Research Journal of Applied Sciences 2 (10): 1071-1076, 2007
ISSN: 1815-932X

Evaluation of Groundwater and Stream Quality Characteristics in the Vicinity of a Battery Factory in Ibadan, Nigeria

Modupe O. Dawodu and A. Ipeaiyeda
Department of Chemistry and Biochemistry, University of Bowen,
P.M.B. 284, Iwo, Osun State, Nigeria

Abstract: Well water and Oniyere stream in the vicinity of a factory manufacturing lead-batteries in Ibadan, Nigeria were analysed for the following general physico-chemical characteristics: pH, temperature, conductivity, total alkalinity, total hardness, solids, chloride, nitrate, ammonia, dissolved oxygen and chemical oxygen demand. The samples were collected at 6 sampling locations along the stream network (three locations at upstream and another four at downstream) and from 6 wells in different households in the neighbourhood of the factory. The levels of physico-chemical characteristics investigated of the well water were generally below the WHO guidelines for drinking water. However, the well waters, were poor in quality in terms of the levels of pH, Fe, Cu, Ni, Pb and Cd recorded. Thus, the well water requires further purification to ensure its suitability for human consumption. The factory wastewater raised the levels of the metals in the downstream water above their pre-discharge point levels. Thus the factory wastewater impacts the stream with heavy metals.

Key words: Evaluation, Vicinity, stream quality,nitrate, Nigeria

INTRODUCTION

The numerous problems of water shortage and inadequate supply of treated water have made inhabitants of urban settlements resulted in the alternative. Alternatives such as river and groundwaters serve as a direct source of drinking water. Drinking water is vital for life. Yet, it is one of the most significant sources of intake by man of hazardous substances, with attendant impairment of health. The impairment of water bodies in urban areas has been shown to be the primary source of health hazards (Adesina, 1986). In 1971, Nigeria experienced its worst cholera epidemic, in which 14,158 suspected cases and 612 deaths were reported. The epidemic was attributed to contaminated drinking water (Sridhar *et al*., 1981). The total quality of drinking water is therefore, of epidemiological interest (Cabelli, 1983; Campbell and Forbes, 1994).

With increasing industrialization, rivers have become receptacles of wastewaters from industries. Most industries channel the wastewater component into water bodies without adequate treatment prior to the discharge. This practice of direct discharge of industrial wastewater into receiving water bodies is of major concern as it could result amongst other things in a substantial increase in organic load and consequently in depletion of the dissolved oxygen content of the receiving water body (Akinluyi and Odeyemi, 1984; 1987). In an industrial area, possibility exists for percolation and migration of pollutants via soil into drinking wells. Thus, drinking well may be impaired physicochemically. Physicochemical impairment usually results from the presence in water of a variety of toxic metals, anions and other carcinogens (Zyka, 1988; Lam *et al*., 1994).

In humans, the intake of poor quality drinking water has been implicated in the incidence of motor neurone disease (Iwani *et al*., 1994), reproductive disorders and cardiovascular diseases (Clayton, 1976). The monitoring of drinking water quality has been widely practiced and reported, for example in Egypt (Awadallah *et al*., 1993), Kuwait (El Shamy *et al*., 1971), Bostwana (Smith and Sabone, 1994) and Canada (O'Neill *et al*., 1992). The quality monitoring of drinking water in Ibadan has been documented (Onianwa *et al*., 1999). However, there is still a significant dearth of information in the scientific literature on the quality of many drinking wells around industrial areas. Ibadan city in Nigeria is one of the largest in the sub-Saharan Africa, with an estimated population of more than 4 million and an area of about 180 sq. km. The National Water Corporation is responsible for planning, treating and supplying public water. The supply has been inadequate and forced inhabitants of the city to resort to drinking water from wells and streams. The intake of hazardous substance via

Corresponding Author: Modupe O. Dawodu, Department of Chemistry and Biochemistry, Bowen University, P.M.B. 284, Iwo, Osun State, Nigeria

drinking well and stream waters around industrial areas is possible. The possibility arises from the fact that the quality of such waters is suspect for the impact of wastewater from those industries. With a view to studying the influence of the factory activities on drinking wells and stream, a study was undertaken on well water and stream around a factory manufacturing lead batteries in Ibadan.

MATERIALS AND METHODS

The sampling location: The West African Batteries Ltd is located at Sobaloju, around Wofun area in the northeastern part of Ibadan (Fig. 1). The Oniyere stream which passes through the area receives wastewater from the industry. On northern and southern areas of the stream and industry are residential area and vegetation. A number of complaints about the drinking well and stream by the inhabitants of the area made this location an area of interest for study. Such complaints include the itching of skin when the well water is drunk. At many places the stream emits noxious odour. Within the industry, water use is concentrated primarily in boiler, feed and demineralised sections of the factory. Wastewater from these sections are drained separately through a channel, converged at a point and subsequently emptied into Oniyere stream via a drainage.

Materials: A total of seven samples of water was collected along the stream in the months of November and December, 2000. Three samples were collected upstream, one sample was collected at a point where the effluent intersected the stream and two samples were collected downstream. Also, 2 samples of wastewater at different locations along each channel conveying the wastewater from boiler, feed and demineralised sections of the factory were collected. Well water samples were similarly collected from 6 different households in the neighbourhood of the factory.

The sampling was undertaken by first rinsing the clean plastic bottles with the water before collecting the samples. The samples were then stored in an ice chest. Separate samples collected for heavy metal analysis were fixed in the field with 3 mL analar grade nitric acid per litre sample. Samples analyzed for dissolved oxygen were collected in 300 mL Winkler bottles and preserved with 2 mL of manganous sulphate and 2 mL of an alkali iodide azide of sodium solution.

Methods: All laboratory analyses were carried out using standard methods (APHA-AWWA-WPCF, 1981; Department of the Environment, 1972; ASTM, 1982) for the different parameters. The specific standard methods used were as follows: Turbidity, alkalinity (acid-base titrimetry), hardness (EDTA-titrimetry), nitrate (phenoldisulphonic acid colorimetric method), ammonia (nesslerisation colorimetric method), dissolved oxygen (Winkler' titration) and COD (potassium dichromate oxidation and titrimetry). Fe, Cu, Ni and Pb were determined by atomic absorption spectrophotometry.

All chemicals used were of reagent grade and deionized water was used throughout the experimentation. Procedural blanks, reagent blanks, preparation of standard solutions under clean laboratory environment were some of the measures taken during the experimentation to ensure acceptable data quality. Procedure for the COD determination was evaluated with potassium hydrogen phthalate standard.

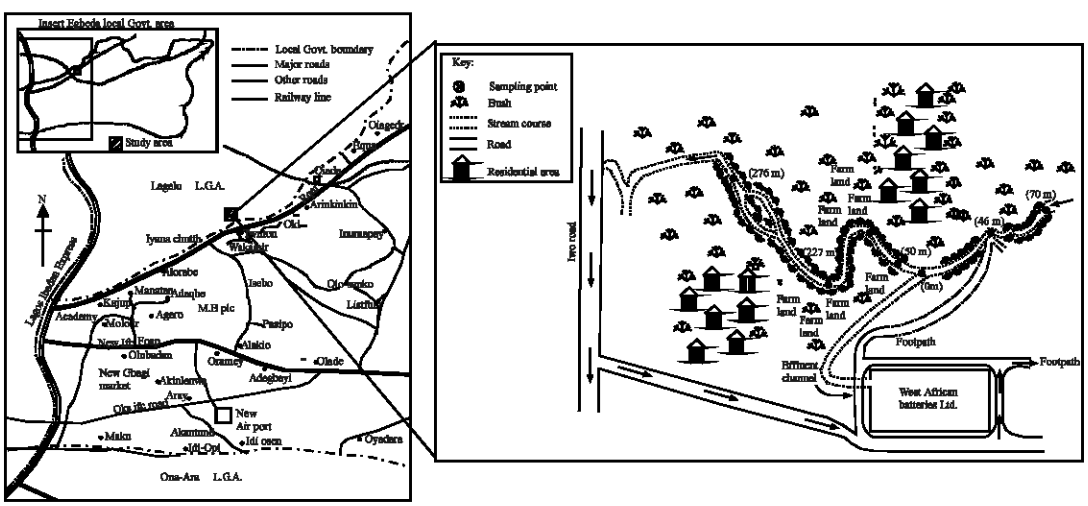

Fig. 1: Map showing the study area at Iwofun and sketch of the stream, factory and sampling locations

Statistical analysis of analytical data: One way parametric Analysis of Variance (ANOVA) and Dunean multiple range test of variable with harmonic mean sample size of 3.6 at $p<0.05$ were used to ascertain statistical significance difference in the observed concentrations in the upstream and downstream water. Note that the group size are unequal.

RESULTS AND DISCUSSION

The average levels and range of concentrations of the various parameters analysed on waters from the stream, factory and wells around the factory are presented in Table 1 and 2. The appropriate limits of WHO drinking water standards (WHO, 1996) for the parameters analysed are quoted in the Tables for comparison with well water.

The statistical analysis carried out on the results tested the impact of wastewater from the factory on groundwater quality. Hence, statistical significance difference in physico-chemical characteristics of the factory wastewater and well water around the factory is ascertained.

pH: The pH of well water samples ranged from 6.8 to 7.7 and were within the range of the internationally accepted standard for potable water. The average pH value of the downstream water compared well statistically with the upstream pH value (Table 1). Hence, the factory wastewater appears not to be a serious threat to either well waters around the factory and the receiving stream.

Temperature: As evident from the range of 26 to 60 for factory wastewater, a few such sample had temperature values higher than the nationally recommended maximum limit of 35°C (FEPA, 1991). Thus, thermal shock on the receiving downstream water is possible. However, average temperature values of well, downstream and upstream water samples were below the nationally recommended maximum limit of 35°C statistical comparison of temperature values of well and downstream water samples with upstream types revealed no significant difference at 95% confidence interval.

Dissolved solids: The average dissolved solids level of well water, 472±49 mg L^{-1} was much lower than the internationally accepted guideline limit of 1000 mg L^{-1} ranging from 432 to 526 mg L^{-1}. There was much significant difference between the average dissolved solids concentrations of the factory wastewater and well water. Thus, well as a source of drinking water in the neighbourhood of the factory was not impacted by wastewater. There was no significant difference between the dissolved solids levels in upstream and downstream water. This suggested that the factory wastewater never impacted the stream with its dissolved solids content.

Table 1: Some Physicochemical characteristics of the water samples

	Upstream water		Factory wastewater		Well water		Downstream water		WHO limits
Parameters	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range	1993
pH	8.40±029	8.2 -8.6	6.7±1.3	6.6 -8.2	7.3±0.5^{a}	6.8 -7.7	8.4±0.3^{a}	8.2 -8.8	6.5-8.5
Temperature (^{0}C)	28^{ab}	-	46.7±18.4^{b}	26.0-60	25.7±0.6^{a}	25 - 26	29.7±2.1^{a}	28-32	-
Conductivity (µS cm^{-1})	9.10±1.4^{bc}	7.5-10.1	3.6±3.9^{bc}	0.2-7.9	0.7±0.1^{a}	0.6-0.8	10.4±1.7^{c}	8.8-12.1	-
Turbidity (FTU)	7.10±1.6^{bc}	6.4-8.9	10.70±3.4^{bc}	7.4-14.1	1.2±0.4^{d}	0.7-1.5	9.5±1.0^{b}	8.3-10.1	5
Alkalinity (mg L^{-1})	222.00±22^{a}	201-245	0.03±0.01^{b}	0.02-0.04	79.3±4.7^{c}	74.1-83.5	269.0±14^{d}	253-280	-
Total Hardness (mg L^{-1}) $CaCO_3$	163.00±16^{b}	147-178	7.20±3.2^{a}	4.6-10.8	159.0±6^{b}	153-164	142.0±8^{b}	134-150	500
Calcium Hardness (mg L^{-1}) $CaCO_3$	83.70±15.0^{b}	75.0-101	71.70±15.3^{ab}	15.1-85.3	49.3±5.1^{a}	45.2-48.4	88.3±7.6^{b}	80.1-95.4	-
Total Solids (mg L^{-1})	901.00±43^{b}	852-917	117.00±19^{a}	95.5-131	355.0±271^{c}	546-474	870.0±110^{b}	744-942	1000
Total Suspended Solids (mg L^{-1})	169.00±17^{b}	150-184	17.40±6.3^{a}	10.1-21.3	17.0±2.7^{a}	14.2-19.5	145.0±37^{b}	103-172	-
Total Dissolved Solids (mg L^{-1})	732.00±26^{b}	702-750	99.10±13.3^{a}	85.4-11.2	472.0±49^{ab}	432-526	725.0±75^{ab}	641-782	1000
Ammonia Nitrogen (mg L^{-1})	1.34±0.33^{b}	1.06-1.71	0.22±0.07^{a}	0.15-0.28	0.32±0.09^{a}	0.24-0.44	1.22±0.11^{b}	1.10-1.31	-
Nitrate Ni (mg L^{-1})	2.96±0.91^{ab}	2.20-3.96	1.41±0.47^{a}	0.90-1.82	4.31±0.63^{b}	3.61-4.82	3.23±0.44^{b}	2.95-3.74	50
Dissolved Oxygen (mg L^{-1})	2.08±0.19^{b}	1.94-2.30	0.57±0.16^{a}	0.43-0.74	3.47±0.47^{c}	2.94-3.85	0.85±0.59^{a}	0.42-1.52	7.5
COD (mg L^{-1})	68.7±22.0^{a}	54.0-94.1	135.00±49^{a}	82.1-178	44.3±8.3^{a}	35.0-51.5	116.00±5^{a}	110-120	-

Table 2: Levels of metals in the water samples

	Upstream water		Factory wastewater		Well water		Downstream water		WHO limits
Parameters	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range	1993
Iron (mg L^{-1})	1.50±08^{a}	1.42 -1.57	2.09±1.95^{a}	0.03 -3.90	0.57±0.25^{a}	0.29 -0.78	1.62±0.09^{a}	1.52 -1.68	0.30
Copper (mg L^{-1})	< 0.001	-	2.73±2.32^{a}	< 0.001-4.37	1.22±0.08^{a}	1.15-1.31	1.43±0.21^{a}	1.23-1.64	1.0
Nickel (mg L^{-1})	0.18± 0.03^{a}	0.15-0.20	0.52±0.11^{a}	< 0.001-0.59	0.40±0.05^{a}	0.35-0.44	0.25±0.06^{a}	0.20-0.31	0.02
Lead (mg L^{-1})	1.24± 0.06^{a}	1.19-1.30	1.47±0.16^{a}	< 0.001-1.58	1.05±0.19a	0.89-1.25	1.69±0.21^{a}	1.45-1.84	0.01
Cadmium	0.002± 0.001	0.001-0.002	0.006±0.001^{ab}	< 0.001-0.007	0.003±0.001^{ab}	0.002-0.004	0.006-0.001	0.004-0.007	0.003

Means within rows with different superscripts (a,b,c) are significantly different, LSD ($p<0.05$)

Suspended solids and turbidity: The suspended solids concentrations in the factory wastewater compared well with the well water. This ranges from 10.1-21.3 mg L^{-1} for the factory wastewater and 14.2 to 19.5 mg L^{-1} for the well water. Many wells are poorly constructed (Sangodoyin, 1993) and as such receive little seepage from sewage tanks and urban runoff. No limits are specified by WHO for suspended solids levels, but levels should not impart a turbidity to the drinking water higher than the turbidity limits of 5FTU. The current EC guidelines (Smeets and Amavis, 1981) specifies that suspended solids should be completely absent. It was noted that the average turbidity level of 1.2±0.4 FTU in well water was much lower than the WHO stipulated limit. The factory wastewater never impart a turbidity to the downstream water. This is deduceable from insignificant difference between average turbidity levels in the factory wastewater and downstream water.

Conductivity: Conductivity values are often related to the dissolved solids concentrations (Kashiwabara and Tsude, 1994; Twort *et al*., 1995). Conductivity values of the factory wastewater ranged from 0.22 to 7.9 μS cm^{-1}. Thus, these low conductivity values suggest low total dissolved solids levels in boiling and cooling water of the demineralised section of the factory. No limits are stipulated for conductivity but the values should not reflect an associated dissolved solids levels, the conductivity values obtained for the factory wastewater and well water are similarly acceptable values. The conductivity values in the drinking wells ranged from 0.55 to 0.82 μS cm^{-1}. There was no significant difference between the average conductivity values of 9.1±1.4 μS cm^{-1} for upstream and 10.4±1.7 μS cm^{-1} for downstream water. Hence, the factory wastewater shows no significant impact on the conductivity level of downstream water.

Total alkalinity: The average alkalinity value in the well water was 79.3±4.0 mg L^{-1}. This was far higher than 0.03± 0.01 mg L^{-1} for the factory wastewater. This suggests that such high alkalinity values are not likely due to lots of physical and chemical processes such as feeding, boiling and demineralization involved in the operation system within the factory. No limits are defined for alkalinity by WHO. The bicarbonate ion concentrations are reflected mainly in alkalinity values in drinking water (Sarapata, 1994). This buffers against acidic effect of such water.

Total hardness: Hardness of water is of major public concern in many parts of the world, where incidences of cardiovascular disorders such arteriosclerosis have been correlated with the hardness of the water Masironi *et al*., 1972; Biersteker, 1976; Clayton, 1975; Piispanen, 1993). The average level of hardness in the well water was 159±6 mg L^{-1}. This value is far below the maximum allowable limit of 500 mg L^{-1}. An earlier report of the monitoring of drinking water quality in Ibadan in 1999 gave 134± mg L^{-1} as the average level of hardness in the well (Onianwa *et al*., 1999). In this study, the average level of hardness was about the earlier value reported of the drinking wells in Ibadan. This value (159±6 mg L^{-1}) was far higher than 7.2±3.2 mg L^{-1} of total hardness in the factory wastewater. Statistical comparison of these two average values showed much significant difference, Hence, such high total hardness levels in well water are not likely due to the factory wastewater. The difference I values of hardness of the upstream and downstream waters was not significant. The levels of hardness ranged from 147 to 178 mg L^{-1} for the upstream water and 134 to 150 mg L^{-1} for the downstream water. Thus, the factory does not impart hardness causing matters into the stream.

Nitrate: Nitrate levels in groundwater which exceed the WHO limits are not common (Smith and Sabone, 1994; Stuart *et al*., 1995). Nitrate levels in the well water samples ranged from 1.51 to 2.61 mg L^{-1}. The range of nitrate levels in the factory wastewater was 0.62-0.74 mg L^{-1}. The difference in nitrate levels of well water and factory wastewater was statistically significance. Therefore, the wells around the factory is in no way affected by the factory wastewater.

Measures of organic pollution (DO, COD): The dissolved oxygen levels ranged from 2.94 to 3.85 mg L^{-1} in the well water and 0.43 to 0.74 mg L^{-1} in the factory wastewater. These values are far below the recommended level of 6.8 mg L^{-1} (FEPA, 1991) for the support of aquatic life. Depletion to levels such as those obtained in the factory wastewaters may have negative impact on aquatic life downstream. Arising from low dissolved oxygen and high COD levels, non existent of fish population was observed at upstream location.

Heavy Metals (Fe, Cu, Ni Pb): Recovery studies for the metals analyzed using AAS ranged between 85% and 104%. The levels of these metals in this study were generally above the specified WHO limits (Table 2). Copper levels in the upstream were below the detection limit of the analysis for the element. Statistical comparison of the levels of these metals in upstream and downstream waters showed that they were not significantly different. However, the levels of these metals in the downstream water were generally higher than the levels in the upstream water. Thus, downstream water is impacted with heavy metals by the factory wastewater.

CONCLUSION

The analytical results revealed that the physicochemical characteristics of the well waters around the battery factory meet the WHO guidelines for drinking water. However, requirement for further purification to ensure their wholesome suitability for human consumption are necessary. The purification of groundwater becomes necessary because of the relatively high levels of heavy metals in many samples of well water. Lead is used principally in the production of lead-acid batteries, although their use for this purpose in many countries is being phased out. Only if the decreasing use of lead for this purpose is encouraged in Nigeria, intake of lead from drinking wells around the battery factory would decrease.

REFERENCES

Adesina, H.O., 1986. Urban environment and epidemic disease. Proceedings of National Conference on Development and the Environment (Nigerian Institute of Social and Economic Research (NISER), Ibadan, Nigeria), pp: 234-256.

Akinluyi, T.O. and O. Odeyemi, 1984. Human waste disposal and feacal pollution of the River Niger Delta waters, Water International, 9: 37-41.

Akinluyi, T.O. and O. Odeyemi, 1987. Decreasing fish productivity in the Niger Delta of Nigeria. A microbiological perspective. Nig. J. Applied Sci., 5: 97-105.

APHA/AWWA/WPCF, 1981. Standard methods for the Examination of Water and Wastewater (APHA/AWWA/WPCF, Washington).

ASTM, 1982. Water: Annual Book of ASTM Standards, Part 31 (ASTM, Washington).

Awadallah, R., S. Ismail, M. Abdel aal and M. Soltan, 1993. Investigation of drinking and Nile water samples of Upper Egypt. Water SA, 19: 217-230.

Biersteker, K., 1975. Hard or soft drinking water? Possible implications for public health in the Netherlands. Hardness: Drinking Water Public Health, Proc. Eur. Sci. Colloq., pp: 349-358.

Cabelli, V.J., 1983. Public Health and water quality. Significance of viral diseases transmitted by drinking water and recreational water. J. Water Sci., Technol., 15: 2-9.

Campbell, D.M. and G.I. Forbes, 1994. Public health medicine and drinking water in Scotland. Int. J. Environ. Hlth. Res., 4: 86-92.

Clayton, D.G., 1976. Water hardness and cardiovascular mortality in England and Wales. Hardness: Drinking Water Public Health, Proc. Eur. Sci. Colloq., pp: 323-340.

Department of the Environment. 1972. Analysis of Raw, Potable and Waste Water (DoE, London).

El-Shamy, H.K., I.I. Mansi and O.A. Al-Fulaij, 1971. Drinking Water in Kuwait. J. Am. Water Works Assoc., 63: 783-786.

Federal Environmental Protection Agency of Nigeria (FEPA). 1991. Guidelines and Standards for Environmental Pollution Control in Nigeria (FEPA, Lagos.)

Iwani, O., C.S. Mom, T. Watanabe and M. Ikeda, 1994. Association of metal concentration in drinking water with incidence of motor neurone disease in a focus on the Kiipeninsula of Japan. Bull. Environ. Contamin. Toxicol., 52: 109-116.

Kashiwabara, M. and T. Tsude, 1974. Relation between dissolved matter and conductivity of Ichikawa industrial water. Kogye Yossui., 186: 44-49.

Lam, R.F., J.P. Brown, A.M. Fan and A. Miles, 1994. Chemicals in California drinking water: Source contaminants, risk assessment, risk management and regulatory standards. J. Hazard Water., 39: 173-192.

Masironi, R., A.T. Miesch, M.D. Crawford and E.I. Hamilton, 1972. Geochemical environments, trace elements and cardiovascular diseases. Bull. WHO, 47: 139-150.

O'Neill, H.J., T.L. Pollock, G.L. Brun, J.A. Doull, D.A. Leger and H.S. Bailey, 1992. Toxic chemical survey of municipal drinking water sources in Atlantic Canada 1985-1988. Water Pollu. Res. J. Canada, 27: 715-732.

Onianwa, P.C., O.J. Ogunniyi and A.A. Ogunlowo, 1999. General physicochemical quality of drinking water in Ibadan, Nigeria. Int. J. Environ. Edu. Inform., 18: 143-154.

Piispanen, R., 1993. Water hardness and cardiovascular mortality in Finland. Environ. Geochem. Hlth, 15: 201-208.

Sangodoyin, A.Y., 1993. Consideration on contamination of groundwater by waste disposal systems in Nigeria. Environ. Technol., 14: 957-964.

Sarapata, J.S., 1994. Bicarbonate alkalinity in drinking water. J. North Engl. Water Works Assoc., 108: 277-287.

Smeets, J. and R. Amavis, 1981 European Community's directive relating to the quality of water intended for human consumption. Water, Air and Soil Pollution, 15: 483-502.

Smith, P.G. and T.G. Sabone, 1994. Drinking water quality in the Gantsi District of Botswana. Intern. J. Environ. Hlth. Res., 4: 141-147.

Sridhar, M.K.C., P.A. Oluwande and A.O. Okubadejo, 1981. Health hazards and pollution from open drains in a Nigerian city. Ambio, 10: 29-33.

Stuart, M.A., F.J. Rich and G.A. Bishop, 1995. Survey of nitrate contamination in shallow domestic drinking water wells of the Inner Coastal Plain of Georgia. Ground Water, 33: 284-290.

Twort, A.C., F.M. Raw and F.W. Crawley, 1995. Water Supply (Edward Arnold, Rondon).

WHO, 1996. Guidelines for Drinking Water Quality 2. Recommendations World Health Organisation. Geneva.

Zyka, V., 1988. Trace elements (lead, copper zinc, cadmium, arsenic) in drinking waters of Czechoslovakia. Geology of Pruzkum, 30: 162-167.