Al-Azhar Bull. Sci. Vol. 16, No. 2 (Dec.): pp. 25-43, 2005

SURVEY OF COMMERCIAL BOTTLED DRINKING WATER IN EGYPT

EL-SHAHAT, M. F.*; ABD EL-HALIM, S. H.(LATE)*; EL-SAYED, M. A.** AND ABD EL-FATTAH, N.S.**

**Chemistry Department, Faculty of Science, Ain Shams University*
***Central Lab., Ministry of Health & Population*

Abstract

Inorganic constituents were analyzed in six major brands of commercial bottled water and in six brands of the imported mineral drinking water used by many Egyptians and tourists visiting Egypt. The inorganic analysis included determination of both anion and cation species lead and cadmium. For the purpose of comparison, selected samples of tap water from Cairo were also analyzed. Ion Chromatography (IC) was used for the analysis of anions and cation. Ion selective electrode (ISE) was used for measuring physical constants. Atomic absorption spectrometry was used for the analysis of heavy metals. All water samples (tap water from Cairo and bottled drinking water from around Cairo) were within the acceptable levels of the world health organization (WHO) guidelines and were lower than maximum contaminated level (MCL) established by the united states Environment Protection Agency (USEPA). One of the imported mineral drinking water brand was in high level than MCL (Sulphate in San Peligreno brand was 588 mg/L). Mineral water is exempt from allowed level. The exemption are aesthetically based allowable levels and do not relate to a health concern tap water from Cairo was of a higher quality than any of the bottled water with regard to the analyzed chemical constituents. Differences in concentrations of anions and cations were found, depending on the source of the water. The concentrations of fluoride, calcium, magnesium, sulphate and TDS in some imported mineral drinking water were greater than those of Egyptian bottled drinking water.

Introduction

Bottled drinking water has become a healthier choice than tap water for many people because they believe that bottled drinking water contains fewer contaminants, or dislike the taste of chlorinated tap water. Therefore, the annual consumption of bottled drinking water in the world is substantial (Pip, 2000). For health concern, there is increasing attention on the quality of bottled drinking water (Allen and Darby, 1994, Calabrase, 1997, Misund et al, 1999, Ikem et al., 2002). In Egypt, fertile Nile river valleys with abundant water supplies were the center for beginning civilization with growth, demand for water has increased dramatically, and its uses have become much more varied. Good quality drinking water may be consumed in any desired amount without adverse effect on health. Such water is called (potable).

Refreed by:Mostafa M. Emarra & Hassan A. Shehata

It is free from harmful levels of impurities such as bacteria, viruses, minerals, and organic substances. It is also aesthetically acceptable and is free of unpleasant impurities, such as objectionable taste, color, turbidity and odor. The most common problem in household water supplies may be attributed to hardness, iron, sulphate, sodium, chloride, acidity, and disease- producing pathogens, such as bacteria and viruses .Several metal ions such as: sodium, potassium, magnesium and calcium are essential to sustain biological life. Elements such as; magnesium and calcium have been linked to reduced frequency of sudden death and osteoporosis, respectively (Garzon, 1998) and both may exert protective effects against gastric cancer (Yang et al 1998). Garzon and Eisenberg advocated the consumption of brands that are high in magnesium and calcium and low in sodium. However, individuals with stones in the upper urinary are ill – advised to consume bottled waters with a high calcium content (Mayne and Edward 1990). High concentration of sulphate in drinking water have been associated with gastrointestinal effects such as decreased transit time (Heizer et al 1997).

Nitrate is a common contaminant in ground water (Mayne and Edward 1990) and has been implicated in gastric cancer mortality and other disorders (Schubert et al 1999). Cadmium and lead are toxic heavy metals with long retention times and significant tissue accumulation. Cadmium may have a half-life in bone of 38 years (Berman 1980) and has carcinogenic properties (Lauwerys 1979). Lead is a neurotoxin, responsible for the most common type of human metal toxicosis (Berman 1980). Low-level lead exposure has been associated with reduced IQ in children (Needleman 1993) and attention deficit disorders (Yule and Rutter 1985). Copper is an essential element in human nutrition, but it may reach high levels in tap water through contact with copper fitting.

There are about six metals, essential for optimal growth, development, and reproduction. These are manganese, iron, cobalt, copper, zinc and molybdenum, which are in small enough quantities to be considered trace elements. However, all essential trace metals become toxic when their concentration becomes excessive. Drinking water containing the above trace metals in very small quantities may actually reduce the possibility of deficiencies of trace elements in the diet. In addition to the metals essential for human life, water may contain toxic metals like: mercury, lead, cadmium, chromium, aluminum, barium, silver and arsenic. These metals can cause chronic or acute poisoning and should be eliminated from drinking water, if possible. Over 90% of Cairo's drinking water is drawn from the Nile. The Cairo water Authority has many clean water treatment plants. The finished water goes to storage or pump stations for distribution. At this point, as it enters the distribution system, Cairo's drinking water is nearly always clean, as reported by El-Gohary (1994). However, problems in the water distribution system or storage sometimes lead to erratic water supplies and/or contaminants entering the drinking water in several areas. Erratic water pressure and unreliable supply may cause pollution from contaminated ground water which or sewage through damaged joints (Myllylä, 1995). Ground water which provides about 8 % of Cairo's drinking water comes entirely from a semi-confined highly permeable sandy aquifer under the Nile valley. Ground water quality varies widely.

In this paper, the results of investigation of the concentration of certain pollutants in six brands of the most common commercial bottled drinking water and six brands of the imported mineral drinking water are presented. For comparison, random sample of tap water from the Greater Cairo district of Egypt was analyzed for the same constituents.

Materials and Methods

Sampling

Six different brands of the most popular bottled water: Baraka, Aqua, Delta, Schweppes, Teba and Alpha and six different mineral water imported from different countries: Evian (France), San Peleigrino carbonated (Italy), San bandito carbonated (Italy), Aqua Montana (Italy), Heaven (Bulgaria) and Font Sylvia (Spain) were purchased from local markets in Egypt during the summer of 2003. Three bottles of 1.5 l size were purchased for each brand. All brands of bottled water are sold in sealed plastic bottles. All bottles were kept sealed, and refrigerated at 4°C until the time of analysis. Tap water samples were randomly collected from Kaser El-Nile, Abdeen, and El-Mataria in Cairo during the summer of 2003.

Three replicates of 2 L each were collected from tap water faucets that were left running for at least 5 min before collecting the samples. Tap water was kept in sealed glass bottles, refrigerated and transferred to the laboratory for analysis.

Equipments

Ion chromatography DX 500 (Dionex 500, USA) used for the determination of anions and cations in water samples using CD 20 conductivity detector. The column ion pac AS 14 (4 x 250 mm) and its guard column GS 14 (4 x 50 mm) is used for anions whereas, the column ion pac CS 12A (4 x 200 mm) and its guard column GS 12A (4 x 50 mm).

An Orion digital pH/mV meter (Model SA 720) equiped with combination glass electrode (Orion 81-02).

A Perkin-Elmer model 4110ZL Atomic Absorption Spectrophotometer with Zeeman background correction was used for this study. The spectrophotometer was equipped with AS-50 auto-sampler and an HGA-700 graphite furnance. Hollow cathode lamp (Perkin-Elmer) for lead and cadmium and pyrolytically coated graphite tubes were used.

DL 53 titrator for the determination of alkalinity (Mettler Toledo, Switzerland) with electrode with AgCl (0.02 N H_2SO_4 for titration)

Results and Discussion

Calcium

We noticed that Barka water had slightly higher levels than tap water. Natural water sources typically contained concentrations up to 10 mg/L for calcium. However, concentrations of up to 100 ppm are fairly common in natural source of water (National academy of sciences, 1977). The taste threshold for the higher concentrations are acceptable to consumers. Calcium is one of the major elements responsible for water hardness. Water containing less than 60 ppm of Ca is considered as soft water. Carbonated water (San Pelegrino) from Italy has the highest concentration of calcium (about 200 mg/L). Hardness levels above 500 mg/L are generally considered to be aesthetically unacceptable, although this level is tolerated in some communities (Zoeteman, 1980).

Magnesium

No significant difference in magnesium concentration between tap water and some bottled water was detected. But Barka show high value than tap water (26 mg/L). Also San Pelegrino has the highest concentration of magnesium (Magnesium was about 58.8 mg/l).

Silicon

The silicon level in tap water was very low (less than 2 mg/L). All brands of bottled water contained substantial amounts of silicon. No health effect of silicon has been reported by WHO and no proposed guideline level is available.

Sodium

Sodium concentration in samples collected from tap water in Cairo was at less level than the bottled water, which was at approximately 25 mg/L. The sodium concentration of an Alpha brand was the highest level, which was at approximately

128 mg/L. Sodium concentration in Evian, San Bendito carbonated and Aqua Montana brands were the smallest one.

Lead

Materials that contain lead have frequently been used in the construction of water supply distribution systems and plumbing systems in private homes and other buildings. The most commonly found materials include service lines, pipes, brass and bronze fixtures, and solders and fluxes. Lead in these materials can contaminate drinking water as a result of the corrosion that takes place when water comes into contact with those materials. Lead can cause a variety of adverse health effects in humans. At relatively low levels of exposure, these effects may include interference in red blood cell chemistry, delays in normal physical and mental development in babies and young children, slight deficits in the attention span, hearing, and learning abilities of children, and slight increases in blood pressure of some adults (Shelton, 2003). Tap water from Cairo was high in lead levels (0.5 ppb Pb) than most bottled water except for Aqua Montana brand imported from Italy (0.8 ppb Pb) but all examined values are still below the recommended WHO guideline.

Acidity

The pH of water for all samples was approximately (7.1-8). The pH of carbonated imported water was about 5.1.

Conductivity

Conductivity value for Baraka brand showed higher value than tap water due to high concentration of total dissolved solids and the same for carbonated San Pelegrino brand showed higher values than other brands.

Chlorides

Tap water from Cairo contained chlorides less than 30 mg/L. Some bottled water was close to tap water expect for Schweppes water which showed highest level (76 mg/L chloride). In some imported mineral drinking water the concentration of chloride is very low (Evian 4.95 mg/L, San Bendito 2.9 mg/L) than the concentration of chloride in Cairo tap water. The taste threshold of the chloride anion in water is dependent on the associated cation, taste thresholds for sodium chloride and calcium chloride in water are in range 200-300 mg/L (Zoeteman, 1980).

Chloride in drinking water originates from natural sources, sewage and industrial effluents, urban run-off containing de-icing salt, and saline intrusion. No health-based guideline value was proposed by the WHO for chloride in drinking water.

However, chloride concentrations in excess of about 250 mg/L can give rise to detectable taste in water. Chloride in water may be considerably increased by treatment processes in which chlorine is used.

Fluorides

Tap water from Cairo contains about 0.25 mg/L fluoride and bottled water of Safi brand contained much more fluoride than tap water. Some imported mineral water like Font selvia contained high concentration of fluoride (3.22 mg/L).

Traces of fluoride are present in many waters. However, higher concentrations are often associated with underground sources. In areas rich in fluoride-containing minerals, well waters may contain up to about 10 mg of fluoride per liter. Fluorides may also enter a river as a result of industrial discharges (Slooff, 1988). In ground water, fluoride concentrations vary with the type of rock that the water flows through but do not usually exceed 10 mg/L (EPA, 1985).

High fluoride levels, above 5 mg/L have been found in several countries (e.g. Algeria, China, Egypt, India and Thailand) (EPA, 1985). The guideline value is 1.5 mg/L set in 1984 (Murray, 1986). Concentration above this value cause an increase in dental fluorosis, and much higher concentrations may lead to skeletal fluorosis.

Nitrates and nitrites

None of the water samples that were analyzed showed any significant level of nitrate ions expect some imported mineral water (San Bendito 1.7 mg/L as nitrogen, Aqua Montana 3.6 mg/L as nitrogen).

The extensive epidemiological data by WHO support the current guideline value of nitrate-nitrogen of 10 mg/L. The tap water from Cairo showed no detectable amounts of nitrite ions. Nitrite ion concentrations in bottled water (from Egypt and the imported) range from below the detection limit to (0.001 mg/L in Alpha brand, 0.0015 mg/L in San Bendito). The nitrate concentration in surface water is normally low (0-18 mg/L) but can reach high levels as a result of agricultural run-off and contamination with human or animal wastes. As a result of agricultural activities, the nitrate concentration can easily reach several hundred milligram per liter (WHO, 1985).

For example, concentrations of up to 1500 mg/L were found in the ground water in an agricultural area of India (Jacks and Sharma, 1983). Experiments suggest that neither nitrate nor nitrite acts directly as a carcinogen in animals, but there is some concern about a possible increased risk of cancer in humans from the endogenous and exogenous formation of N-nitrosoamine compounds, many of which are carcinogenic in animals. The WHO guideline value for nitrite is 3 mg/L as nitrogen. Because of the possibility of the simultaneous occurrence of nitrite and nitrate in drinking water, the sum of the ratios of the concentrations of each to its guideline value should not exceed 1 i.e.

$$\frac{C_{nitrite}}{GV_{nitrite}} + \frac{C_{nitrate}}{GV_{nitrate}} \leq 1$$

where C = concentration, GV = guideline value

Sulphates

Sulphate concentrations in all samples (tap water from Cairo and the bottled water from Egypt) were relatively similar except for Safi bottled water where it was significantly lower (13.1 mg/L). Also, the imported mineral water, all samples were in low concentration of sulphate expect for San Peleigrino where it was with higher concentration of sulphate 588 mg/L. Reported taste threshold concentrations in drinking water are 250-500 mg/L (median 350 mg/L) for sodium sulphate, 250-1000 mg/L (median 525 mg/L) for calcium sulphate, and 400-600 mg/L (median 525 mg/L) for magnesium sulphate (National Academy of Sciences, 1977).

Concentrations of sulphates at which water was determined to have an "offensive taste" were approximately 1000 and 850 mg/L for calcium and magnesium sulphates, respectively (Zoeteman, 1980). Addition of calcium sulphate and magnesium sulphate (but not sodium sulphate) to distilled water was recommended to improve the taste. An optimal taste was found at 270 and 90 mg/L for calcium sulphate and magnesium sulphate; respectively (Zoeteman, 1980).

Sulphate is one of the least toxic anions, however, catharsis, dehydration, and gastrointestinal irritation have been observed at high concentrations. Magnesium sulphate, or Epsom salts, has been used as a cathartic for many years. No heath-based guideline is proposed for sulphate by either WHO or EPA. However, because of the gastrointestinal effects resulting from the ingestion of drinking water containing high sulphate levels, it is recommended that health authorities be notified of sources of drinking water that contain sulphate concentrations in excess of 500 mg/L.

Recommendations

All analysed samples (tap water and bottled water) were almost free of ammonia, nitrite, nitrate except few traces of nitrite in tap water and some bottled water like Barka brand (ammonia and nitrate), Schweppes brand (nitrate), Alpha brand (nitrite) and also found nitrate in all imported mineral water except Heaven brand and Font selvia brand. But all examined water were within the WHO concentration guidelines. Bottled water of all Egyptian brands contained higher levels of sodium, silicon than tap water but they have nearly the same concentration of potassium and calcium except Safi (K about 17.5 mg/L) (Barka, Ca about 65 mg/L). Tap water contained higher levels of aluminum, lead and manganese but in acceptable limit. In this study most bottled and tap waters are of good quality. Tap water costs less and is at least as safe as bottled water but some people who suffer from renal insufficiency need water free of sodium for their health and can found it in some bottled water.

Table 1: Concentrations of elements and anions in various sources of drinking water in Egypt.

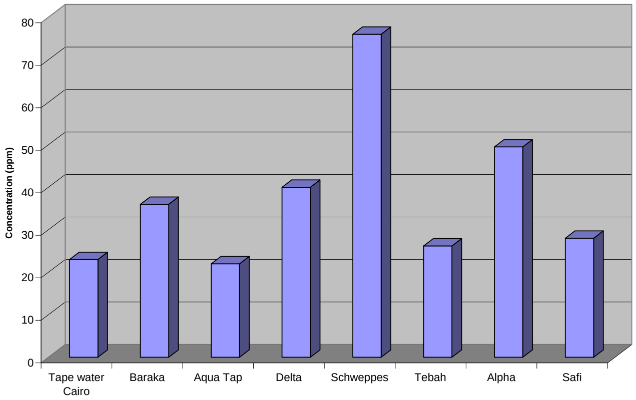
Parameter	Tap water (Cairo)	Baraka	Aqua	Delta	Schweppes	Tebah	Alpha	Safi
pH	7.70	7.40	7.6	7.5	7.9	7.1	7.2	7.20
Ammonia, NH_3 (ppm)	Nil	0.10	Nil	Nil	Nil	Nil	Nil	Nil
Nitrite, NO_2^- (ppm)	0.0005	Nil	Nil	Nil	Nil	Nil	0.001	Nil
Nitrate, NO_3^{2-}(ppm)	Nil	0.60	Nil	Nil	0.165	Nil	0.37	Nil
Chloride, Cl^- (ppm)	23.00	36.00	22	40	76	26.2	49.50	28.00
Fluoride, F^- (ppm)	0.25	0.18	0.16	0.13	0.1	0.2	0.33	0.44
Sulphate, SO_4^{2-} (ppm)	27.00	50.00	18.04	27	39	24.5	29.46	13.10
Sodium, Na^+ (ppm)	25.00	47.00	40	38	54	35	128.00	34.00
Potassium, K^+ (ppm)	4.80	5.00	3.85	4.5	4.35	4	4.40	17.50
Calcium, Ca^{2+}(ppm)	34.00	65.00	28.8	35.2	38.33	28	9.04	7.36
Magnesium, Mg^{2+} (ppm)	10.00	26.40	12.86	17.28	16.20	13.73	5.83	7.90
Silica, SiO_2 (ppm)	1.00	28.00	28	28	24.2	20	20.00	18.00
Bicarbonate, HCO_3^- (ppm)	148.84	305.00	192.15	191.5	164.7	173.2	278.65	107.60
Conductivity (μS/cm)	320	690.00	400	500	589	414	570.00	300.00
Total dissolve solids (ppm)	210	450.00	280	334	375	279	405.00	200.00
Iron (ppb)	100	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Manganese (ppb)	100	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Aluminum (ppb)	120	8	6	0.1	5	0.1	0.01	0. 8
Lead (ppb)	0.5	0.4	0.3	0.4	0.4	0.5	0.3	0.1
Cadmium (ppb)	0.3	0.2	0.1	0.15	0.3	0.2	0.1	0.2

Table 2: Concentrations of elements and anions in some imported mineral water.

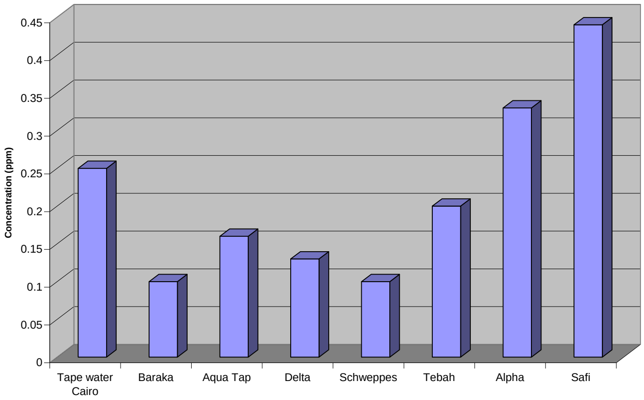
Parameter	Evian (France)	San Pelegrino carbonated (Italy)	San Bendito carbonated (Italy)	Aqua Montana (Italy)	Heaven (Bulgaria)	Font selvia (Spain)
pH	7.4	5.1	5.2	7.7	7.1	7.6
Ammonia, NH_3 (ppm)	0.1	Nil	Nil	0.1	0.1	Nil
Nitrite, NO_2^- (ppm)	Nil	Nil	0.0015	0.001	Nil	Nil
Nitrate, NO_3^{2-}(ppm)	0.95	0.7	1.7	3.6	Nil	Nil
Chloride, Cl^- (ppm)	4.95	70	2.9	8	58	12
Fluoride, F^- (ppm)	0.05	0.6	0.08	0.2	0.3	3.22
Sulphate, SO_4^{2-} (ppm)	11.00	588	4.5	15.6	27	10
Sodium, Na^+ (ppm)	5.5	46.2	7.48	6	63	50
Potassium, K^+ (ppm)	1	3	1.2	0.7	5.25	1
Calcium, Ca^{2+}(ppm)	74.5	212	49.7	78.6	42.4	34.8
Magnesium, Mg^{2+} (ppm)	26.4	58.8	30.4	38.4	25.7	5.76
\Silica, SiO_2 (ppm)	14.5	9.4	17	23	22	22
Bicarbonate, HCO_3^- (ppm)	346.48	244	274.5	381.25	270.84	202.52
Conductivity (µS/cm)	520	1570	420	610	650	390
Total dissolve solids (ppm)	335	955	270	400	400	258
Iron (ppb)	Nil	Nil	Nil	Nil	Nil	Nil
Manganese (ppb)	Nil	Nil	Nil	Nil	Nil	Nil
Aluminum (ppb)	Nil	Nil	Nil	Nil	Nil	Nil
Lead (ppb)	0.3	0.01	0.01	0.8	0.6	0.4
Cadmium (ppb)	0.2	0.003	0.003	bdl	0.3	0.1

bdl: below detection limit

Chloride



Fluoride



Sulphate

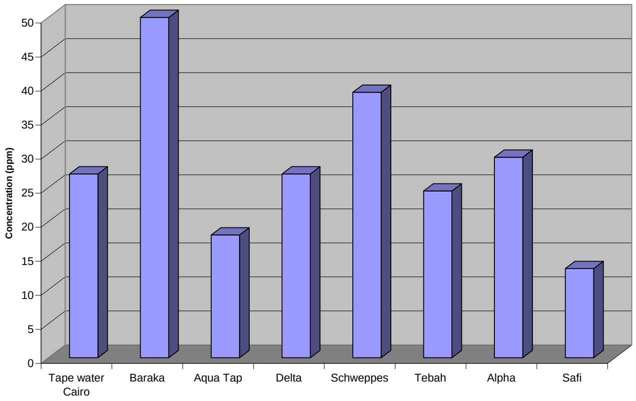
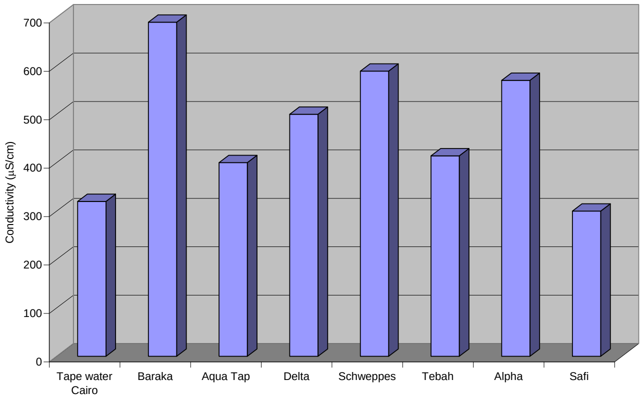


Fig.1: Concentration of anionic species (Cl^-, F^-, SO_4^{2-}), conductivity and TDS in drinking water

Conductivity



TDS

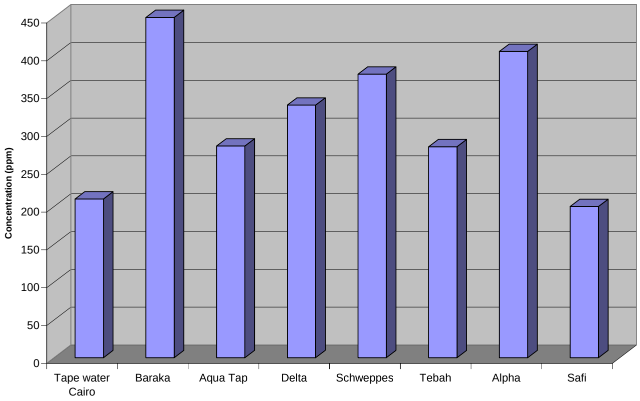
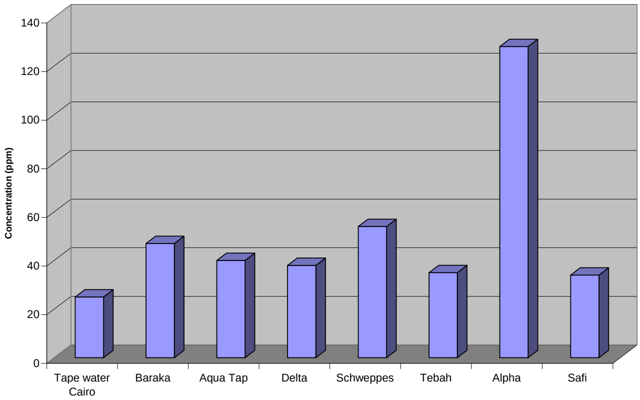
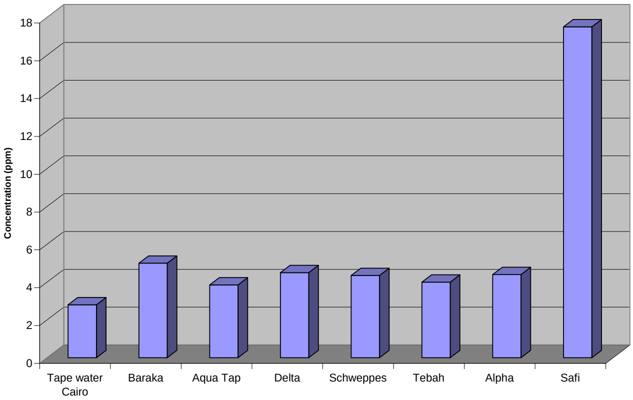


Fig.1 (Continued)

Sodium



Potassium



Calcium

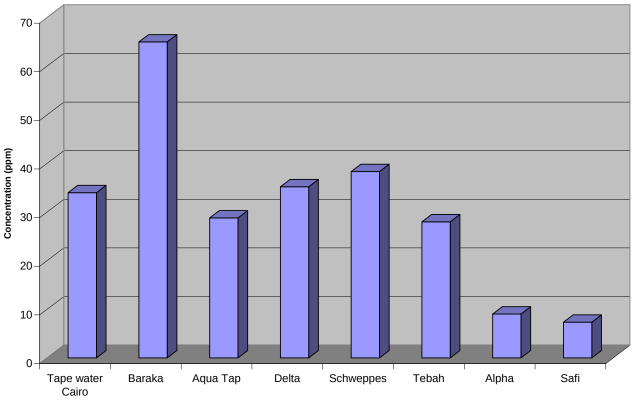
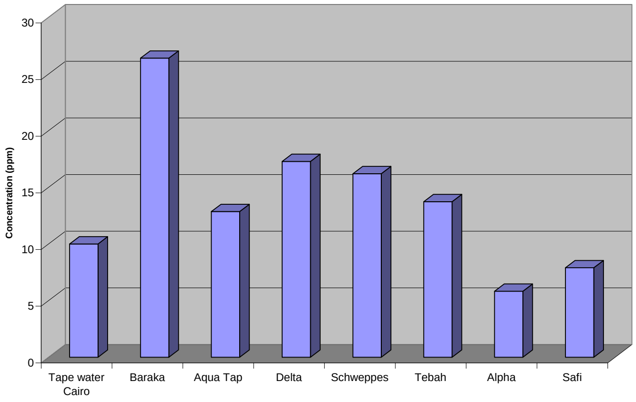


Fig.2: Concentration of elements (Na^+, K^+, Ca^{2+}, Mg^{2+}, SiO_2) in drinking water

Magnesium



Silica

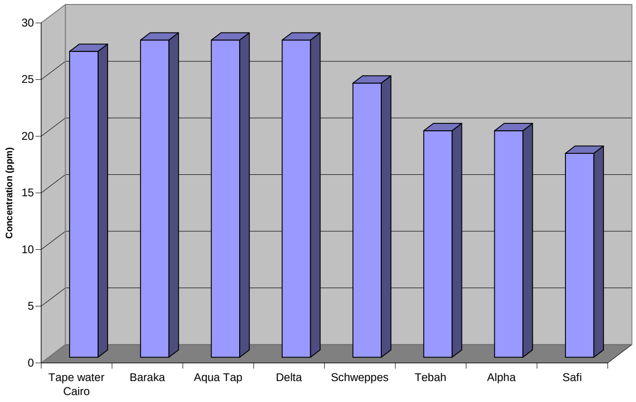
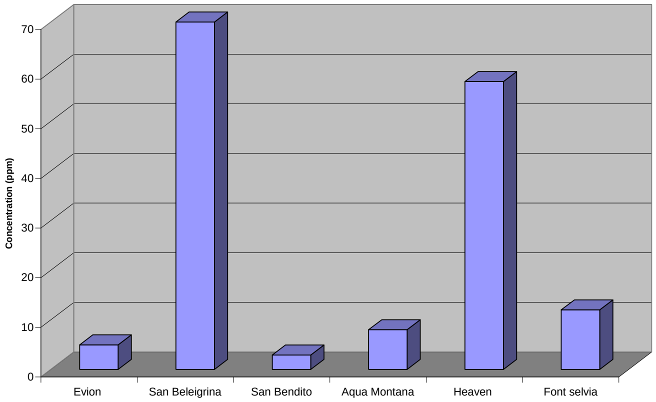
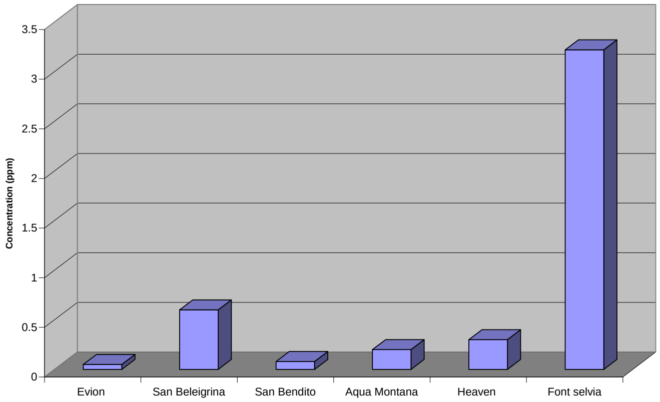


Fig. 2: (Continued)

Chloride



Fluoride



Sulphate

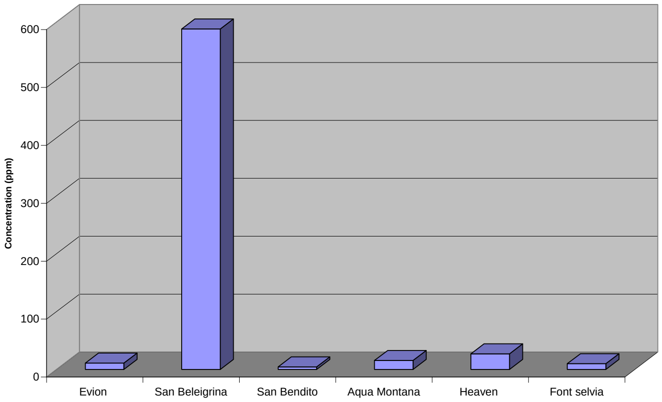
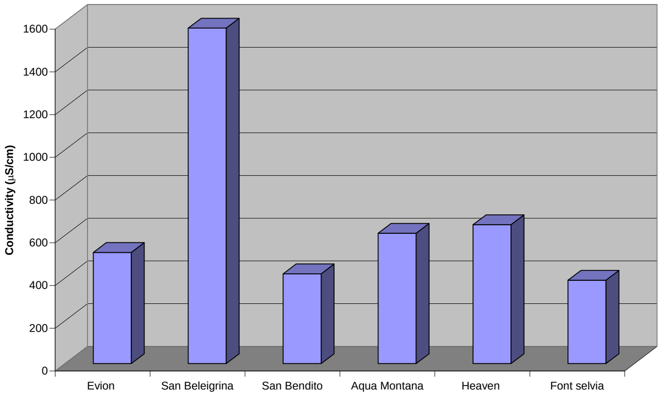


Fig.3: Concentration of anionic species (Cl^-, F^-, SO_4^{2-}), conductivity and TDS in Mineral water

Conductivity



TDS

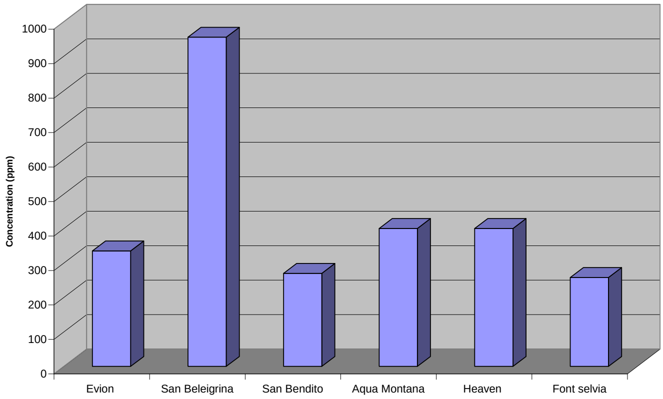
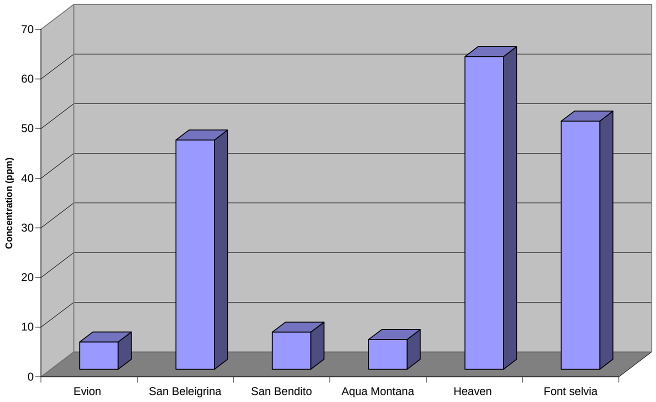
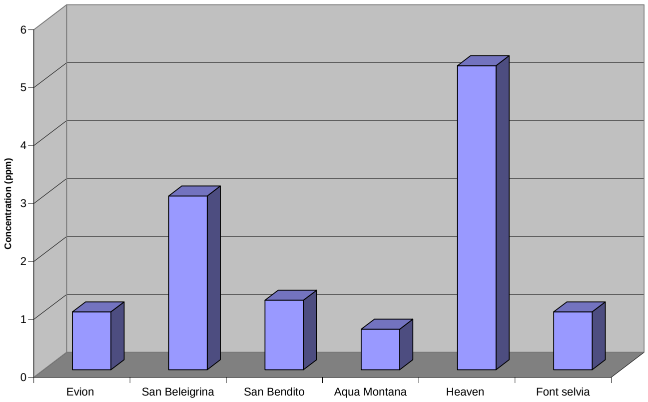


Fig. 3. (Continued)

Sodium



Potassium



Calcium

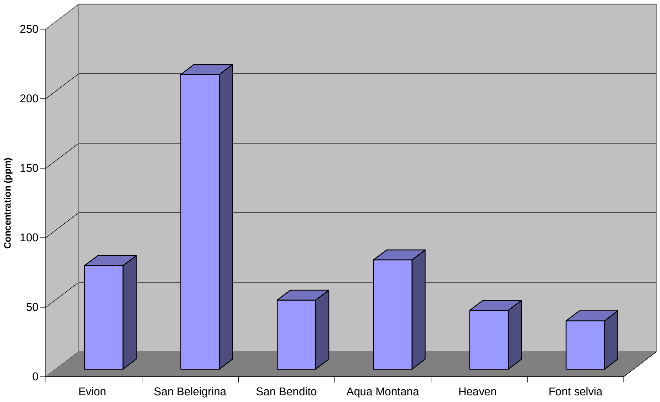
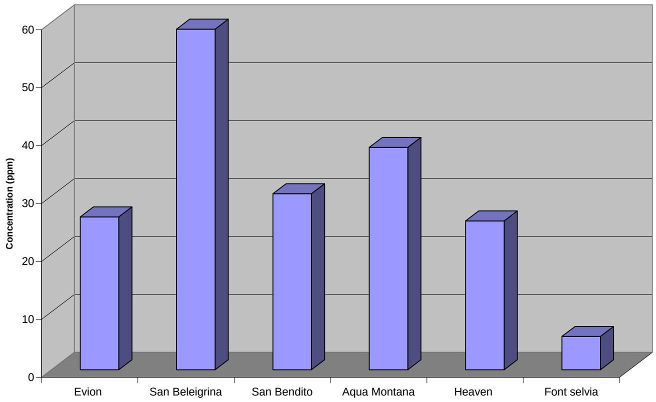


Fig.4: Concentration of elements (Na^+, K^+, Ca^{2+}, Mg^{2+}, SiO_2) in Mineral water

Magnesium



Silica

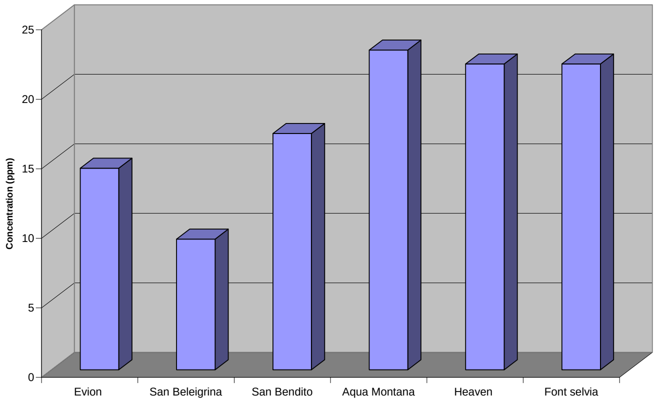


Fig.4: (Continued)

References

1. ALLEN, L. & DARBY, J.L., (1994). Quality control of bottled and bended water in California: a review and comparison to tap water, J. Environ. Health, 56, 17-22.
2. BERMAN, E. (1980). Toxic metals and their analysis. Philadelphia, PA. Heyden and Son, Ltd.
3. CALABASE, D.M. (1997). Bottled H_2O-Better Nutr. 59, 46.
4. El-GOHARY, F. (1994). J. Am. Chamber Commerce Egypt 10, 2.4-2.5 and 2.9-2.11.
5. ENVIRONMENTAL PROTECTION AGENCY (EPA), (1985). Office of drinking water. Drinking water criteria document on fluoride, TR-823-5. US Environmental Protection Agency, Washington, DC.
6. GARZON, P. & EISENBERG, M. J. (1998). Variation in the mineral content of commerically available bottled waters implications for health and disease. Am. J. Med., 105, 125-30.
7. HEIZER, W.D., SANDLER, R.S., SEAL, E. JR., MURRAY, S.C., BUSBY, M.G., SCHLIEBE, B.G. & PUSEK, S.N. (1997). Intestinal effects of sulphate in drinking water on normal human subjects. Dig Dis Sci., 42; 1055-1061.
8. IKEM, A., ODUEYUNGBO, S., EGIEBOR, N. O. & NYAVOR, K. (2002). Chemical quality of bottled waters from three cities in eastern Alabama. Sci. Total Environ., 285, 165-175.
9. JACKS, G. & SHARMA, V. P. (1983). Nitrogen circulation and nitrate in ground water in an agricultural catchment in southern India. *Environ*. *Geol*. 5, 61-64.
10. LAUWERYS, R.R. (1979) Health effects of cadmium in: trace metals exposure and health effects (Diferrante E, ed) Oxford Pergamon Press, 43-64.
11. MAYNE, P.D. & Edwards, L. (1990). What on earth are we drinking? Br J uroll 66:123-126.
12. MISUND, A., FRENGSTAD, B., SIEWERS, U. & REIMANN, C. (1999). Variation of 66 elements in European bottled mineral waters. Sci Total Environ. 243/244, 21-41.
13. Murray, J. J. (Ed.). (1986). *Appropriate* U*se of Fluorides for Human Health*. World Health Organization, Geneva.
14. MYLLYLÄ, K. S. (1995). Third world mega-cities, case Cairo: environment runs parallel with development. In Regions and Environment in Transition; In Search for New Solutions, Series A 16 (M. Sotarauta, and J. Vehmas, Eds.), pp. 217-2-8. University of Tampere, Department of Regional Studies.
15. NATIONAL ACADEMY OF SCIENCES. (1977). Drinking water and Health. National Research Council, Washington, DC.

16. NEEDLEMAN, H.L. (1993). The current status of childhood low-level lead toxicity. Neurotoxicology 14: 161-166 (1993).

17. PIP, E. (2000). Survey of bottled drinking water in Manitoba, Canada. Environ. Health Perspect. 108, 863-866.

18. SCHUBERT, C., KMOBELOCH, L., KANOREK, M.S. & ANDERSON, H.A. (1999). Public response to elevated nitrate in drinking water wells in Wisconsin Arch Eviron Health 54: 242-247.

19. SHELTON, T.B. (2003). Interpreting Drinking Water Quality Analysis: What do the numbers mean? Ph.D. Rutgers University, New Brunswick NJ 08903.

20. SLOOFF, W. (Eds.). (1988). *Basis document fuoriden*, Report no. 758474005. National Institute of Public Health and Environmental Protection, Bilthoven, Netherlands.

21. WHO. (1985). *Health Hazards from Nitrate in Drinking water*. Report on a WHO meeting, Environmental Health Series, No. 1, Copenhagen, 5-9 March 1984. WHO Regional Office for Europe, Copenhagen.

22. YANG, C.Y., CHENG, M.F., TSAI, S.S. & HSIEH, T.I. (1998). Calcium, magnesium, and nitrate in drinking water and gastric cancer mortality JPN J Cancer Res 89: 124-130.

23. YULE, W. & RUTTER, M. (1985). Effect on children's behavior and cognitive performance a critical review. In: Dietary and environmental lead. Human Health Effects (Mahoffey R, ed), New York Elsevier, 211-251.

24. ZOETEMAN, B. C. J. (1980). Sensory Assessment of Water Quality. Pergamon Press, New York, NY.