries. No fixed trend of variation of fluoride among the sampling stations could be ascertained which may be due to human activity, use of artificial fertilizers, and waste disposal. Analysis of quartiles, positive kurtosis, and negative skewness are indicative of sharp asymmetric distribution of fluoride with a long left tail in the study area.

Arsenic in the study area can enter the water supply from natural deposits in the earth or from industrial and agricultural pollution. It is widely believed that naturally occurring arsenic dissolves out of certain rock formations when groundwater levels drop significantly. High arsenic levels are often used to indicate improper well construction or the location or overuse of chemical fertilizers or herbicides. Most of the water samples in the present study meets or falls below the current standard for arsenic, which is 0.05 ppm (WHO 2004). Wide data range and high standard deviation in case of arsenic is likely to bias the normal distribution statistic. This observation is supported by large differences between mean and median. Positive kurtosis and skewness value point toward sharp arsenic distribution with a long right tail in the study area.

The Pearson's correlation coefficient is a measure of linear association among different variables. Correlation coefficient ranges between -1 (a perfect negative relationship) and $+1$ (a perfect positive relationship). A value of 0 indicates no linear relationship. Since the directions of association of the measured variables are unknown in advance, two-tailed test of significance was carried out and presented in Table 3. It is also observed that some of the water quality parameters are negatively correlated and hence is significant at the 0.05 level.

Conclusion

A statistical analysis of water quality parameters with special reference to lead, iron, fluoride, and arsenic in the tea garden belt of Darrang district, Assam, India has been carried out. Different statistical estimations, viz. mean, mode, median, variance, skewness, and kurtosis, performed for each parameter indicate that their distribution in the study area is widely off normal with a long asymmetric tail either on the right or left side of the median. The width of the third quartile was consistently found to be more than the second quartile for each parameter. Wide data range in case of arsenic indicates the presence of extreme values in the form of outliers. All the water samples analyzed in the present investigation are contaminated with lead, which needs immediate attention for future protection of water in the area. The supply of pure and safe water is inadequate in the study area and was almost nonexistent in the rural areas around the tea gardens of Darrang district, Assam. People use water for drinking mostly from tube wells, ring wells, and streams. As a result, scarcity as well as chemical contamination of water affects a large number of people. Based on the study, it is concluded that the intrinsic drinking water quality in the area is not encouraging. Thus, suitable protective measures for drinking water sources in the area are recommended.

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References

Aowal, A. F. S. A. (1981). Design of an iron eliminator for hand tube wells. *Journal of I.W.W.A., XIII*(1), 65.

APHA (1998). *Standard methods for the examination of water and wastewater* (20th ed.). New York: APHA, AWWA and WEF.

Baruah, A., Sharma, R. N., Chowdhary, P. K., et al. (1995). Assessment of ground water quality around oil installations of Rudrasagar, Assam, India. *Ecology Environment and Conservation, 1*(1–4), 43–45.

Chakravarti, D., Chanda, C. R., Samanta, G., Chowdhury, U. K., Mukherjee, S. C., Pal, A. B., et al. (2000). Fluorosis in Assam, India. *Current Science, 78*, 1421–1423.

Chakraborti, D., Rahman, M. M., Paul, K., Choudhury, U. K., Sengupta, M. K., Lodh, D., et al. (2002). Arsenic calamity in the Indian subcontinent: What lessons have been learned? *Talanta, 58*(1), 3–22. doi:10 1016/S0039-9140(02)00270-9.

Das, B., Talukdar, J., Sarma, S., Gohain, B., Dutta, R. K., Das, H. B., et al. (2003). Fluoride and other inorganic constituents in ground water of Guwahati, Assam. *Current Science, 85*, 657–661.

Kotoky, P., Barooah, P. K., Goswami, A., Borah, G. C., Gogoi, H. M., Ahmed, F., et al. (2008). Fluoride and endemic fluorosis in the Karbianglong District, Assam, India. *Fluoride, 41*(1), 42–45.

Sushella, A. K. (2007). *A treatise on fluorosis* (pp. 15). New Delhi: Fluorosis Research and Rural Development Foundation.

Train, R. E. (1979). *Quality criteria for water*. Washington: USEPA.

Trivedy, R. K. (1990). Quality criteria of drinking water prescribed by Indian Standard Institution (ISI), IS:10500-1989. In R. K. Trivedi (Ed.), *Environmental directory of India* (pp. 279–281). Karad: Enviro Media.

WHO (2004). *Guidelines for drinking water quality* (3rd ed.). Geneva: World Health Organisation.

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DISTRIBUTION OF SOLUBLE SALTS IN THE SOILS OF TEA GARDEN BELT OF DARRANG DISTRICT, ASSAM, INDIA

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ABSTRACT

A study on soluble salt contents with reference to pH, EC, Cl^-, SO_4^{2-}, Ca and Mg in the soils of tea garden belt of Darrang district, Assam has been presented in this communication. A total of twenty soil samples collected from inside and outskirts of five selected tea gardens have been analysed and studied separately. The implications presented in this paper are based on statistical analyses of the raw data. Normal distribution analysis (NDA) and reliability analysis (Correlation Matrix) are employed to find out the distribution pattern and other related information. Differences between mean and median in each case, high standard deviation, significant kurtosis and skewness indicate that the soluble salts in the soils of the study area exhibit unsymmetrical distribution with a long asymmetric tail, extending either towards higher or lower values with respect to the median. The study reveals the potential risk of soil nutrient imbalance in the area.

Key words : Soil quality, NDA, Quartile, Correlation, Skewness, Kurtosis.

INTRODUCTION

The need for soil quality monitoring at a global level grows and increases exponentially as land use intensifies. Two methods for interpreting soil test results are generally practised by most public soil test laboratories for making fertilizer and lime recommendations. Eckert (1987) referred to them as the "Sufficiency Level" (SL) and "Basic Cation Saturation Ratio" (BCSR) concepts[1]. The BCSR method was first endorsed in a series of publications based on research in New Jersey[2-5]. A study on soluble salt

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contents in the soils of tea garden belt of Darrang district, Assam has been presented in this communication. The term soluble salts refer to the inorganic soil constituents that are dissolved in the soil water. Measurement of soil electrical conductivity gives an indication of the total concentration of soluble salts in the soil. The soluble salts found in soil predominantly consist of calcium, magnesium, sodium, chloride and sulphate. Exchangeable calcium and magnesium is the amount of cation exchange sites occupied by calcium and magnesium ions in the cation exchange complex relative to their valency. The ratio of exchangeable calcium to exchangeable magnesium may affect plant growth. Cumming and Elliott (1991) indicate that ratios between 5 : 1 and 1 : 1 are desirable[6]. Sulphate anion is the primary form of sulphur adsorbed by plants and mostly exists in the subsoil. It is easily absorbed by clay and adsorption increases with pH[7]. Chloride ion in soil can supply chlorine to the plants. Although chlorine has been identified as an essential micronutrient element since 1954[8], there has been little focus on its soil determination for deficiency. Recent studies have indicated that soil chlorine level is a factor influencing the probability of obtaining a yield response to chlorine[9]. Thus, monitoring of soluble salt levels in the soil can be very useful for determining the suitability of a new planting site.

The implications presented in this paper are based on statistical analyses of the raw data. Normal distribution analysis (NDA) and reliability analysis (Correlation Matrix) are used for interpretation of data. Correlation between different parameters in specific environmental conditions has been shown to be useful when such correlation exists and determination of few parameters would be sufficient to give some idea about the quality of the soil in the area. The primary objective of this study is to present a statistically meaningful soil quality database of the region.

Study area

The study area Darrang district is situated in the eastern parts of India on the northeast corner of Assam. Located on the bank of mighty river Brahmaputra, the district is largely plain. The district lies between $26^{0}25^{/}$ and $26^{0}55^{/}$ northern latitude and $91^{0}45^{/}$ and $91^{0}20^{/}$ east longitude (approximately). The district covers an area of 3, 465.30 sq. km and falls in the sub-tropical climatic region and enjoys monsoon type of climate. There are twenty eight major tea gardens in the district (Fig. 1).

Sampling information

Twenty soil samples were collected in and around the five selected tea gardens by adopting lottery method during January to June, 2008, where no appropriate chemical testing of soils are done on a regular basis (Table 1).

Table 1 : Soil sampling locations

Name of the tea garden	Sample No. (Inside)	Sample No. (Outside)	Number of samples
Tangoni	A1-A2	A11-A12	04
Paneri	B1-B2	B11-B12	04
Dimakusi	C1-C2	C11-C12	04
Corramore	D1-D2	D11-D12	04
Ghagrapara	E1-E2	E11-E12	04

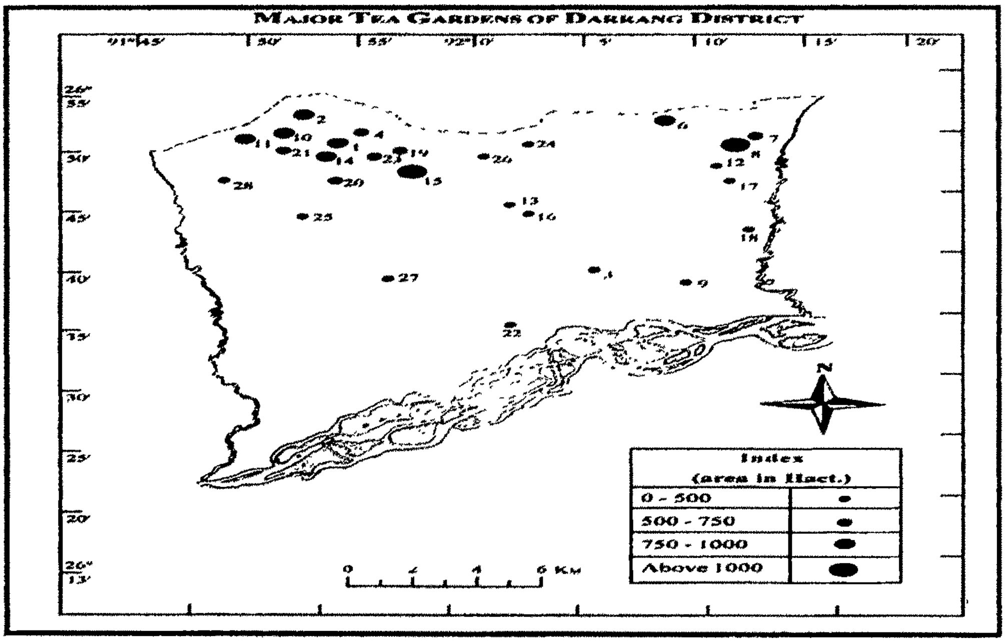

Fig. 1 : Distribution of tea gardens in Darrang district

EXPERIMENTAL

Materials and methodology

Soil samples were collected by adopting simple random sampling technique by maintaining a distance of about 50 meters between two samples. Soil samples were prepared by collecting small portions of surface soil. A "V" shaped cut of 0 to 6-inch depth at random locations was made in each sampling site and one inch of soil on either side of pit was scraped and collected in polythene bags. Quartering technique was adopted to reduce the size of the sample to the required mass. The field collected soil samples after assigning identification number were air-dried in oven set at 100 F (38^0C) for 12 hours. The air-dried sample is crushed by hand using a pestle and mortar and analyzed for pH, electrical conductivity (EC), exchangeable Ca, Mg, sulphate and chloride by selecting standard procedures which, in our experience, are appropriate for soils of the study area[10].

Statistical analysis

Sample data were subjected to statistical treatment using normal or Gaussian distribution statistic and correlation analysis. Some more statistical estimates derived from the normal distribution were also made in the present study for analyzing soil quality data and have been shown below:

Sample variance (r^2): Sample variance is given as the square of the standard deviation (r).

Kurtosis: Kurtosis is an indicator of the relative sharpness or flatness of the peak compared to normal distribution. Positive kurtosis indicates a sharp distribution while negative kurtosis indicates a flat one.

Skewness: It is a measure of the asymmetry of distribution. The normal distribution is symmetric and has a skewness value of zero. A distribution with a significant positive skewness has a long right tail. A distribution with a significant negative skewness has a long left tail. As a rough guide, a skewness value more than twice its standard error is taken to indicate a departure from symmetry.

Percentile (P_i): Percentile at 25%, 50%, 75% were calculated. Pi at 25% is called first quartile, at 50% second quartile and at 75% third quartile. Pi is also known as the cumulative probability function, which lies in the range $0 < Pi < 1$ for i =1, ..., n.

RESULTS AND DISCUSSION

To look into the trend and distribution patterns of soluble salts in the soils of tea garden belt of Darrang district, conventional descriptive statistics based on normal distribution and correlation analysis have been presented in Tables 2, 3, 4 and 5 with regard to pH, EC, Cl^-, SO_4^{2-}, Ca and Mg.

Table 2. Soil quality parameters inside tea gardens

Sample No.	pH	EC (mmho cm^{-1})	Cl^- (mg/100g)	SO_4^{2-} (mg/100g)	Ca (meq/100g)	Mg (meq/100g)
A1	4.01	1.60	15.60	3.12	1.12	0.30
A2	4.00	1.20	15.40	1.10	2.70	0.70
B1	4.99	1.20	11.36	1.91	1.73	0.37
B2	4.98	0.09	11.20	1.57	3.00	0.20
C1	4.55	6.60	14.91	2.18	0.72	0.12
C2	4.90	4.69	14.20	3.92	1.50	0.50
D1	4.55	0.56	28.03	2.99	2.40	0.40
D2	4.38	0.58	27.20	3.76	2.30	0.20
E1	4.77	0.44	22.01	4.21	2.60	0.60
E2	4.72	0.48	26.60	4.66	0.36	0.08
Descriptive statistics						
Mean	4.590	1.745	18.650	2.940	1.840	0.350
Standard error	0.115	0.680	2.103	0.383	0.284	0.071
Median	4.635	0.890	15.500	3.057	2.015	0.340
Mode	4.550	0.090	11.200	1.100	0.360	0.200
Range	0.990	6.510	16.830	3.560	2.640	0.600
Standard deviation	0.364	2.151	6.649	1.210	0.899	0.206
Variance	0.132	4.628	44.209	1.465	0.809	0.043
Skewness	-0.668	1.782	0.466	-0.137	-0.423	0.420
Kurtosis	-0.703	2.264	-1.671	-1.365	-1.165	-0.870
P25	4.288	0.470	13.490	1.825	1.020	0.180
P50	4.635	0.890	15.500	3.057	2.015	0.335
P75	4.920	2.373	26.750	3.993	2.625	0.525

Table 3. Soil quality parameters outside tea gardens

Sample No.	pH	EC (mmho cm^{-1})	Cl^- (mg/100g)	SO_4^{2-} (mg/100g)	Ca (meq/100g)	Mg (meq/100g)
A11	5.13	0.36	22.01	4.42	2.88	0.80
A12	5.40	0.80	29.40	4.38	1.20	0.20
B11	4.79	1.60	12.07	3.91	2.48	0.40
B12	4.88	0.13	12.60	0.56	1.30	0.40
C11	5.03	1.40	30.53	4.62	2.12	0.18
C12	5.70	0.90	23.80	5.38	2.60	0.80
D11	5.15	0.41	25.24	0.56	1.76	0.15
D12	5.20	1.12	22.43	1.28	1.20	0.40
E11	5.05	0.40	24.85	3.66	1.60	0.51
E12	5.20	0.78	25.66	4.23	1.40	0.48
			Descriptive statistics			
Mean	5.150	0.792	22.860	3.230	1.850	0.430
Standard error	0.082	0.151	1.951	0.629	0.198	0.073
Median	5.140	0.792	24.325	4.230	1.680	0.400
Mode	5.200	0.130	12.070	0.560	1.200	0.400
Range	0.910	1.470	18.460	4.820	1.680	0.600
Standard deviation	0.258	0.479	6.169	1.889	0.625	0.231
Variance	0.066	0.229	38.061	3.567	0.390	0.053
Skewness	0.876	0.396	-0.923	-0.686	0.523	0.550
Kurtosis	1.436	-0.825	0.185	-1.493	-1.356	-0.490
P25	4.993	0.391	19.658	0.920	1.275	0.195
P50	5.140	0.792	24.325	4.230	1.680	0.400
P75	5.250	1.191	26.595	4.520	2.510	0.582

Table 4 : Correlation matrix for soil quality parameters inside tea gardens

	pH	EC	Cl^-	SO_4^{2-}	Ca	Mg
pH	1					
EC	0.022	1				
Cl^-	-0.1792	-0.3752	1			
SO_4^{2-}	0.164	-0.0841	0.6524	1		
Ca	0.0284	-0.5156	-0.0514	-0.3894	1	
Mg	-0.197	-0.1227	-0.1571	-0.1812	0.5482	1

Table 5 : Correlation matrix for soil quality parameters outside tea gardens

	pH	EC	Cl^-	SO_4^{2-}	Ca	Mg
pH	1					
EC	0.3448	1				
Cl^-	0.3541	0.6577	1			
SO_4^{2-}	0.5322	0.4129	0.5731	1		
Ca	0.2895	0.0169	0.09	0.5213	1	
Mg	0.3609	-0.2286	-0.3462	0.4316	0.6287	1

pH and electrical Conductivity (EC) :

Soil pH is a good indicator for possible nutrient problems. Problem acid soils have a pH of less than 5.6 and usually below pH 5.0. Soils in the range 5.6 to 6.0 are moderately acidic and below 5.5 are strongly acidic in nature[11]. Significant negative skewness and kurtosis value for pH inside tea gardens indicates a flat distribution with a long tail on the left of the median. However, the distribution pattern of pH outside the tea gardens is sharp with a long right tail. The soil in the area was found to be significantly acidic in nature with a mean value of 4.59 inside the tea gardens. The factors like constant addition of chemicals to the soil along with excessive rainfall results in severe acidity build up in the soil system and affect the nutrient uptake of the tea plantation. Since soil is biodynamic, variation of soil pH in the study area may either result in non availability of nutrients in the available form to the plant or excessive availability of a particular nutrient, resulting in unbalanced growth of the plant or starvation of a particular nutrient.

It has also been noticed that EC of our study area has potential to cause specific ion toxicity or upset the nutritional balance in soil. The width of the third quartile is greater than even twice the second quartile inside as well as outside soil samples, which for a symmetric distribution should be equal. The width of quartiles for EC in the study zone represents a long asymmetric tail.

Calcium and magnesium (Ca and Mg) :

Ca and Mg are classified as secondary nutrients. They are secondary only in the probability of deficiencies and are taken up by plants in quantities similar to phosphorus. We have measured the amounts of exchangeable Ca and Mg since this is the plant available form. Calcium and magnesium deficiency symptoms can be rather vague since the situation often is accompanied by a low soil pH. The high acidity of soils limits the availability of Ca and Mg to the plant, which is evident from the plot of Ca/Mg ratio in the study area (Fig. 2) and also from the chemical rating chart (Table 6)[12].

Table 6. Ranking for laboratory exchangeable cation test results[12]

Test Name	Unit	Very low	Low	Moderate	High	Very high
Exchangeable calcium	meq/100g	<2	2-5	5-10	10-20	>20
Exchangeable magnesium	meq/100g	<0.3	0.3-1	1-3	3-8	>8
Calcium / Magnesium ratio		<1 (Ca def.)	1-4 (Ca low)	4-6 (Balanced)	6-10 (Mg low)	>10 (Mg def.)

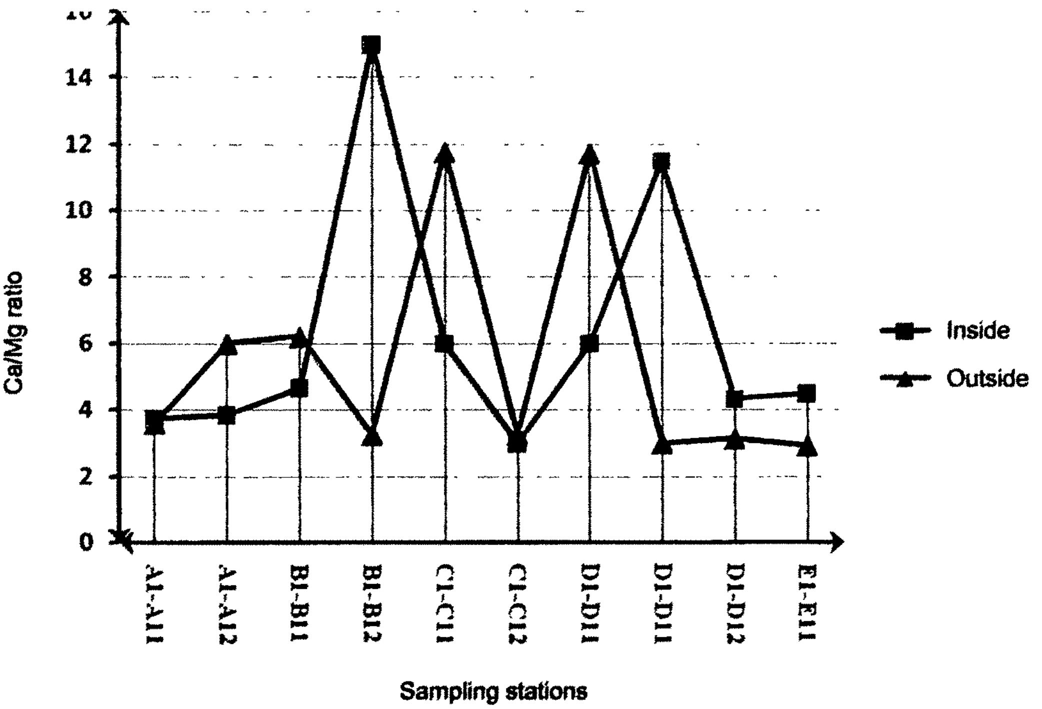

Fig. 2 : Distribution of Ca/Mg ratio in the tea garden belt of Darrang district

It is also observed that Ca and Mg share a significant correlation with pH at the 0.05 level in the study area. The distributions for both appear to be asymmetric and flat with the common feature of third quartile being wider than the second and negative kurtosis values.

Chloride and sulphate (Cl^-, SO_4^{2-}) :

From NDA, it is apparent that the distributions of SO_4^{2-} and Cl^- are not normal as is evident from the differences between mean and median values. The data range is also large for SO_4^{2-} and Cl^- in the area. Kurtosis and skewness in each set of samples is also indicative of the asymmetric nature of the distributions. The distributions of Cl^-, SO_4^{2-} in the area are represented in Fig. 3 and 4.

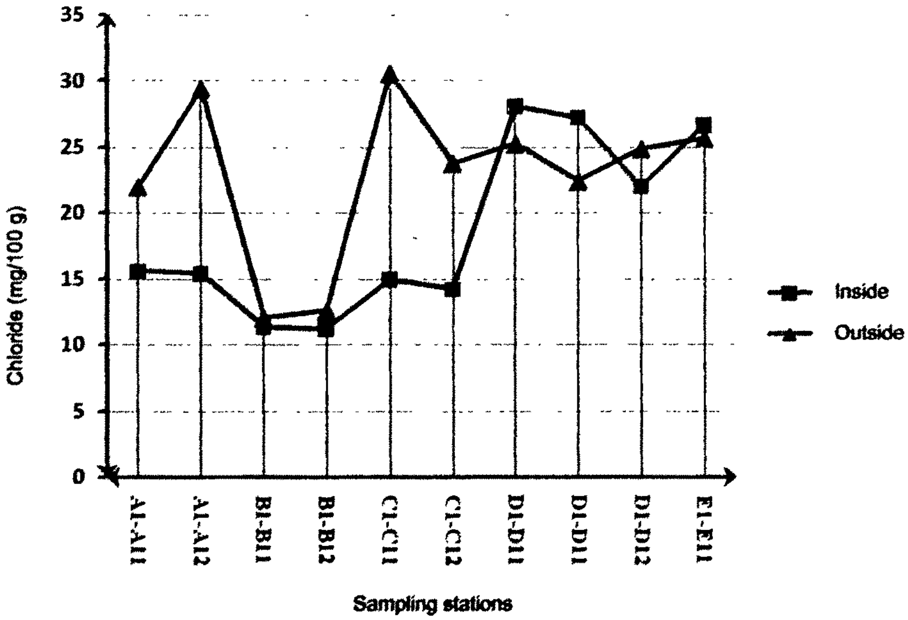

Fig. 3 : Distribution of Cl^- in the tea garden belt of Darrang district

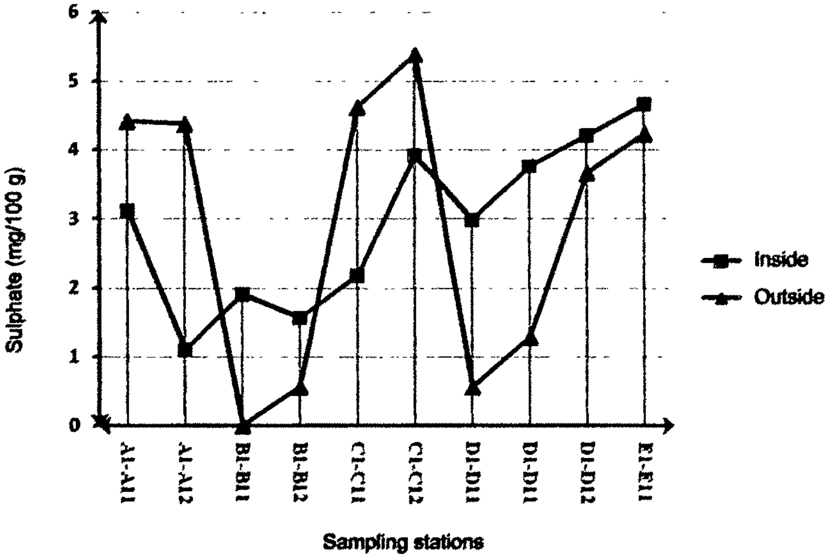

Fig. 4 : Distribution of SO_4^{2-} in the tea garden belt of Darrang district

CONCLUSION

A concise statistical analysis of soluble salt contents in soils of tea garden belt of Darrang district, Assam has been carried out with special reference to pH, EC, Cl^-, SO_4^{2-}, exchangeable Ca and Mg. The width of the third quartile was consistently found to be more than the second quartile for each parameter. Differences between mean and median in each case, high standard deviation, significant kurtosis and skewness indicate that the soluble ions in the soils of the study area exhibit unsymmetrical distribution with a long asymmetric tail extending either towards higher or lower values with respect to the median. Wide data range in each case indicates the presence of extreme values in the form of outliers, which are likely to bias the normal distribution statistics. It is, therefore, concluded that the distribution pattern of the studied parameters in the study area is widely off normal.

REFERENCES

1. D. J. Eckert, Soil Test Interpretation - Basic Cation Saturation Ratios and Sufficiency Levels. in, Soil Testing, Sampling, Correlation, Calibration and Interpretation, SSSA Special Publication No. 21, Soil Sc. Soc. of America, Madison, Wisconsin, USA, (1987) pp. 53-64
2. F. E. Bear and S. J. Toth, Soil Sci., **65**, 67-74 (1948).
3. A. S. Hunter, Soil Sci., **67**, 53-62 (1949).
4. A. S. Hunter, S. J. Toth and F. E. Bear, Soil Sci., **55**, 61-72 (1943).
5. A. L. Price, M. Zimmerman and F. E. Bear, Soil Sci., **63**, 69-78 (1947)
6. R. W. Cumming and G. L. Elliott, Soil Chemical Properties in, P. E. V. Charman and B. W. Murphy (Eds), Soils - Their Properties and Management, A Soil Conservation Handbook for NSW, Sydney University Press, Melbourne (1991).
7. Soil and Plant Analysis Council, Soil Analysis Hand Book of Reference Methods, CRC Press, Boca Raton, London, (2004) p. 159.
8. A. D. M. Glass, Plant Nutrition, An Introduction to Current Concepts, Boston, MA, Jones and Barlett Publishers (1989).

9. P. E. Fixen, R. H. Galderman, J. R. Gerwing and A. G. Farber, J. Fert. Issues, 4, 91-97 (1987).

10. M. L. Jackson, Soil Chemical Analysis, Prentice-Hall of India Private Limited, New Delhi (1973), pp. 214-255.

11. Indian Council of Agricultural Research (ICAR), Hand Book of Agriculture, 3rd Edition, New Delhi, Krishi Anusandhan Bhawan, Pusa, New Delhi (2005) p. 61

12. http//www.dlwc.nsw.gov.au/care/soil/ssu/tests/tests1.htm, date assessed 15/10/ (2008).

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Heavy Metal Contamination of Groundwater in the Tea Garden Belt of Darrang District, Assam, India

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Abstract: A study has been carried out on heavy metal contamination of groundwater with respect to cadmium, manganese, zinc and copper in the tea garden belt of Darrang district, Assam, India. Heavy metals in groundwater are estimated by using Atomic Absorption Spectrometer, Perkin Elmer AA 200. Univariate statistics along with skewness, kurtosis and '*t*' test have been employed to test the distribution normality for each metal. The study reveals that the groundwater of the area is highly contaminated with cadmium. A good number of samples are also found to contain manganese at an alert level. The concentrations of copper and zinc in the groundwater of the area are within the guideline values of WHO. Statistical results show that all the metals under study exhibit an asymmetric distribution in the area with a long asymmetric tail on the right of the median. Keeping in view of the high concentrations of cadmium and manganese, it is suggested to test the potability of groundwater of the area before using it for drinking.

Keywords: Cadmium, Manganese, Skewness, Kurtosis and t-Test.

Introduction

Heavy metal contamination of groundwater more often than not goes unnoticed and remains hidden from the public view. Presently, it has raised wide spread concerns in different parts of the world and results reported by various agencies have been alarming[1-2]. There is also evidence of prevailing heavy metal contamination of groundwater in many areas of India[3-5]. **Cadmium is today regarded as the most serious contaminant of the modern age. Copper is classified as a priority pollutant because of its adverse health effects. Manganese is most often a concern for systems that use a groundwater source. Zinc is an essential element and is** generally considered to be non-toxic below 5.0 mg/L. Thus, the monitoring of groundwater quality has been universally recognized as the quality of ground water cannot be restored once it is contaminated, by stopping the flow of pollutants from the source. The elevated metal level in groundwater is a new public concern in Assam. But unfortunately, very few data on heavy metal contamination of groundwater are available in Assam. The need is for a more systematic and careful study eliminating all possible sources of error and to build up a reliable database. Groundwater ccontamination of metals with respect to cadmium, manganese, zinc and copper in the tea garden belt of Darrang district, Assam has been presented in this study.

Profile of the study area

The study area Darrang district is situated in the eastern parts of India on the northeast corner of Assam. Located on the bank of mighty river Brahmaputra, the district is largely plain. The district lies between $26^0 25^/$ and $26^0 55^/$ northern latitude and $91^0 45^/$ and $91^0 20^/$ eastern longitude Figure 1.

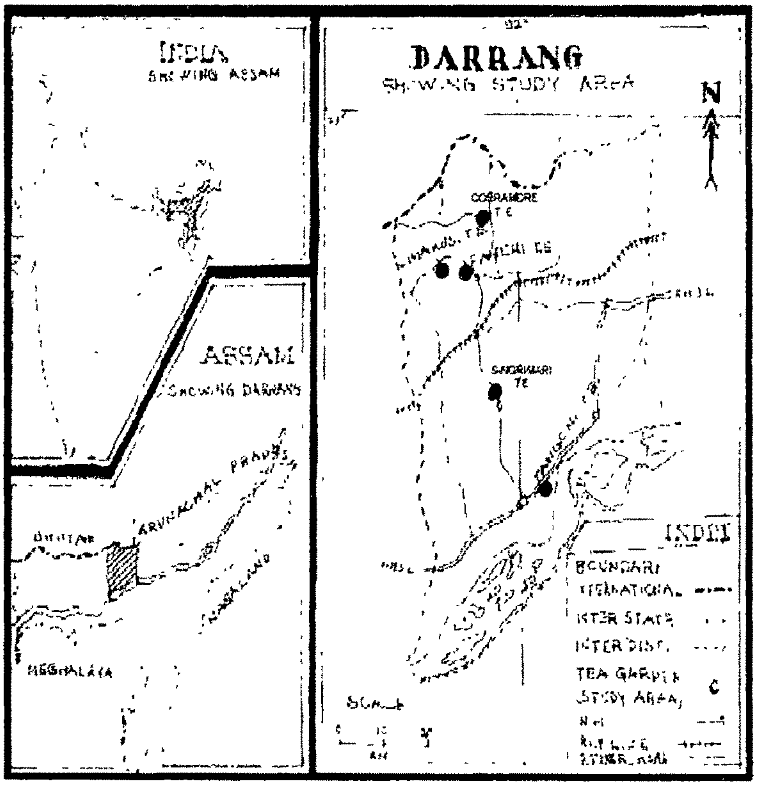

Figure 1. Sketch map of Darrang district showing its location.

Sampling information

For the present study, twenty eight water samples were collected inside as well as outside five tea gardens of Darrang district during June to November, 2008 (Table 1).

Table 1. Water sampling locations and sources.

S. No.	Sampling stations	Source	S. No.	Sampling stations	Source
A1	Inside Tangoni Tea Garden	Tubewell	B1	Outside Tangoni Tea Garden	Tubewell
A2	Inside Tangoni Tea Garden	Tubewell	B2	Outside Tangoni Tea Garden	Tubewell
A3	Inside Tangoni Tea Garden	Tubewell	B3	Outside Paneri Tea Garden	Tubewell
A4	Inside Paneri Tea Garden	Tubewell	B4	Outside Paneri Tea Garden	Ringwell
A5	Inside Paneri Tea Garden	Tubewell	B5	Outside Dimakusi Tea Garden	Tubewell
A6	Inside Paneri Tea Garden	Tubewell	B6	Outside Dimakusi Tea Garden	Tubewell
A7	Inside Dimakusi Tea Garden	Tubewell	B7	Outside (Ghagrapara) Corramore tea garden	Ringwll
A8	Inside Dimakusi tea garden	Ringwell	B8	Outside (Ghagrapara) Corramore tea garden	Ringwell
A9	Inside (Ghagrapara division) Corramore tea garden	Ringwell	B9	Outside Corramore Tea Garden	Ringwell
A10	Inside (Ghagrapara division) Corramore tea garden	Ringwell	B10	Outside Corramore Tea Garden	Ringwell
A11	Inside Corramore tea garden	Stream	B11	Outside Singrimari Tea garden	Ringwell
A12	Inside Corramore Tea Garden	Stream	B12	Outside Tangoni Tea Garden	Ringwell
A13	Inside Singrimari Tea Garden	Tubewell	B13	Outside Paneri Tea Garden	Tubewell
A14	Inside Singrimari Tea Garden	Tubewell	B14	Outside Dimakusi Tea garden	Ringwell

Experimental

Separate water samples were selected by random selection and compiled together in clean and sterile one litre polythene cans rinsed with dilute HCl to set a representative sample and stored in an ice box. Samples were protected from direct sun light during transportation to the laboratory and metals were analyzed as per the standard procedures[6]. All the metals were estimated by using Atomic Absorption Spectrometer (Perkin Elmer AA 200). The instrument was used in the limit of precised accuracy and chemicals used were of analytical grade. Doubly-distilled water was used for all purposes.

Data analysis

Univariate statistics were used to test distribution normality for each metal. The confidence interval was calculated at 0.05 level. *t*-Test is done under null hypothesis (H_0) by taking the assumption that the experimental data are consistent with the mean rating given by WHO[7]. Simple correlation analysis was used to relate the metal concentrations among themselves. Moment coefficients of skewness and kurtosis were calculated to express how the shapes of sample frequency distribution curves differ from ideal Gaussian (normal). Skewness was calculated as third moment of the population mean. In asymmetrical distributions, skewness can be positive or negative. Kurtosis was calculated as fourth moment of the population to describe the heaviness of the tails for a distribution. Some more statistical estimates derived from the normal distribution in the form of sample variance, 1^{st}, 2^{nd}, 3^{rd} Quartile, Inter Quartile Range (IQR) were also made in the present study to find out the distribution pattern of the data and other related information Details of these may be found in standard books on statistics and software packages[8].

Results and Discussion

The results of analysis of various metals in groundwater samples of the tea garden belt of Darrang district, Assam are given in Table 2. To get an idea about the distribution pattern of the metal contents in groundwater inside and outside the tea gardens separately, data are graphically represented in Figure 2 and 3 respectively. To look into the trend and distribution patterns of cadmium, manganese, zinc and copper in groundwater of the study area, data obtained from 28 sampling stations were exposed to several statistical treatments as discussed briefly in the methodology section. A conventional descriptive statistics based on normal distribution has been shown in Table 3.

Table 2. Metal contents of groundwater in the tea garden belt of Darrang district.

S. No.	Cu, ppm	Mn, ppm	Cd, ppm	Zn, ppm
A1	0.147	BDL	0.102	0.011
A2	0.089	BDL	0.112	0.027
A3	0.067	BDL	0.098	0.553
A4	0.032	0.026	0.016	0.172
A5	0.021	0.065	0.086	0.066
A6	0.043	BDL	0.023	0.012
A7	0.001	BDL	0.154	0.236
A8	0.011	0.002	BDL	0.346
A9	0.012	BDL	0.272	0.308
A10	0.083	0.001	0.154	0.177
A11	0.017	BDL	0.015	0.402
A12	0.018	BDL	BDL	0.064
A13	0.039	0.028	0.051	0.067
A14	0.037	0.041	0.079	0.321
B1	0.081	3.440	BDL	0.418
B2	0.098	0.600	BDL	0.541
B3	0.005	BDL	BDL	0.022
B4	0.009	BDL	0.015	0.321
B5	0.004	BDL	0.198	0.195
B6	0.001	0.003	0.169	0.231
B7	0.047	BDL	0.081	0.355
B8	0.055	BDL	0.110	1.493
B9	0.027	BDL	0.146	0.541
B10	0.021	BDL	0.102	0.413
B11	0.033	0.0045	0.001	0.211
B12	0.005	0.107	BDL	0.511
B13	0.007	0.085	BDL	0.481
B14	0.062	BDL	0.093	0.472

BDL: Below Detection Limit

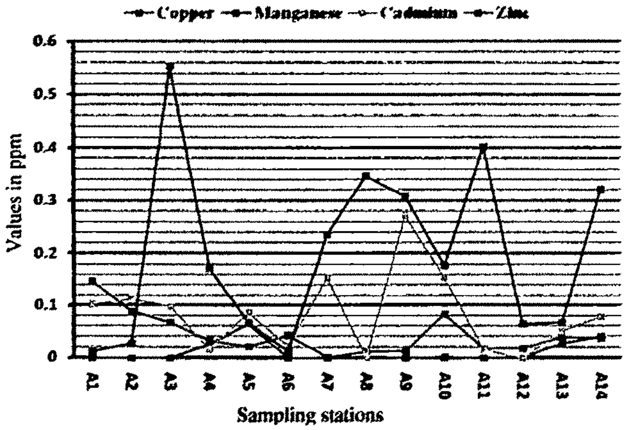

Figure 2. Variation of metal contents of groundwater inside the tea gardens.

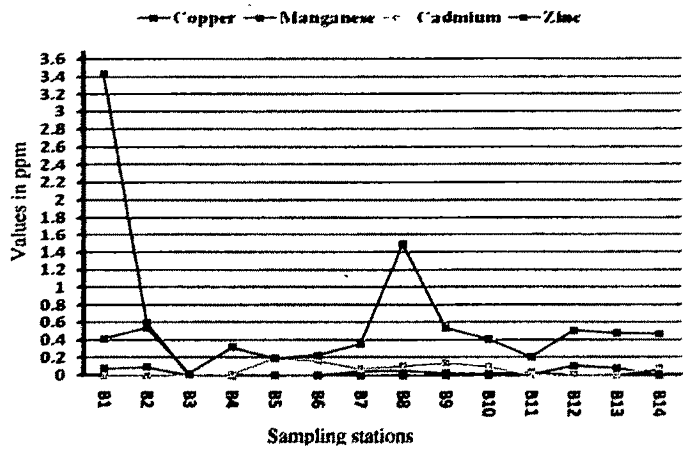

Figure 3. Variation of metal contents of groundwater outside the tea gardens.

Table 3. Descriptive statistics of the metal contents of groundwater in the study area.

Statistics	Cu	Mn	Cd	Zn
Mean	0.038	0.157	0.074	0.320
Standard Error	0.007	0.123	0.014	0.055
Median	0.030	0.000	0.080	0.315
Range	0.150	3.440	0.270	1.400
Standard Deviation	0.036	0.653	0.073	0.291
Variance	0.001	0.427	0.005	0.085
Skewness	1.298	5.058	0.822	2.420
Kurtosis	1.648	26.127	0.277	9.230
1st Quartile	0.010	0.000	0.000	0.093
2nd Quartile	0.030	0.000	0.080	0.315
3rd Quartile	0.060	0.028	0.112	0.459
IQR	0.044	0.026	0.109	0.246
WHO Rating, in ppm	2.000	0.400	0.003	5.000 (US Limit)
t-test value	289.774	1.949	5.154	85.134
Comment, 0.05 level	Significant	Non significant	Significant	Significant
95% CL	[0.024-0.052]	[0.001-0.412]	[0.046-0.103]	[0.207-0.433]
No of Samples	28	28	28	28

Pearson's correlation coefficient matrix is presented in Table 4 to measure the linear association among different metals under study. Since the directions of association of the measured variables are unknown in advance, two-tailed test of significance was carried out.

Table 4. Correlation table.

	Cu	Mn	Cd	Zn
Cu Fe	1.0000			
Mn	0.2770	1.0000		
Cd	-0.0068	-0.2445	1.0000	
Zn	0.0184	0.0925	0.0431	1.0000

In most of the samples under investigation, the cadmium contents were much above the guideline value of 0.003 ppm as set by WHO[7]. Cadmium above the permissible limit can potentially cause nausea, vomiting, diarrhea, muscle cramps, salivation, sensory disturbances, liver injury, convulsions, shock and renal failure along with kidney, liver, bone and blood damage from a lifetime exposure. Differences between mean and median, significant positive skewness and kurtosis value indicate that the distribution of cadmium in the study area is highly asymmetric. This is also evident from the width of the third quartile, which is much greater than the first and second quartile. The cadmium contamination of groundwater in the area should be accorded maximum attention.

Manganese at concentrations above 0.15 ppm stains plumbing fixtures and laundry and produces undesirable taste in drinks. The WHO limit for manganese in drinking water is 0.05 ppm[7]. It is observed that as many as seven samples under observation contain manganese either at toxic or alert level. Thus, manganese contamination of groundwater in the area needs proper attention. A broad third quartile and positive skewness in case of manganese represents a long asymmetric tail on the right of the median. Heaviness of the tail for manganese distribution in the area is evident from very high positive kurtosis value.

The permissible limit for copper in drinking water is 2.0 mg/L[7]. This was set to ensure the water tastes good and to minimize staining of laundry and plumbing fixtures. The distribution of copper in groundwater of the study area is found to be within the permissible limit of WHO[7] with an average of 0.038 ppm. Asymmetric nature of copper distribution is also apparent from the normal distribution statistics with positive skewness and kurtosis values.

Although the groundwater of the study area are by and large safe with regard to zinc as may be seen from Table 2, its distribution is still not uniform in the area. Wide data range and high standard deviation in case of zinc is likely to bias the normal distribution statistic. This observation is supported by positive kurtosis and skewness value, which point towards sharp zinc distribution with a long right tail in the study area.

From the correlation of the studied metals as shown in Table 3, significant correlation was found among cadmium, copper and manganese. Cadmium shares a clear negative correlation with manganese and copper content at the 0.05 level in the area.

Conclusions

Statistical observations on Cd, Mn, Cu and Zn in groundwater of teagarden belt of Darrang district, Assam show that all these metals exhibit an asymmetric distribution with a long asymmetric tail on the right of the median. It is observed that the groundwater of the area is contaminated with cadmium. A sizeable number of groundwater samples contain manganese at an alert level. The concentrations of copper and zinc in the groundwater of the area are either low or moderate and within the guideline values of WHO. Keeping in view of the unusually high concentrations of the harmful metals, *viz.* cadmium and manganese, it is advisable to test the potability of groundwater of the area before using it for drinking.

Acknowledgements

Kamala Kanta Borah is thankful to the University Grants Commission, New Delhi and Regional Office, Guwahati for allowing Teachers Fellowship vide no. F.5-43/TF/207 (NERO) /415 dated 25th April, 2008.

References

1. Friberg L, Nordberg G F and Vouk V B, Ed., Handbook of the toxicology of metals, Elsevier, Amsterdam, 1986, **2**, 130-184.
2. WHO/UNEP GEMS, Global fresh water quality; published on behalf of the World Health Organization/United Nations Environment Programme, Oxford, Blackwell Reference, 1989.
3. Sharma A, Sharma D K, Jangir J P and Gupta C M, *Indian J Environ Protect,* 1989, **9(4)**, 294-296.
4. Bhattacharjee S, Chakravarty S, Maity S, Dureja V and Gupta K K *Chemosphere,* 2005, **58**, 1203-1217.
5. Bhattacharya P, Chatterjee D and Jacks G, *Water Resources Development,* 1997, **13**, 79-92.
6. APHA (American Public Health Association), Standard method for examination of water and wastewater, New York, 20th Ed., 1998.
7. W.H.O, Guidelines for Drinking water Quality, 3rd Ed, World Health Organisation: Geneva, 2004.
8. Meloun M, Militky J and Forina M, Chemometrics for Analytical Chemistry, Vol. 1: PC-aided Statistical Data Analysis; Ellis Horwood Ltd: Chichester, England, 1992.

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WATER QUALITY ISSUES IN THE TEA GARDEN BELT OF DARRANG DISTRICT, ASSAM

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ABSTRACT

The present research has been carried out to study some of the water quality parameters in and around the selected tea gardens of Darrang district, Assam. Sixteen water samples are analysed by adopting standard analytical techniques of APHA. In this study, the tools used for data analysis are mainly experimental, aimed at defining possible relationships, trends, or interactions among the measured variables of interest. Descriptive statistics in the forms of mean, variance, standard deviation, standard error, median, range of variation and percentile at 95%, 75% and 25% are computed for eight water quality parameters. t-test is done under null hypothesis (H_0) by taking the assumption that the experimental data are consistent with the mean rating given by W.H.O. One-way ANOVA and confidential limit at 95% is also calculated by using ORIGIN 6.1 version. It is found that the inherent quality of waters in the tea garden belt of Darrang district, Assam is low and a suitable socio-economic and policy environment to maintain and improve water quality is also required.

Key words: pH, ANOVA, Sulphate, Phosphate, Nitrate, Water quality, Tea garden belt.

INTRODUCTION

Water is the most precious gift of the nature. It is indispensable for sustenance of life and is one of most important component which influences economic, agricultural and industrial growth of mankind. The effect of water on almost everything in our environment is far more significant than might be imagined. There is growing shortage of usable water resources and it is going to be one of the major issues of the twenty first century. Human

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use of fresh water has registered a 35 fold increase in the last 300 years. As a whole, 3500 km^3 of fresh water was withdrawn from different sources throughout the world for human use every year[1]. Pollution of fresh water occurs due to three major reasons- excess nutrients from sewage, wastes from industries, mining and agriculture[2]. W.H.O has given a set of guideline values for drinking water quality[3]. These guideline values, along with tolerance limits prescribed by the Indian Standard Institute (ISI)[4] and EPA standards of USA are also important in determining water quality[5]. Every effort should be made to achieve a drinking-water quality as safe as practicable.

It is observed that the tea garden belt in Assam has lately been subjected to large-scale human interference and pollution of water is rising at alarming rates due to the use of huge amount of agrochemicals for better production which contaminates ground water through percolation and rivers and other water bodies through surface run-off[6]. The loss of quality is causing health hazards and death of human which disturbs the whole ecology system of this region. The present research has been undertaken to study some of the water quality parameters in and around the selected tea gardens of Darrang district, Assam.

Study area

The study area Darrang district is situated in the eastern parts of India on the northeast corner of Assam.

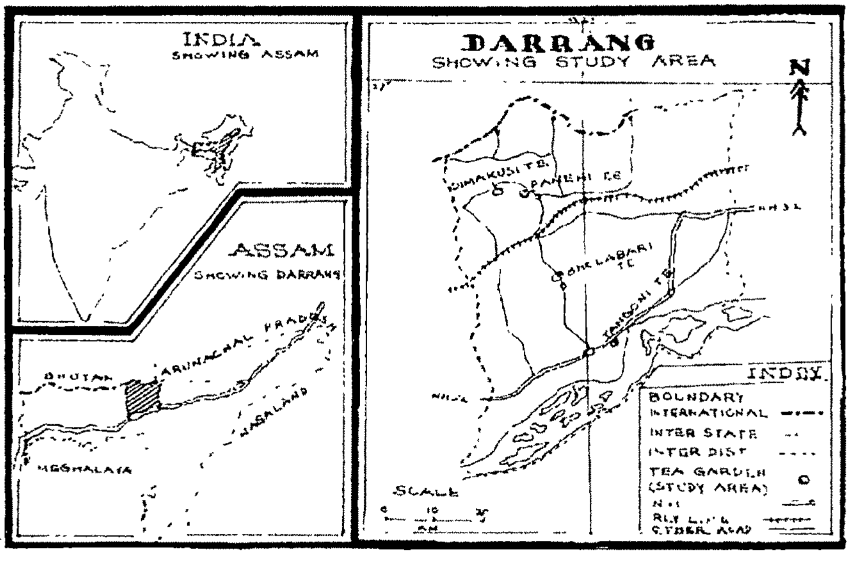

Fig. 1: Distribution of tea gardens in Darrang district

Located on the bank of mighty river Brahmaputra, the district is largely plain. The district lies between 26°25′ and 26°55′ northern latitude and 91°45′ and 91°20′ east longitude (approximately). The district covers an area of 3,465.30 sq. km and falls in the sub-tropical climatic region, and enjoys monsoon type of climate. There are twenty eight tea gardens apart from twenty privately owned tea gardens in the district (Fig. 1).

EXPERIMENTAL

Materials and methodology

Separate water samples were selected by random selection and compiled together in plastic bottles to set a representative sample. pH and conductivity were determined quickly after sampling. Samples were protected from direct sun light during transportation. The parameters studied are pH, conductivity, chloride (Cl^-), sulphate (SO_4^{2-}), nitrate (NO_3^-), phosphate (PO_4^{3-}), fluoride (F^-) and iron (Fe). Standard analytical techniques were adopted for physico-chemical analysis of water samples[7]. The instruments were used in the limit of précised accuracy and chemicals used were of analytical grade.

In this study, the tools used for data analysis are mainly experimental, aimed at defining possible relationships, trends, or interactions among the measured variables of interest. The observed parameters are related graphically (Figs. 2-9). Descriptive statistics in the forms of mean, variance (V), standard deviation (SD), standard error (SE), median, range of variation, and percentile at 95%, 75% and 25% (P95%, P75%, P25%) are calculated and summarized in tabular forms (Tables 2-9). t-test is done under null hypothesis (H_0) by taking the assumption that the experimental chemical water quality data are consistent with the mean rating given by W.H.O (2004). The calculated value of t is compared with tabulated value at 5% level of confidence. Confidential limit (CL 95%) at 95% is also computed by adopting standard statistical equations. Statistical analysis along with one-way ANOVA is carried out using ORIGIN 6.1 version.

Sampling information

Water samples were collected in and around four selected tea gardens of Darrang district during June to November, 2007 (Table 1).

Table 1. Water sampling locations

Sample No	Source	Place	Sample No.	Source	Place
A1	Tube Well	Tea Garden (Tangoni)	C1	Tube Well	Tea Garden (Dimakusi)
A2	Ring Well	Tea Garden (Tangoni)	C2	Supply Water	Tea Garden (Dimakusi)
A3	Tube Well	Outside Tea Garden (Tangoni)	C3	Tube Well	Outside Tea Garden (Dimakusi)
A4	Ring Well	Outside Tea Garden (Tangoni)	C4	Ring Well	Outside Tea Garden (Dimakusi)
B1	Tube Well	Tea Garden (Paneri)	D1	Tube Well	Tea Garden (Bhulabari)
B2	Supply Water	Tea Garden (Paneri)	D2	Ring Well	Tea Garden (Bhulabari)
B3	Tube Well	Outside Tea Garden (Paneri)	D3	Tube Well	Outside Tea Garden (Bhulabari)
B4	Ring Well	Outside Tea Garden (Paneri)	D4	Ring Well	Outside Tea Garden (Bhulabari)

RESULTS AND DISCUSSION

Table 2: Water test values for pH

Location	A	B	C	D
1	7.39	6.92	6.61	6.40
2	7.51	6.91	6.60	6.38

Cont...

Location	A	B	C	D
3	7.20	6.39	6.49	6.91
4	6.80	6.53	6.52	6.72
		Statistical analysis		
Median	7.2	6.53	6.52	6.4
Mean	7.22	6.68	6.55	6.60
Variance	0.096	0.072	0.0035	0.066
SD	0.311	0.269	0.0599	0.257
SE	0.155	0.134	0.029	0.129
Range	0.71	0.53	0.12	0.53
WHO Rating	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5
t-test	8.206	13.482	65.753	14.739
Comment (0.05 level)	S	S	S	S
P 25%	7.2	6.53	6.52	6.4
P 75%	7.39	6.91	6.6	6.72
P 95%	7.51	6.92	6.61	6.91
95% CL	[6.73 - 7.78]	[6.25-7.11]	[6.46-6.64]	[6.19-7.01]
One-Way ANOVA		F = 6.438, p = 0.0076		
Comment (0.05 level)		Means are significantly different		

Table 3: Water test values for conductance in mmho/cm

Location	A	B	C	D
1	2.6	2.0	2.5	2.4
2	2.4	2.4	2.4	2.2
3	0.6	2.5	3.8	2.3
4	2.2	2.4	3.6	2.1

Cont...

Location	A	B	C	D
		Statistical analysis		
Median	2.2	2.4	2.5	2.2
Mean	1.95	2.33	3.08	2.25
Variance	0.837	0.049	0.529	0.017
SD	0.915	0.222	0.727	0.129
SE	0.457	0.111	0.364	0.065
Range	2	0.5	1.4	0.3
USPHS Rating (mmho/cm)	0.3	0.3	0.3	0.3
t-test	3.608	18.265	7.629	30.209
Comment (0.05 level)	S	S	S	S
P 25%	2.2	2.4	2.5	2.2
P 75%	2.4	2.4	3.6	2.3
P 95%	2.6	2.5	3.8	2.4
95% CL	[0.49-3.41]	[1.97-2.68]	[1.92-4.23]	[2.04-2.46]
One-Way ANOVA	F = 2.556, p = 0.104			
Comment (0.05 level)	Means are not significantly different			

Table 4: Water test values for chloride in mg/L

Location	A	B	C	D
1	85.2	21.3	22.3	35.5
2	90.9	21.4	22.7	34.0
3	10.0	17.1	25.6	31.2
4	26.0	24.1	25.3	30.4

Cont...

Location	A	B	C	D
		Statistical analysis		
Median	26	21.3	22.7	31.2
Mean	53.03	20.98	23.98	32.78
Variance	1683.75	8.356	2.943	5.683
SD	41.034	2.891	1.715	2.384
SE	20.517	1.445	0.858	1.192
Range	80.9	7	3.3	5.1
WHO Rating (mg/L)	250	250	250	250
t-test	9.601	158.459	263.529	182.251
Comment (0.05 level)	S	S	S	S
P 25%	26	21.3	22.7	31.2
P 75%	85.2	21.4	25.3	34
P 95%	90.9	24.1	25.6	35.5
95% CL	[0-118.3]	[16.38-25.57]	[21.25-26.70]	[28.98-36.57]
One-Way ANOVA	F = 1.965, p = 0.173			
Comment (0.05 level)	Means are not significantly different			

Table 5: Water test values for sulphate in mg/L

Location	A	B	C	D
1	4.9	0.7	1.3	23.6
2	2.5	0.8	1.3	21.1
3	22.0	2.1	11.1	20.2

Cont...

Location	A	B	C	D
4	68.0	0.6	10.2	19.9
		Statistical analysis		
Median	4.9	0.7	1.3	20.2
Mean	24.35	1.05	5.98	21.2
Variance	922.19	0.497	29.275	2.820
SD	30.368	0.705	5.411	1.679
SE	15.184	0.352	2.705	0.839
Range	65.5	1.5	9.8	3.7
WHO Rating (mg/L)	250	250	250	250
t-test	14.861	706.495	90.201	272.497
Comment (0.05 level)	S	S	S	S
P 25%	4.9	0.7	1.3	20.2
P 75%	22	0.8	10.2	21.1
P 95%	68	2.1	11.1	23.6
95% CL	[0-72.67]	[0.07-2.17]	[0-14.84]	[18.53-23.87]
One-Way ANOVA	F = 2.168, p = 0.145			
Comment (0.05 level)	Means are not significantly different			

Table 6: Water test values for nitrate in mg/L

Location	A	B	C	D
1	0.03	0.5	0.3	0.8
2	0.02	0.9	0.2	0.9
3	0.05	0.4	0.1	0.7

Cont…

Location	A	B	C	D
4	0.7	0.3	0.06	0.8
Statistical analysis				
Median	0.03	0.4	0.1	0.8
Mean	0.2	0.525	0.165	0.8
Variance	0.111	0.069	0.012	0.007
SD	0.334	0.263	0.108	0.082
SE	0.167	0.132	0.054	0.041
Range	0.68	0.6	0.24	0.2
WHO Rating (mg/L)	50	50	50	50
t-test	298.591	376.242	926.745	1205.149
Comment (0.05 level)	S	S	S	S
P 25%	0.03	0.4	0.1	0.8
P 75%	0.05	0.5	0.2	0.8
P 95%	0.7	0.9	0.3	0.9
95% CL	[0-0.73]	[0.11-0.94]	[0- 0.34]	[0.67-0.93]
One-Way ANOVA	F = 7.2168, p = 0.005			
Comment (0.05 level)	Means are significantly different.			

Table 7: Water test values for phosphate in mg/L

Location	A	B	C	D
1	2.60	0.05	0.71	0.65
2	0.15	0.49	0.02	0.78
3	0.12	0.51	0.52	0.75
4	0.09	0.70	0.48	0.69

Cont...

Location	A	B	C	D
		Statistical analysis		
Median	0.12	0.49	0.48	0.69
Mean	0.74	0.4375	0.4325	0.7175
Variance	1.538	0.076	0.087	0.003
SD	1.240	0.275	0.292	0.059
SE	0.620	0.138	0.146	0.029
Range	2.51	0.65	0.69	0.13
USPHS Rating (mg/L)	0.1	0.1	0.1	0.1
t-test	1.032	2.453	2.272	21.103
Comment (0.05 level)	NS	NS	NS	S
P 25%	0.12	0.49	0.48	0.69
P 75%	0.15	0.51	0.52	0.75
P 95%	2.6	0.70	0.71	0.78
95% CL	[0- 2.71]	[0- 0.88]	[0- 0.89]	[0.62-0.81]
One-Way ANOVA	F = 0.271, p = 0.845			
Comment (0.05 level)	Means are not significantly different			

Table 8: Water test values for iron in mg/L

Location	A	B	C	D
1	0.41	0.28	3.0	3.0
2	0.28	0.31	2.9	3.1
3	0.35	2.9	0.36	3.0
4	0.65	2.9	0.39	3.0

Cont...

Location	A	B	C	D
		Statistical analysis		
Median	0.35	0.31	0.39	3.0
Mean	0.423	1.598	1.663	3.025
Variance	0.026	2.262	2.212	0.003
SD	0.1607	1.50405	1.48729	0.05
SE	0.080	0.752	0.744	0.025
Range	0.37	2.62	2.64	0.1
WHO Rating (mg/L)	0.3	0.3	0.3	0.3
t-test	1.525	1.725	1.832	109
Comment (0.05 level)	NS	NS	NS	S
P 25%	0.35	0.31	0.39	3.0
P 75%	0.41	2.9	2.9	3.0
P 95%	0.65	2.9	3.0	3.1
95% CL	[0.17-0.68]	[0-3.99]	[0-4.03]	[2.94-3.11]
One-Way ANOVA		F = 4.024, p = 0.034		
Comment (0.05 level)		Means are significantly different.		

Table 9: Water test values for fluoride in mg/L

Location	A	B	C	D
1	0.70	0.61	0.51	0.60
2	0.62	0.58	0.46	0.51
3	0.61	0.58	0.42	0.30
4	0.34	0.45	0.38	0.29

Cont...

Location	A	B	C	D
Statistical analysis				
Median	0.61	0.58	0.42	0.3
Mean	0.5675	0.555	0.4425	0.425
Variance	0.025	0.005	0.003	0.024
SD	0.157	0.071	0.056	0.155
SE	0.078	0.036	0.028	0.077
Range	0.36	0.16	0.13	0.31
WHO Rating (mg/L)	1.5	1.5	1.5	1.5
t-test	11.885	26.465	38.038	13.907
Comment (0.05 level)	S	S	S	S
P 25%	0.61	0.58	0.42	0.3
P 75%	0.62	0.58	0.46	0.51
P 95%	0.70	0.61	0.51	0.60
95% CL	[0.32-0.81]	[0.44-0.67]	[0.35-0.53]	[0.18-0.67]
One-Way ANOVA	F = 1.550, p = 0.253			
Comment (0.05 level)	Means are not significantly different			

N.B.: NS = Non Signifiant, S = Signifiant

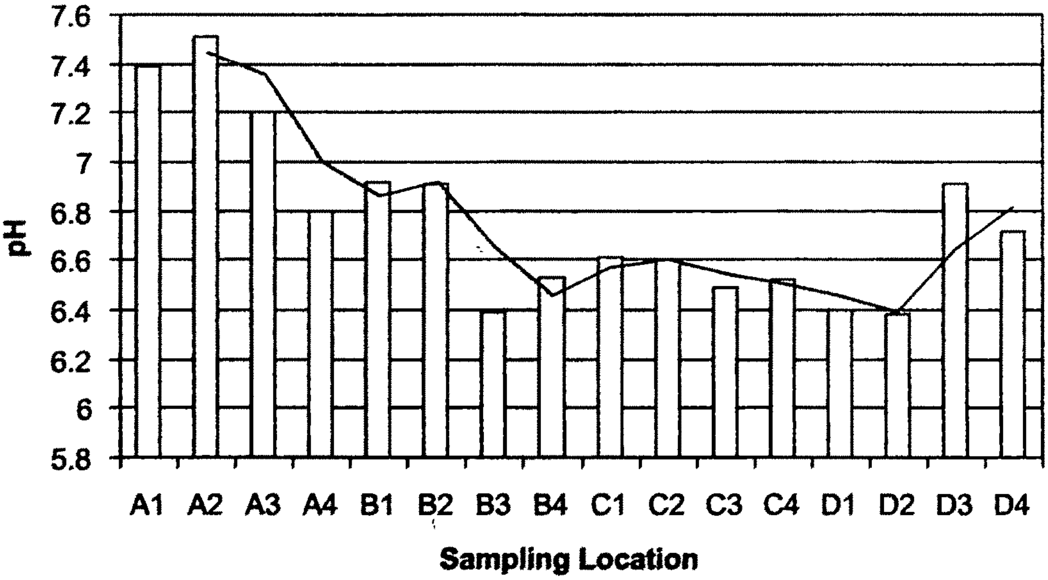

Fig. 2. Variation of pH among different sampling stations

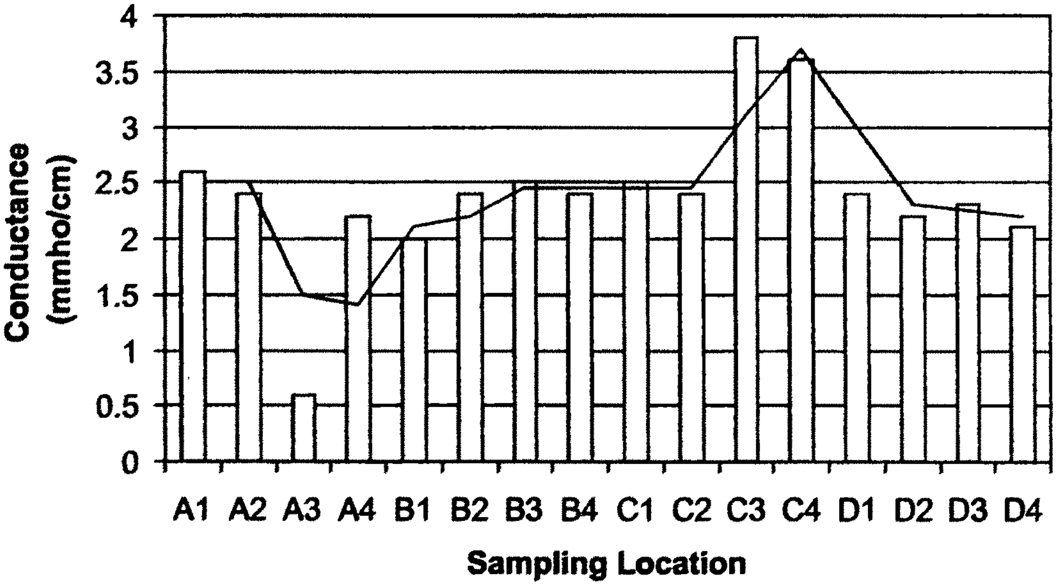

Fig. 3. Variation of conductance among different sampling stations

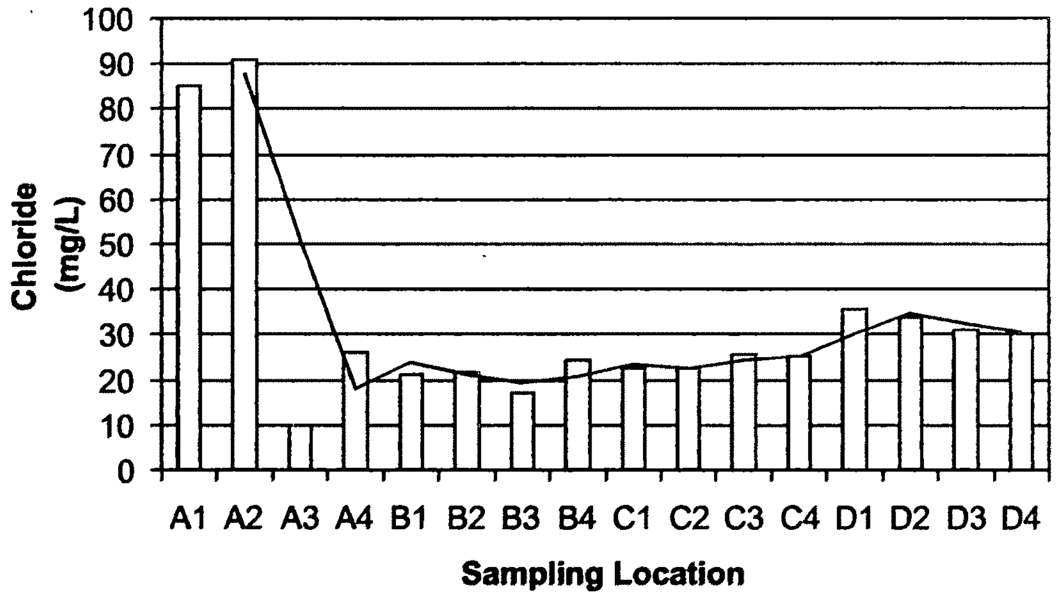

Fig. 4. Variation of chloride among different sampling stations

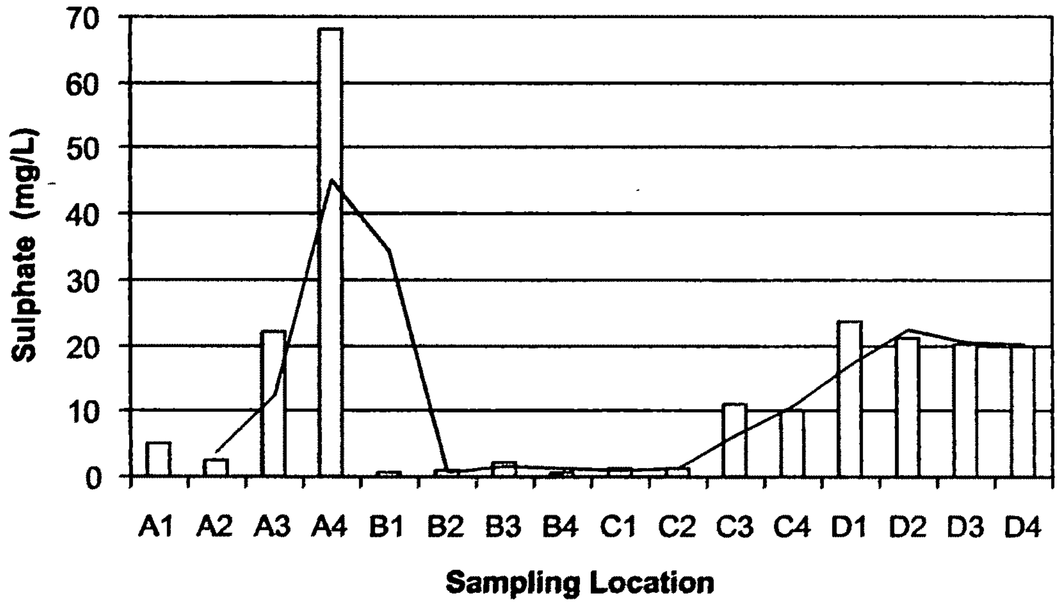

Fig. 5. Variation of sulphate among different sampling stations

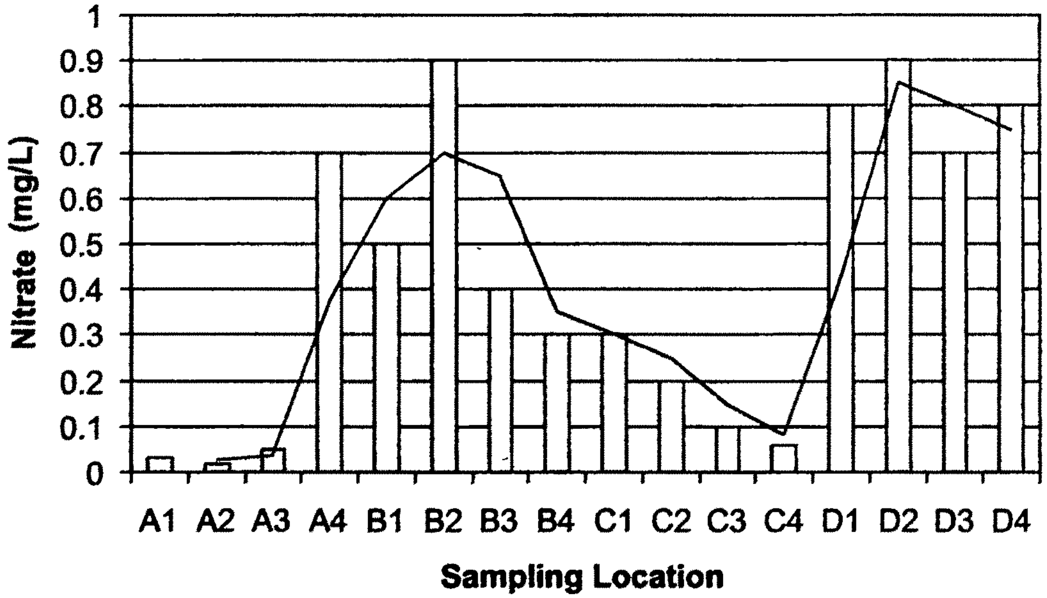

Fig. 6. Variation of nitrate among different sampling stations

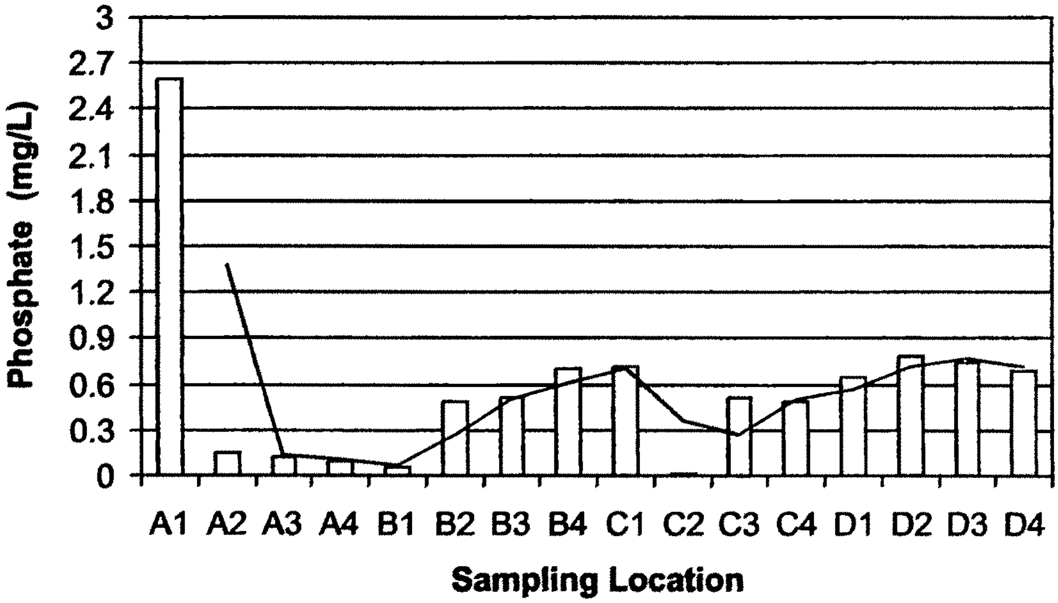

Fig. 7 Variation of phosphate among different sampling stations

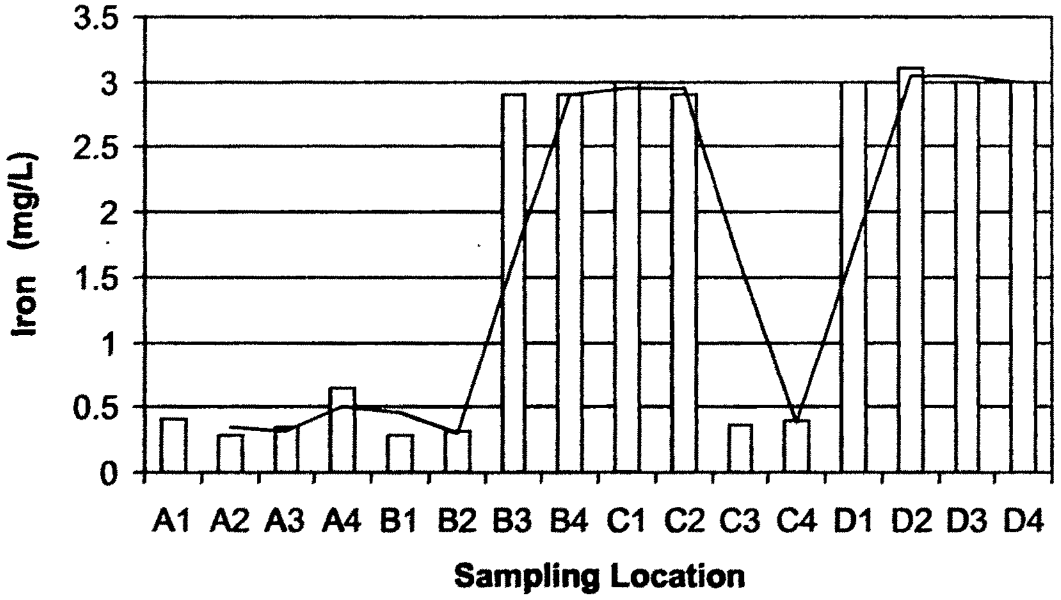

Fig. 8 Variation of iron among different sampling stations

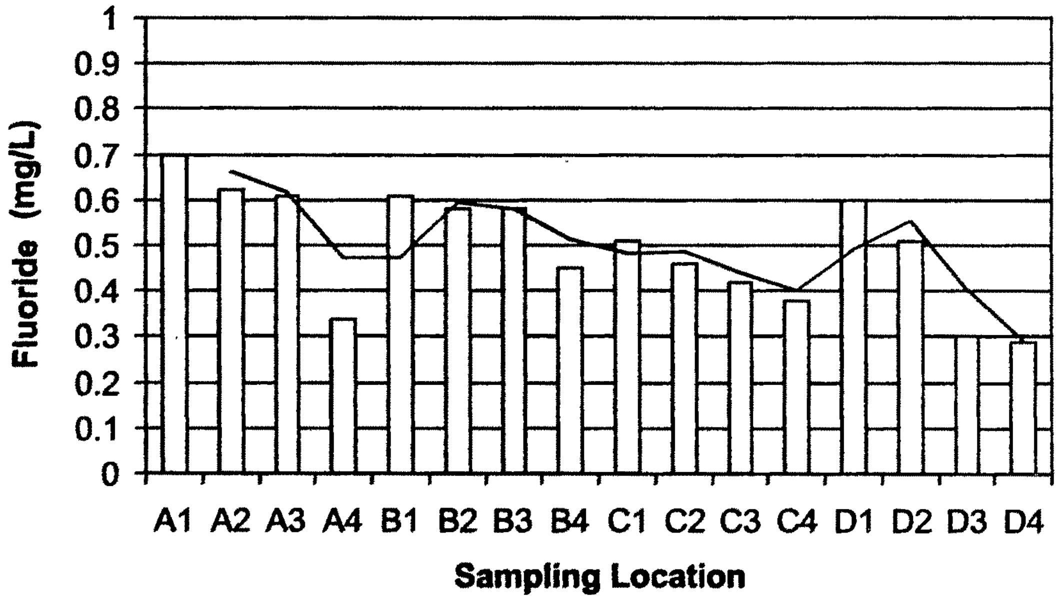

Fig. 9 Variation of fluoride among different sampling stations

Statistical observations

By comparing calculated | t | value with tabulated t at 5% probability level of significance, we may either reject or accept our null hypothesis H_0. If the value is significant then there will be evidence provided by our samples against our H_0. It is clear from the Tables 2-9 that proper water management is of urgent concern in the study area. The statistical values also show that most of the studied water quality parameters are significant implying that the null hypothesis may be rejected. The calculated confidential limit will give the range within which the unknown value of the parameter is expected to lie.

Environmental observations

In all the sampling stations, the variation of pH is narrow and in general, the pH is towards the acidic side except at sampling location No. A1, A2 and A3, where water is alkaline. The conductance of water in the study area have values greater than the maximum permissible limit (0.3 mmho cm^{-1}) of USPH and indicates that water is markedly polluted with its reference.

Chloride, sulphate and nitrate contents above the permissible limits can cause serious health problems to the consumer. Their concentrations in water under study are within the approved WHO guide line values for safe drinking water and no fixed trend of variation among the sampling stations could be ascertained, which may be due to precipitation, evaporation, human activity and waste disposal. The phosphate content of water needs serious attention as all of the samples except for A4, B1 and C2 exceeded the USPH guide line value of 0.1 mg/L.

The iron concentration is highest at source D2 that is 3.1 mg/L and minimum at source at A2 that is 0.28 mg/L. The data exceeds the WHO guideline value of 0.3 mg/L in most of the cases. The concentration of iron in water in the area is not suitable for food processing, dyeing, bleaching and many activities. The values for fluoride in water are ranging from 0.29 mg/L to 0.70 mg/L. In the present investigation, the fluoride concentrations were found to be within the permissible limit of W.H.O., but in some locations, where the fluoride concentration in water is less than 0.7 mg/L may cause dental carries.

CONCLUSION

The inherent quality of waters in and around the tea gardens of Darrang district, Assam is low and a suitable socio-economic and policy environment to maintain and improve water quality is also lacking. It is, therefore, immediately required that the water sources be properly protected from potential contaminants, and that appropriate treatment be selected for future use of water in the region. Thus, village level - microanalysis of the impact of water availability and water quality on the quality of life of people needs to be done in the study area.

REFERENCE

1. D. K. Asthana and Meera Asthana, Environment, Problems and Solutions, S. Chand and Company Ltd. Publication, Chapter- Fresh Water (1999) p. 65-70.
2. M. Mayback, D. V. Chapman and R. Helmer (Eds.), Global Environment Monitoring System, Global Fresh Water Quality, Basil Blackwell Ltd., Oxford (1989) p. 107-163.
3. WHO, Guide Lines for Drinking Water Quality, 3rd Edition, World Health Organisation, Jeneva (2004).
4. R. K. Trivedi (Ed.), Quality Criteria of Drinking Water prescribed by Indian Standard Institute (ISI), in, Environment Directory of India, Enviro Media, Karad (India) (1990) p. 279-281.
5. R. E. Train, Quality Criteria for Water, USEPA, Washington DC (1979).
6. B. Bhuyan, S. Kakati and H. P. Sarma, Poll. Res., **25(3)**, 571-575 (2006).
7. A. P. H. A, Standard Methods for the Examination of Water and Wastewater, 19th Ed. American Public Health Association, Washington DC, (1995).

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Variation of bulk density and organic matter in soils of tea garden belt of undivided Darrang district, Assam

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Abstract

Quantitative measures to monitor soil physical properties like bulk density and organic matter are more developed now and are still being explored as to how these measures control the total pore space and pore size distribution in soil. The present study has been undertaken to study the variation of SOM and ρ_b in and around some selected tea gardens of Darrang district, Assam for strengthening regional soil quality database so that purpose-oriented soil assessments and predictions can be made in the area. Thirty soil samples were collected from the study area and analysed for SOM and ρ_b as per standard procedures. The study reveals SOM and ρ_b in the area exhibit an unsymmetrical distribution with a long tail either on the right or left side of the mean. It is, therefore, important that we value and conserve our soils so that they will continue to be useful in the future.

Key Words: Compaction, Bulk density, Soil organic matter, Soil quality.

Introduction

Assessment of soil quality requires the measurement of the present state of the soil and judgements about its suitability for use. Soil physical properties like bulk density and organic matter control the total pore space and pore size distribution in soil. Bulk density (ρ_b) is a measure of the mass of particles that are packed into a volume of soil. It is useful in estimating, evaluating, and calculating many physical soil properties. The measurement of ρ_b provides a relative value of the porosity and compaction of a soil. Thus, ρ_b is an important soil structure attribute. Saxton et al. estimated generalized bulk densities and soil-water characteristics from texture and developed a set of equations from which soil-water characteristic equations for a number of soil textural classes can be derived [1]. One of the dominating factors changing ρ_b is the soil's organic matter (SOM) concentration that alters the soil's compressibility [2]. The term SOM has been used in different ways to describe the organic constituents of soil. Baldock and Skjemstad defined the term as "all organic materials found in soils irrespective of origin or state of decomposition" [3]. Adams estimated the change in soil bulk density from change in soil organic matter and organic carbon content [4]. Loss of organic matter from soil is a cause for concern because organic matter contributes to soil quality in many ways. Because of the many useful effects on soil quality, retention of soil organic matter is a high priority in sustainable soil management. The benefits of increasing soil organic matter include carbon sequestration and an increase in the capacity of the soil to store water and nutrients. No previous work to explore the distribution pattern of ρ_b and SOM was found in Darrang district, Assam. Although various chemical parameters of soil quality in the tea garden belt of Lakhimpur, Darrang and Sonitpur district of Assam was reported [5, 6, 7, 8], there is no earlier statistics available for ρ_b and SOM. Thus, the present study has been undertaken to study the variation of SOM and ρ_b in and around some selected tea gardens of Darrang district, Assam in order to strengthen the national and local soil quality database so that purpose-oriented soil assessments and predictions can be made in the area.

Materials and Methods

The study area Darrang district is situated in the eastern parts of India on the northeast corner of Assam. Located on the bank of mighty river Brahmaputra, the district is largely plain. Geographically, the district lies between $26^0 25'$ and $26^0 55'$ northern latitude and $91^0 45'$ and $91^0 20'$ eastern longitude (approximately). The district covers an area of 3,465.30 km^2 and falls under sub-tropical climatic region, and enjoys monsoon type of climate. Thirty soil samples were collected in and around the six selected tea gardens by adopting simple random sampling technique by maintaining a distance of about 50 meters between two samples during January to June, 2008. Soil sampling locations are presented in Table 1.

Table 1: Soil sampling locations

Sl. No.	Name of the Teagarden	Sample No's (Inside)	Number of Samples	Sample No's (Outside)	Number of Samples
1	Tangoni	A1-A3	03	A11-A12	02
2	Paneri	B1-B3	03	B11-B12	02
3	Dimakusi	C1-C3	03	C11-C12	02
4	Corramore	D1-D3	03	D11-D12	02
5	Ghagrapara	E1-E3	03	E11-E12	02
6	Singrimari	F1-F3	03	F11-F12	02

Bulk density was measured by cylindrical core method [9]. Soil organic carbon content in % was measured by following the procedure of Nelson and Sommers [10]. % Soil organic matter was calculated by using the equation:

% soil organic matter = % organic Carbon x 1.724 [11]

Results and Discussion

To look into the trend and distribution patterns of ρ_b and SOM in the soils of tea garden belt of Darrang district, data were exposed to several statistical treatments. Experimental data and conventional descriptive statistics based on normal distribution have been presented in Table 2 and 3 respectively.

Table: 2 Experimental data of SOM and bulk density in the study area

Sample No	SOM (%)	ρ_b (g/cm^3)
A1	1.48	0.775
A2	2.02	0.791
A3	3.48	0.991
B1	4.19	1.033
B2	3.31	0.994
B3	1.49	0.876
C1	5.00	0.921
C2	3.05	0.689
C3	2.79	1.090
D1	6.07	1.300
D2	3.52	1.450
D3	2.63	1.110
E1	3.90	1.230
E2	3.24	1.360
E3	3.05	1.320
F1	3.31	1.020
F2	3.05	1.480
F3	2.81	1.320
A11	3.50	0.866
A12	3.31	0.956
B11	3.26	1.130
B12	4.12	1.240
C11	2.09	1.010
C12	1.69	0.891
D11	1.34	0.791
D12	4.12	0.871
E11	2.95	0.987
E12	2.00	0.998
F11	4.83	1.010
F12	2.03	1.580

Table: 3 Descriptive statistics of experimental data

Descriptive Statistics	SOM (%)		ρ_b (g/cm^3)	
	Inside tea gardens	Outside teagardens	Inside tea gardens	Outside teagardens
Mean	3.244	2.936	1.097	1.027
Standard error	0.263	0.319	0.056	0.061
95% Confidence Interval for Mean	[2.670-3.798]	[2.234-3.640]	[0.98- 1.22]	[0.893-0.162]
5% Trimmed mean	3.185	2.920	1.099	1.010
Median	3.145	3.105	1.062	0.993
Variance	1.242	1.224	0.057	0.045
Standard deviation	1.114	1.107	0.239	0.212
Minimum	1.480	1.340	0.689	0.790
Maximum	6.070	4.830	1.480	1.580
Range	4.590	3.490	0.791	0.790
Inter quartile range	0.865	1.958	0.410	0.224
Skewness	0.766	0.176	0.007	1.776
Kurtosis	1.603	-1.113	-1.071	3.780

The bulk density of soil is inversely related to the porosity of the same soil. High bulk density is an indicator of low soil porosity and soil compaction. At the same time, bulk density also increases with clay content. The soil texture in the study area is classified as clay. The mean bulk density of soil inside and outside the tea gardens of the study area was found to be 1.097gm/cm^3 and 1.027gm/cm^3 respectively. The soils of the study area, thus, have low permeability and the decrease in soil porosity means that plant roots are often physically impeded by compact subsoil layers. This also implies that the subsoil of the area cannot held sufficient amount of available nutrients and water. The soils in the area are likely to exhibit properties which are somewhat difficult to manage or overcome. For example, soils in the area are often too sticky when wet and too hard when dry to cultivate. Subsoil in most of the sampling stations is found to be never wet up properly and others can have high mechanical impedance or poor aeration resulting in poorly developed root systems. The skewness and kurtosis values for bulk density inside and outside the tea gardens indicate that its distribution in the study area is not uniform with a long right tail with respect to the mean. Wide data range and high standard deviation obtained for bulk density in both inside and outside the tea gardens also likely to bias the normal distribution statistic in the area

Monitoring soil organic carbon levels provides a good measure of the fertility of the soil. Good soils are generally understood to be sandy loom soils high in organic matter (4-10%). The soil samples in and around the tea gardens of Darrang district, Assam are found to contain low organic matter and are, therefore, difficult for plant root penetration. Within the study area there is a wide variety of soils. Some are highly productive and extremely important for agriculture, while others are thin and infertile with low agricultural potential. It may be due to sewage containing toxic metals, precipitation of acidic and other airborne contaminants as well as persistent use of fertilizers and pesticides in the tea gardens. Typically soil organic carbon varies as a function of climate and land use. It generally follows continental rainfall and temperature patterns. The climate is also not conducive to production and retention of high levels of organic matter. The distribution of SOM in the study area is found to be highly unsymmetrical. Positive skew obtained for SOM indicates an asymmetric tail extending towards higher values. Positive kurtosis data inside the tea garden indicates a sharp distribution while negative kurtosis outside the tea gardens indicates a flat distribution pattern of SOM.

Conclusion

A comprehensive analytical and statistical analysis of distribution of soil bulk density and SOM in both inside and outside the tea gardens of Darrang district, Assam has been presented. Setting and monitoring physical properties of soil is important to ensure that soil function is maintained, not only for the current land use, but also for potential future uses. Statistical observations show bulk density and SOM exhibit an asymmetric distribution with a long tail either on the right or left side of the mean in the study area. Wide data range, high **standard deviation, differences between mean and median, significant skewness and kurtosis value indicate that the distribution of the studied parameters in the study area is widely off** normal. It is, therefore, important that we value and conserve our soils so that they will continue to be useful in the future.

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References

[1] KE Saxton; WL Rawls; JS Rosenberger; RI Papendick. *Soil Sci. Soc. Am. J.*, **1986,** *50,* 1031-1036.
[2] J Ruehlmann; M Körschens. *Soil Sci Soc Am J.*, **2009,** *73,* 876-885.
[3] JA Baldock; JO Skjemstad. Soil organic carbon/soil organic matter, In: K.I. Peverill et al. (ed.) Soil analysis: An interpretation manual, CSIRO Publishing, Melbourne, Australia, **1999,** pp. 159–170.
[4] WA Adams. *J. Soil Sci.*, **1973,** *24,* 10-17.

[5] B Bhuyan; HP Sarma. *Ecol. Env. & Cons.*, **2006**, *12(1)*, 75-79.
[6] KK Borah; B Bhuyan; HP Sarma. *Int. J. Chem. Sci.*, **2009**, *7(3)*, 1563-1574.
[7] J Dutta; B Bhuyan; AK Misra. *Int. J Chem. Sci.*, **2008**, *6(2)*, 1099-1105.
[8] J Dutta; B Bhuyan; AK Misra. *J. Pharm. Chem.* **2009**, *3(4)*, 116-120.
[9] MA Arshad; B Lowery; B Grossman. Physical Tests for Monitoring Soil Quality. In: JW Doran; AJ Jones (ed.) Methods for assessing soil quality, Madison, WI, **1996**, pp.123-41.
[10] DW Nelson; LE. Sommers. Total carbon, organic carbon, and organic matter. In: AL Page; RH Miller; DR Keeney (ed.), Methods of Soil analysis, Part 2, Chemical and Microbiological Properties. American Society of Agronomy and Soil Science Society of America, Madison, Wisconsin, **1982**, pp. 539–579.
[11] LE Allison. Organic carbon, In CA Black (ed.). Methods of Soil Analysis, Part 2, Chemical and Microbiological Properties, Agronomy No. 9, Madison, WI: American Society of Agronomy, **1965**, pp. 1367-1378.

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Assessment of Soil Fertility Status in and Around the Tea Gardens of Undivided Darrang District, Assam

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Abstract

Soil analysis refers to the general procedure used to assess soil fertility. A statistical analysis of soil quality parameters with respect to available nitrogen, phosphorous, potassium and organic carbon in the tea garden belt of Darrang district, Assam has been presented in this communication. The district lies between $26^0 25'$ and $26^0 55'$ northern latitude and $91^0 45'$ and $91^0 20'$ east longitude and covers an area of 3,465.30 sq. km. A total of twenty soil samples collected from inside and outskirts of five selected tea gardens have been analysed and studied separately. The implications presented are based on statistical analyses of the raw data. Normal distribution analysis (NDA) and reliability analysis (correlation matrix) are used for interpretation of data. Statistical observations on pH, N, P, K and %C in soils of the study area show that all these parameters exhibit a non-uniform distribution. Comparisons with the recommended rating of ICAR imply that the soil samples contain N, P and C either at moderate or high level, while K status in soil is very low. Keeping in view of these observations, it is concluded that soil nutrient imbalance and their off normal distribution are the key issues that needs to be taken up in the area.

Key Words: Soil Quality, Acidity, ANOVA, Confidential Limit, t test.

Introduction

Soil is one of the most important components of the earth's biosphere and is indispensable for the continued existence of life on the planet. Interest in evaluating the quality and health of our soil resources has been stimulated by increasing awareness that soil functions not only in the production of food and fiber but also in ecosystems function and the maintenance of local, regional, and global environmental quality[1]. A soil is not considered "healthy" if it is managed for short-term productivity at the expense of future degradation[2]. For healthy growth of plants, it is necessary that all the needs of plants be met with according to their requirements. An estimate (1990) showed that 10% of the fertile soil of the planet has been transferred by human activities from forest into deserts, while 25% or more is at risk[3]. Intensive agricultural practice with continuous negligence of nutrient replenishment has led to depletion of the fertility of soils in most parts of India. But unfortunately, much less is known about the fertility status and management of the soils in North Eastern India. Available literature shows that the long-term exploitation of soil under the tea gardens in Assam has led to impoverishment of soil fertility and stabilization of yields, despite increasing application of external inputs such as fertilizers and pesticides[4,5,6]. Unless site-specific nutrient supply recommendations are developed and promoted by regular testing of soil, the trend of soil fertility depletion will not be reversed. Classical soil quality control theory suggests that once a sample point exceeds a defined number of standard deviations from the mean, then this forms an outlier. However, it requires a thorough examination of the changing soil fertility status to establish whether this was an aberrant spike or a longer-term trend. The present research has been carried out to study the soil fertility status in the tea garden belt of Darrang district, Assam. The specific objectives of this study are to determine the levels of acidity (pH), available nitrogen (N), potassium (K), phosphorous(K) and carbon (% C) in soil, and their distribution pattern in and around five tea gardens of Darrang district of Assam, India so that purpose-orientated soil quality assessments and predictions can be made in the area.

Study Area

The study area Darrang district is situated in the eastern parts of India on the northeast corner of Assam. Located on the bank of mighty river Brahmaputra, the district is largely plain. The district lies between $26^0 25^/$ and $26^0 55^/$ northern latitude and $91^0 45^/$ and $91^0 20^/$ east longitude (approximately). The district covers an area of 3,465.30 sq. km and falls in the sub-tropical climatic region, and enjoys monsoon type of climate. The sampling locations are shown in **Figure 1.**

Twenty soil samples were collected in and around the five selected tea gardens by adopting lottery method during January to June, 2008, where no appropriate chemical testing of soils are done on a regular basis. Soil sampling locations are presented in **Table 1.**

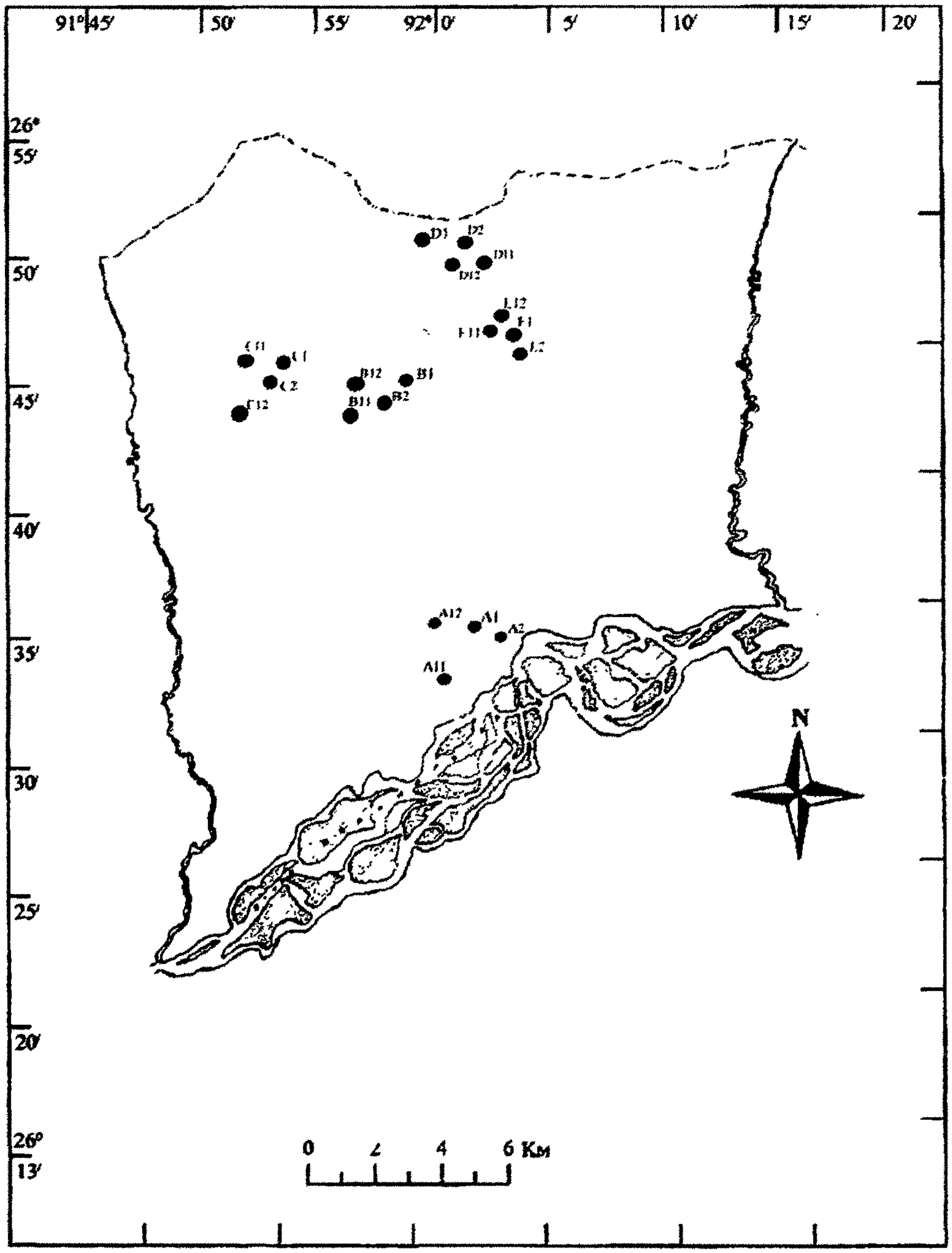

Figure 1: Sketch map of Darrang district showing 20 sampling stations.

Table 1: Soil sampling locations.

Sl. No.	Name of the Teagarden	Sample No's (Inside)	Sample No's (Outside)	Number of Samples
1	Tangoni	A1-A2	A11-A12	04
2	Paneri	B1-B2	B11-B12	04
3	Dimakusi	C1-C2	C11-C12	04
4	Corramore	D1-D2	D11-D12	04
5	Ghagrapara	E1-E2	E11-E12	04

Materials and Methodology

Experimental Analysis

Soil samples were collected by adopting simple random sampling technique by maintaining a distance of about 50 meters between two samples. Soil samples were prepared by collecting small portions of surface soil. A "V" shaped cut of 0 to 6-inch depth at random locations was made in each sampling site and one inch of soil on either side of pit was scraped and collected in polythene bags. Quartering technique was adopted to reduce the size of the sample to the required mass. The field collected soil samples after assigning identification number were air-dried in oven set at 100 F (38^0C) for 12 hours. The air-dried sample is crushed by hand using a pestle and mortar and analyzed for pH, Available N, P, K, and % C by selecting standard procedures which, in our experience, are appropriate for soils of the study area[7].

Statistical Analysis

Sample data were subjected to statistical treatment using normal or Gaussian distribution statistic and correlation analysis. To look into the trend and distribution patterns of pH, Available N, P, K, and % C in soil, data were exposed to several statistical treatments like Mean, Variance (V), Standard Deviation (SD), Standard Error (SE), Median, Range, Confidential Limit (CL) at 95%, and Percentile at 25%, 75%, 95% . One population t-test (t) is performed for all soil quality parameters under the null hypothesis (H_0) by taking assumption that the experimental chemical soil quality data are consistent with the standard rating given by the chemical ranking chart of Indian Council of Agricultural Research[8]. Details of these may be found in standard books on statistics and software packages[9].

Results and Discussion

The experimental results along with conventional descriptive statistics based on normal distribution are summarized in **Table 2** and **3.**

Table 2: Soil quality parameters inside tea gardens.

Sample No		pH	N (kg/ha)	P (kg/acre)	K (kg/acre)	% C
A1		4.01	380.09	16.54	50.13	0.86
A2		4.00	425.72	24.60	45.57	1.17
B1		4.99	582.59	19.47	91.12	2.43
B2		4.98	492.96	14.13	72.9	1.92
C1		4.55	784.27	11.92	45.57	2.9
C2		4.9	492.96	16.13	47	1.77
D1		4.55	873.90	12.61	54.67	3.52
D2		4.38	403.32	6.30	82.1	2.04
E1		4.77	829.08	128.09	62	2.26
E2		4.72	649.8	123.74	71	1.88
Statistical Analysis						
Mean		4.59	591.47	37.35	62.21	2.08
Standard Error		0.12	58.10	14.84	5.18	0.24
Median		4.64	537.78	16.34	58.34	1.98
Mode		4.55	492.96	6.30	45.57	0.86
Range		0.99	493.81	121.70	45.55	2.60
Standard Deviation		0.36	183.74	46.93	16.37	0.77
Variance		0.13	33760.19	2202.73	267.88	0.60
Skewness		-0.67	0.46	1.74	0.60	0.32
Kurtosis		-0.70	-1.44	1.32	-0.98	0.36
P25		4.29	420.12	12.44	46.64	1.62
P50		4.64	537.78	16.34	58.34	1.98
P75		4.92	795.47	49.39	75.20	2.55
95% C. L	Lower Bound	4.33	460.03	3.78	50.50	1.52
	Upper Bound	4.85	722.91	70.93	73.91	2.63
ICAR Rating		6.0-8.5 Normal	280-560 Medium	25-62 Medium	272-690 Medium	0.5-0.75 Medium
$\|t\|$		-34.06	0.54	-1.66	-121.30	5.42
Comment		S	NS	NS	S	S

Table 3: Soil quality parameters outside tea gardens.

Sample No		pH	N (kg/ha)	P (kg/acre)	K (kg/acre)	%C
A11		5.13	448.15	92.47	113	2.03
A12		5.40	313.69	58.24	100.3	1.92
B11		4.79	224.07	47.01	86.58	1.89
B12		4.88	672.23	16.78	95.5	2.39
C11		5.03	268.88	14.31	68.4	1.21
C12		5.70	201.67	10.32	63.8	0.98
D11		5.15	380.92	14.78	68.4	0.78
D12		5.20	582.59	123.28	95.7	2.39
E11		5.05	515.36	127.28	99	1.71
E12		5.20	627.40	61.23	120	1.16
Statistical Analysis						
Mean		5.15	423.50	56.57	91.07	1.65
Standard Error		0.08	54.22	14.19	6.05	0.18
Median		5.14	414.54	52.63	95.60	1.80
Mode		5.20	201.67	10.32	68.40	2.39
Range		0.91	470.56	116.96	56.20	1.60
Standard Deviation		0.26	171.45	44.86	19.14	0.58
Variance		0.07	29395.20	2012.16	366.52	0.33
Skewness		0.88	0.13	0.59	-0.15	-0.16
Kurtosis		1.44	-1.56	-1.12	-1.05	-1.42
P25		4.99	257.68	14.66	68.40	1.12
P50		5.14	414.54	52.63	95.60	1.80
P75		5.25	593.79	100.17	103.48	2.12
95% C. L	Lower Bound	4.97	300.85	24.48	77.37	1.23
	Upper Bound□	5.34	546.14	88.66	104.76	2.06
ICAR Rating		6.0-8.5 Normal	280-560 Medium	25-62 Medium	272-690 Medium	0.5-0.75 Medium
|t|		-41.09	-2.52	-0.38	-98.93	4.90
Comment		S	S	NS	S	S

N. B. S = Significant
NS = Non Significant

The pH values of the soil reflect the health status of the soil as to whether it is fit for cultivation or not. As per ICAR guideline, soils in the range 5.6 to 6.0 are moderately acidic and below 5.5 are strongly acidic in nature. Significant negative skewness and kurtosis value for pH inside tea gardens indicates a flat distribution with a long tail on the left of the median. However, the distribution pattern of pH outside the tea gardens is sharp with a long right tail. The soil in the area was found to be significantly acidic in nature with a mean value of 4.59 inside the tea gardens. t-test analysis of the data suggests that means are significant with reference to the mean rating of ICAR in both outside and inside the tea gardens of the area. One way ANOVA analysis at 0.05 level ($F = 16.25528$, $p = 7.82441E-4$) also suggests that the mean pH inside and outside tea gardens are significantly different.

Nitrogen (N) is essential for plants and usually has a larger effect on crop growth, yield and crop quality than any other nutrient. However, too much available N may lower yields and lessen crop quality. The quantity of N in soils is intimately associated with organic matter levels. Over 90 percent of soil N is associated with soil organic matter. Soil nitrogen distribution profiles and seasonal variation can be used as a diagnostic tool for evaluating the impact of N fertilization on the accumulation of NO_3–N in soil and the risk of NO_3^- leaching. Positive skewness and negative kurtosis values for N in both inside and outside tea gardens indicate flat distribution with a long right tail. The distributions for N in soil also appear to be asymmetric with the common feature of third quartile being wider than the second in the area. Difference between mean, median, mood and significantly high range for N in soil indicate the presence of outliers. It is also noticed from one way ANOVA analysis at 0.05 level ($F = 79.9827$, $p = 4.83827E-8$) that the mean values of N inside and outside tea gardens are significantly not different. However, one population t-test suggests that N content of soil outside the tea gardens vary significantly with respect to the chemical rating chart (ICAR, 2005).

Phosphorus (P) is an essential element classified as a macronutrient because of the relatively large amounts of P required by plants. It plays an essential role in agriculture and for all forms of life: respiration, photosynthesis in green leaves, microbial turnover and decomposing litter[10]. In acid soils, there is a tendency toward lower P levels over time. Significant skewness and kurtosis values for P indicate that its distribution in the study area is not uniform. Significant differences among mean, median and mode along with significant skewness and kurtosis values observed for P inside and outside tea gardens are indicative of departure of sample frequency distribution curve from normal. The ANOVA test ($F = 0.87616$, $p = 0.36164$) at 0.05 level suggests that the means inside and outside tea gardens are not significantly different.

Potassium is very important in maintaining soil health, plant growth and animal nutrition. The consequences of low potassium levels are apparent in a variety of symptoms - restricted growth, reduced flowering, lower yields and lower quality produce. The soils in and around the tea gardens of the study area are potassium deficient and is not in accordance with the rating (lower limit 272 kg/acre) given by ICAR' 2005. This observation is also supported by the statistical t-test data. Soil potassium status also varies significantly in the study area as interpreted by ANOVA test ($F = 13.13083$, $p = 0.00194$). Positive skewness and negative kurtosis values obtained for K inside tea gardens indicate flat distribution pattern with a right tail, while negative skewness and kurtosis value for K outside the tea gardens indicates its flat distribution with a long tail on the left of the median. Asymmetric nature of K distribution is also apparent from the width of the third quartile which is much greater than the first and second quartile in both inside and outside tea gardens. Wide data range and high standard deviation in case of K also bias the normal distribution statistic in the area.

Total carbon provides a measure of the organic matter content of soil. The concept of ''soil quality'' has recognized soil organic matter as an important attribute that has a great deal of control on many of the key soil functions[11]. The soil samples of the area are found to contain high percentage of soil carbon. Positive kurtosis and skewness value for soil carbon inside the tea gardens is indicative of its sharp asymmetric distribution with a long right tail from its median. The scenario is, however, completely opposite for the soil samples taken outside the tea gardens. It is also observed that the width of the third quartile is significantly greater than the second quartile, which for a symmetric distribution should be equal. ANOVA ($F = 1.9734$, $p = 0.17711$) shows that the means for soil carbon do not vary significantly inside and outside tea gardens.

Correlations among the studied parameters are presented in **Table 4** and **5.** Pearson's correlation coefficient measures the closeness of the relationship between chosen independent and dependent variables. If the correlation coefficient is nearer to +1 or -1, it shows the probability of linear relationship between the variables. Since the directions of association of the measured variables are unknown in advance, two-tailed test of significance was carried out and presented in Table 4 and 5. It is observed that some of the soil quality parameters correlation is significant at the 0.01 and 0.05 level.

Table 4: Correlation matrix among the studied parameter inside tea gardens.

		pH	N	P	K	%C
Pearson Correlation	pH	1	0.364	0.214	0.481	0.455
Significance Test. (2-tailed)		-	0.301	0.552	0.160	0.187
Pearson Correlation	N	0.364	1	0.407	-0.115	0.825**
Significance Test. (2-tailed)		0.301	-	0.243	0.751	0.003
Pearson Correlation	P	0.214	0.407	1	0.109	-0.046
Significance Test. (2-tailed)		0.552	0.243	-	0.764	0.899
Pearson Correlation	K	0.481	-0.115	0.109	1	0.140
Significance Test. (2-tailed)		0.160	0.751	0.764	-	0.700
Pearson Correlation	%C	0.455	0.825**	-0.046	0.140	1
Significance Test. (2-tailed)		0.187	0.003	0.899	0.700	-

**** Correlation is significant at the 0.01 level (2-tailed).**

Table 5: Correlation matrix among the studied parameter outside tea gardens.

		pH	N	P	K	%C
Pearson Correlation	pH	1	-0.296	-0.096	-0.205	-0.399
Significance Test. (2-tailed)		-	0.406	0.792	0.570	0.253
Pearson Correlation	N	-0.296	1	0.424	0.657*	0.440
Significance Test. (2-tailed)		0.406	-	0.222	0.039	0.203
Pearson Correlation	P	-0.096	0.424	1	0.626	0.512
Significance Test. (2-tailed)		0.792	0.222	-	0.053	0.130
Pearson Correlation	K	-0.205	0.657*	0.626	1	0.509
Significance Test. (2-tailed)		0.570	0.039	0.053	-	0.133
Pearson Correlation	%C	-0.399	0.440	0.512	0.509	1
Significance Test. (2-tailed)		0.253	0.203	0.130	0.133	-

*Correlation is significant at the 0.05 level (2-tailed).

Conclusion

It observed that the soil in the study area is acidic and K deficient. Comparisons with the recommended rating of ICAR imply that the soil samples contain N, P and C either at moderate or high level. Statistical observations show that all these elements exhibit an uneven distribution with a long asymmetric tail either on the right or left side of the median. The width of the third quartile is consistently found to be more than the second quartile for each parameter. Differences between mean, mode, median and high standard deviation in each case indicate that the distribution of N, P, K and C in the soils of the study area is widely off normal. Wide data range in each case indicates the presence of extreme values in the form of outliers, which are likely to bias the normal distribution statistic. Keeping in view of these observations, it is concluded that soil nutrient imbalance is the key issue that needs to be taken up in the area.

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References

[1] Glanz, J.T., 1995, "Saving Our Soil: Solutions for Sustaining Earth's Vital Resource", Boulder, Colorado: Johnson Books, 182.

[2] Doran, J.W., Sarrantonio, M., Liebig, M., 1998, "Soil health and sustainability", In: Sparks, D.L. (Ed.), Advances in Agronomy, Vol. 56, Academic Press, San Diego, CA, USA, 1–54.

[3] Reid, K (ed), 1998, "Soil Fertility Handbook", Ministry of Agriculture, Food and Rural Affairs, Queen's Printer for Ontario, Toronto.

[4] Bhuyan, B. and Sarma, H. P., 2006, "Evaluation of Soil Fertility Status and Chemical Indicators of Soil Quality in Tea Gardens of Lakhimpur District, Assam", Ecol. Env. & Cons., 12(1), 75-79.

[5] Dutta, J, Bhuyan, B., and Misra, A. K., 2009, "A Case Study on Soil Acidity and Metal Contents in and around the Tea Gardens of Sonitpur District, Assam, (India)", Journal of Environmental Research and Development, 3(4), 1108-1113.

[6] Dutta, J, Bhuyan, B., and Misra, A. K., 2008, "Chemical Estimation of Soil Fertility Status in and around the Tea Gardens of Gahpur Sub-Division, Assam", International Journal of Chemical Sciences, 6(2), 1099-1105.

[7] M. L. Jackson, 1973, "Soil Chemical Analysis", Prentice-Hall of India Private Limited, New Delhi, 227-255.

[8] Indian Council of Agricultural research (ICAR), 2005, "Hand Book of Agriculture", 3rd Edition, New Delhi, Krishi Anusandhan Bhawan, PUSA, New Delhi, 61

[9] Meloun M, Militky J, Forina M, 1992, "PC-aided Statistical Data Analysis". In: Chemometrics for Analytical Chemistry. Vol. 1. Chichester, England: Ellis Horwood Ltd.

[10] Cole, C. V., Innis, G. S., and Stewart, J. W. B. , 1977, "Simulation of phosphorus cycling in semi-arid grassland", Ecology, 58, 1-15.

[11] Doran, J.W., Parkin, T.B., 1994., "Defining and assessing soil quality", In: Doran, J.W., Coleman, D.C., Bezdicek, D.F., Stewart, B.A. (Eds.), Defining Soil Quality for a Sustainable Environment, Soil Sci. Soc. Am., Am. Soc. Agron., Madison, WI, 3–21.