Roumanian Biotechnological Letters *Vol. 14, No. 3, 2009, pp. 4477-4484*

Roumanian Society of Biological Sciences

ORIGINAL PAPER

Use of Human Hair as a Potential Biomonitor for Zinc in the Pendik District Istanbul Turkey

Received for publication, December 20, 2008
Accepted, June 5, 2009

ULKUHAN YASAR AND IBRAHIM ILKER OZYIGIT
Marmara University, Faculty of Science and Arts, Department of Biology, 34722, Goztepe/Istanbul/TURKEY
Correspondence to: Ibrahim Ilker Ozyigit, Marmara University, Faculty of Sciences and Arts, Department of Biology, 34722, Goztepe/Istanbul/TURKEY
E-mail: ilkozyigit@marmara.edu.tr
Telephone: (+90216) 3487759/1185, Fax: (+90216) 3478783

Abstract

A sample of 70 high school students (aged 16 to 20) studied from the Pendik District Istanbul-Turkey in order to determine the levels of zinc in their hair. Levels of Zn were measured by using Varian AA200 model atomic absorption spectrometry. The student's personal data such as age, sex, location, general state of health, diet habits, possible use of pharmaceuticals, alcohol, coffee and tobacco, etc was considered and only healthy student's hair were used as experimental materials. The mean values of Zn in student's hair were measured as 216.19 ±16.50 ppm. The Zn values of six different station's soil samples in the Pendik District were measured to compare with the hair Zn values. According to the results of our study, hair is a good biomonitor for Zn and can be used for diagnostic purposes, as indices body status in humans as well as for detecting certain diseases. Increasing Zn levels in hair could be a monitor for high traffic density while decreasing could be a monitor for industrial pollution. Additionally, higher or lower Zn in human hair could reflect firstly dietary habits, then sex, age, financial status, smoking habits and environmental status.

Keywords: Mineral elements, contaminants, intake, hair levels, biomonitor, zinc

Introduction

Scientists have been using many different living organisms or some of their tissues and organs as biomonitors to estimate contamination levels of metallic and non-metallic pollutants for a long time. For this purpose, vegetal (cyanobacteria, lichens, mosses and trees) [1-4] and animal (mollusks, fishes, birds and small mammalians) [5-8] samples have been extensively used as biomonitors of heavy metal pollution in terrestrial environments. Human is one of the most important biomonitor organisms in the world and is also an important tool in environmental medicine to assess and evaluate the level of internal exposure of the general population and individuals to environmental pollutants [9].

Human biomonitoring has been used in occupational medicine since the early 1930s, and the main matrices used are blood and urine [10]. Blood is an ideal matrix for most chemicals because the plasma is in contact with tissues and organs where chemicals are deposited [11]. After blood, urine is the second most common matrix for human biomonitoring, particularly for water-soluble chemicals and it can be collected as spot or 24-h samples [10]. Other mostly used matrices are hair, nails, breast milk, saliva, meconium, teeth, bones, semen and faeces [10, 11].

Human hair, has gained considerable ground in recent years for use as a biomonitor of trace elements to estimate environmental exposure levels [11]. Nevertheless, it is not only a stable matrix for biomonitoring studies but also a potentially additional tool for the public health surveillance [10, 12]. Hair analysis is rather advantageous, because it can reflect the total body intake of certain elements better than biological fluids, even though careful evaluation of exogenous contamination is mandatory [13]. Moreover, it provides a non-invasive sampling with additional values, such as stable matrix, easy collection, short and long-term exposure tracings and so forth [12].

Since hair is an important biopsy material, like living organisms, non-living materials even the mummy samples can be analyzed by using hair [14]. Simply, blood analyses indicate what is happening; urine what has happened; by the way hair reflects what has happened at the cellular level for a period of about longer times prior to the sampling [15].

In 1980, human hair selected as one of the important monitoring materials for worldwide biological monitoring in the Global Environmental Monitoring Systems (GEMS) of the United Nations Environmental Program [15]. Today, when searched as “human hair” in Isi Web of Science, it can be found that there are over more than 8000 cited scientific studies by using human hair and this result expresses the importance and availability of this material in current science.

In spite of many advantages of using hair in biomonitoring studies, there are also some disadvantages. One of the major disadvantage in the application of hair as a biomonitor is the problem of contamination, and the poorly understood mechanisms of uptake, incorporation and binding of trace elements in the hair matrix, and hence the discrimination of endogenous and exogenous contributions [16]. Furthermore, many factors, such as age, sex, smoking habit, hair color and hair treatment affect the incorporation of contaminants into the hair. Some of them have already been clarified, but some not. It limits the evaluated reference values for hair analysis to a certain extent [17].

Zinc is one of the trace elements that are present in all living structures, both in plants and animals. It is a mineral essential to normal function of human body due to its role in both activating enzyme systems and as a cofactor of several metalloenzymes such as carbonic anhydrase, carboxypeptidase A and B, dipeptidase, pyruvate carboxylase, superoxide dismutase, alkaline phosphatase and DNA-RNA polymerase [18-20].

Many epidemiologic studies suggested that Zn deficiency may be associated with increased risk of some disorders and diseases [19-26]. In addition, profound Zn deficiency is quite rare in humans, but mild to moderate Zn deficiency may be relatively common thorough the world in both less developed and industrialized countries [20, 27].

In this research, we studied 70 healthy student’s hair as experiment materials and determined the Zn values in hair in the Pendik District, Istanbul-Turkey. We also measured Zn values of 6 different station’s soil samples in Pendik to compare the hair Zn values.

Materials and Methods

1. General Information

1. 1. Location

The Pendik District is located on the Anatolian (Asia) side of Istanbul (40°52′39 N, 29°15′05 E), on the North coast of the Marmara Sea (7.5 km). Total land area is 203 km^2, which includes some countryside areas inland (Figure 1).

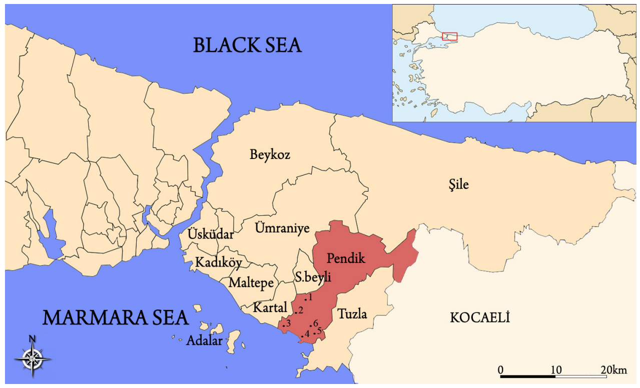

Figure 1: The study area (the Pendik District) and the stations (1-6) that soil samples were collected

1. 2. Geographical Characteristics

Pendik has a rough territory and the land area turns into the hills (Ballıca, Ağılbayırı and Karabayır Hills) through the north side while it is flat at the seacoasts. There are three brooks (Riva, Ballıca and Büyükdere) and there is a big dam (Ömerli) in the district. The climate of research area is typical four-season continental climate of the northern hemisphere and is mostly affected by the Mediterranean climate. The Mediterranean character is associated with the annual distribution of precipitation, being high during the winter months and having a drought period of 3 or 4 months in summer.

The most part of the study area consisted of brownish forest soil without lime (generally formed under the forests) and the remaining parts are alluvial soil, and brownish soil without lime. Furthermore, seacoast has partially sandy and clay soils, and there are limestone and quartz on the Hills [28, 29].

1. 3. Population

The population of Pendik increased rapidly over the last 25 years. While in 1935, the population was 3.514 in 1980, it reached 48.219. After 1980, the population increased fast and in 2009, the population is 520.486. Pendik was always a retreat from the city and by the 20th century it was peppered with holiday and weekend homes of Istanbul's wealthy. Today, Pendik is a heavily populated district, although located far from the city center [28, 30].

1. 4. Economy

There is a total of 5.658 both large and small business firms in the Pendik District and 2.022 of them are showing activity in production sectors while 1.242 of them are building societies. Additionally, Ömerli Dam, Sabiha Gökcen Airport and Formula 1 Area (Istanbul Park) affect the economy of Pendik. Today, Pendik is one of the most important industrial areas of Istanbul and it is projected to be a major urban and industrial area in the future [28].

2. Sample Collection and Treatment

Totally, 70 young high school student's hair samples whose ages are between 16-20 were collected from the Pendik District Istanbul Turkey. Each subject filled in a form to provide personal data such as age, sex, location, location time, general state of health, diet habits, possible use of pharmaceuticals, alcohol, coffee and tobacco, etc. Hair samples weighing approximately 1g were taken from the occipital region of the head, using a stainless steel scissors, and stored in poly-ethylene bags. Dry and clean hair samples were preferred, while gelled, sprayed or dyed were not collected. Hair samples were placed in 100ml beakers, washed with acetone + hexane mixture (1:1 v/v) for a period of 12 hours and then rinsed with distilled water. After being washed, the hair samples were dried at 70°C for 16 hours followed by cooling to room temperature and finally reweighed on an analytical balance. After drying, approximately 0.5g of hair from each sample was weighed and transferred into polytetrafluoroethylene (PTFE) vessels (HP-500) and then 6 ml 65% HNO_3 and 1ml 30% H_2O_2 (Merck) were added. Samples were mineralized in microwave oven (CEM MARS5) as follows: 5min at 1200W maximum power, 115°C and 15min stand by. After cooling, the samples were filtered by Whattman filters and made up to 50ml with double distilled water in volumetric flasks and then stored in clean self-sealing plastic bags in silica gel.

Standard calibration techniques were used and Zn measurements were done by atomic absorption spectrometry (AAS), using a Varian AA200 model. The Zn hollow cathode lamp current was 5mA and the wave length was 213.9nm, slit width 0.5nm. Results were expressed in parts per million (ppm). Mean ± standard errors of mean values of Zn of both groups in hair were calculated for each group. The statistical analyses of the results were calculated in SPSS.

The statistical values (Table 1) and histogram (Figure 2) are given in result and discussion section.

Results and Discussion

In this study, we preferred healthy student's hair as experiment materials and average Zn value was measured as 216.19 ±16.50 ppm (Table 1). The normal limits of Zn in human hair are between 100-280 ppm. In our study 58 student's (83 %) Zn levels were within normal limits while 12 students (17 %) Zn levels were higher, and there were not any Zn values under normal limits (Figure 2).

Statistical Data

Zn hair

N	Valid	70
	Missing	0
Mean		216.1879
Std. Error of Mean		8.47727
Std. Deviation		70.92591
Variance		5030.484
Range		283.61
Minimum		126.77
Maximum		410.38
Percentiles	10	145.5750
	20	158.4960
	30	167.6510
	40	180.7060
	50	194.5700
	60	208.2260
	70	239.8750
	80	275.0980
	90	341.6240
	95	373.0645

Table 1. The statistical data of hair Zn levels.

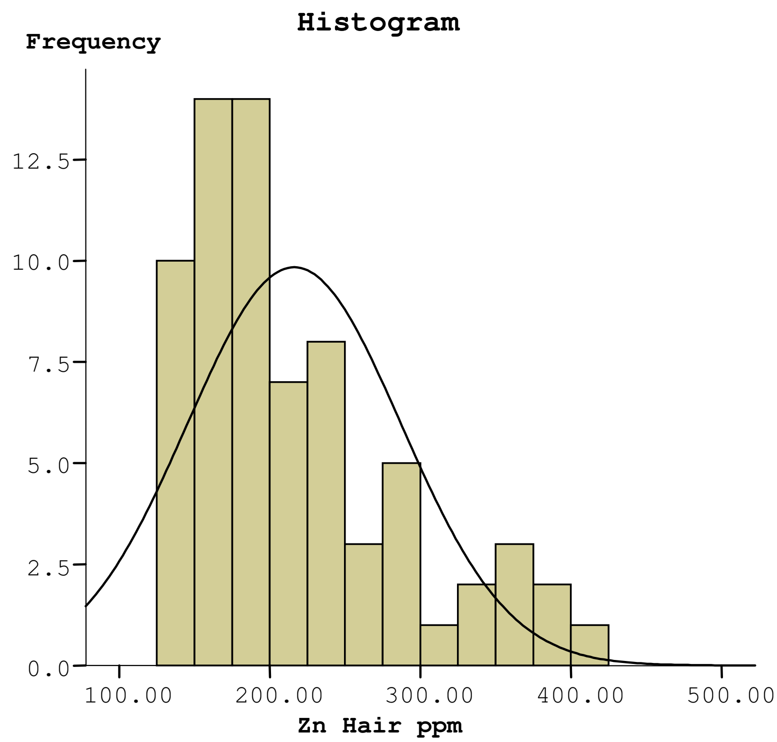

Figure 2: The histogram of hair Zn levels of students living in the Pendik District Istanbul-Turkey.

There are many studies by using human hair and blood for Zn detection in many disorders and diseases and most of them showed decreased hair Zn levels in patients compared with control (healthy) groups. According to the literature, similar to our study, healthy people's Zn values are usually within normal limits in many countries. By the way, in breast and ovarian cancers [20], some types of skin-diseases [26], epilepsy [22] and Down syndrome [19] reduced hair and plasma Zn levels were observed. In addition, a reduction was also observed in plasma Zn and Cu levels of boys with both attention deficit hyperactivity and oppositional defiant disorders [24, 25]. Furthermore, changes in blood Zn have been found in lymphoproliferative disorders as well as in lung and gastrointestinal tumors [20, 31-33]. Low Zn is related to poor wound healing, slow growth rate, low taste perception, slow hair growth and loss, night blindness, dermatitis, acne, strong body odor and an increased risk of dental cavities [23, 34]. It was also reported by other researchers, the decrease in plasma Zn concentration had been observed after stress, trauma, and in several malignancies [20, 33, 35]. In our study, all students were healthy and we did not obtain any lower Zn values.

Station Number	**Station Type**	**Soil Zn value (ppm)**
1	Rural	20.91
2	Urban Roadside	34.87
3	Urban	33.47
4	Urban	22.00
5	Motorway (D-100) Near Navy Yard	130.94
6	Urban Park	26.56

Table2. Stations and soil Zn values in the Pendik District Istanbul-Turkey

In our study, in addition to hair Zn concentrations, we also measured the soil levels in 6 stations. As it was seen in table 2, there was no Zn pollution in soil although Pendik is a fast-growing (urbanized and industrialized) district. By the way, soil Zn values were lower than we had imagined before the study. Although one station's (Motorway D-100 - Near Navy Yard) Zn value was higher 130.94 then others, it was within normal soil Zn limits. Other station's values were between 20.91-34.87 ppm (under normal soil Zn values). As known, in urban areas, there is traffic density and abrasion of the tires of the vehicles that contain ZnO and wastes of the oils from diesel engines cause Zn pollution in roadside [36]. This moderate higher result in Motorway D-100 could be a reflection of high traffic density.

There are some studies, which were performed in other industrialized cities measuring Zn values in hair samples. In one such study, Cd, Cu and Zn values of some tissues of deceased copper smelter workers were measured and an increased Cd and decreased Zn in hair were observed [37]. In another study, the highest Zn values were observed in businessmen (212.3 ppm) while the lowest in workers (98.4 ppm). By the way, workers' Cd values were the highest (1.3 ppm) and the businessmen's Cd values were the lowest (0.4 ppm) [21]. This could be an explanatory result relation between hair Zn levels and the wealth status of people related with other features such as age, job, dietary habits, smoking and alcohol usage etc. In another study, lower Zn levels were measured from the hair samples of industrialized area inhabitants while their Cd values were higher [38]. In addition to the detractive effects of increasing Cd levels in industrialized and polluted areas, the literature also indicated that increased Pb concentrations caused lower Zn and Cu levels in nails in industrialized areas [39].

Previous studies claimed that industrialization and urbanization had detractive effects for Zn concentrations in human hair related with increasing Cd and Pb. Nevertheless, in our study, the Zn levels of healthy students were within normal limits excluding some students higher Zn levels that were mostly living near motorways, which have naturally high traffic density. In a similar study, Al-Nasser and Hasbem (1997) observed increased levels of Zn in gas station workers which had the highest increases; 1.5 times in hair, 1.3 times in nails and 1.7 times in whole blood and in traffic polices 1.4 times in hair, 1.3 times in nails and 1.6 times in whole blood compared to control group [40]. This could also be the result of high traffic density to the increased Zn levels. By the way, Zn can be toxic if exposure is excessive. Although uncommon, high hair Zn might be indicative of Zn overload that could result from Zn contaminated water (galvanized pipes), welding or gross, chronic over supplementation (100 mg/day). Other sources of Zn exposure include: manufacture of brass, bronze, white paint, pesticide production, galvanization of steel and iron products, dry cell batteries, rubber, textile and ceramic industries [41].

It is clearly known that Zn deficiency is a critical nutritional problem for both plant and human in Turkey and soil Zn values are under normal limits [27]. Eyupoglu et al. (1994) analyzed 1511 soil samples that collected from all provinces of Turkey and they showed that 50 % of the cultivated soils in Turkey are Zn-deficient. These Zn-deficient areas are equivalent to 14 Mha of cultivated land in Turkey [42]. In our study, the soil Zn levels were under normal limits but its reflection was not deficit Zn levels in young student's hair in the Pendik District. Nevertheless, 41% of the children who lived in Southeastern Anatolia had very low concentration of Zn (<100 mg kg^{-1}) in their hair. Although soil Zn levels are low in both area, socioeconomic parameters are very different and the deficit Zn levels could be the result of low socioeconomic attributions related with nutritional differences in Southeastern Anatolia. Another study carried out in Chile with Chilean infants who are at risk for isolated Zn and Fe deficiencies because of a low consumption of animal products in low socioeconomic sectors. An observed negative correlation between socioeconomic status and the concentration of Zn in the hair samples was concordant with the fact that a large part of ingested Zn and its availability originated from animal products, which were more expensive. It was also observed that poorer families have a higher risk of infections such as respiratory infections and gastrointestinal infections, which were important causes of the loss of ingested Zn [43]. In our study, although the Pendik District is a fast-growing, urbanized and industrialized district, urbanization and industrialization did not reflect negatively on our students' hair Zn levels. This could be the result of their age groups (16-20), their health and wealth status, dietary habits, non-smoking habits etc. or planned urbanization industrialization in the Pendik District.

According to the results of our study and the previous studies, hair is a good biomonitor for Zn and can be used for diagnostic purposes, as indices body status in humans as well as for detecting certain diseases. It was also seen that in many districts, urbanization and industrialization has detractive effects to the hair Zn levels related with increasing Cd and Pb levels. However, increasing Zn levels in hair could be a monitor for high traffic density while decreasing could be a monitor for industrial pollution. In addition, higher or lower Zn in human hair could reflect firstly dietary habits, age, financial status, smoking habits and environmental status (food, air, water, soil).

Acknowledgement

We wish to express our gratitude Mr. Yusuf Ziya Yılmaz from Çekmece Nuclear Research and Education Center Istanbul/TURKEY for measurements of the samples.

References

1. H. KUPPER, P.M.H. KRONECK, *Heavy metal uptake by plants and cyanobacteria*. In A. SIGEL, H. SIGEL, R. SIGEL, eds., Metal Ions in Biological Systems, Vol. 44, Marcel Dekker Inc., New York, (2005), pp 92-142.
2. R.M. GODINHO, H.T. WOLTERBEEK, T. VERBURG, M.C. FREITAS, *Environmental Pollution*, 151(2), 318-325 (2008).
3. J.R. ABOAL, J.A. FERNANDEZ, J.A. COUTO, A. CARBALLEIRA, *Environmental Monitoring and Assessment*, 137(3), 371-378 (2008).
4. A.N. BERLIZOV, O.B. BLUM, R.H. FILBY, I.A. MALYUK, V.V. TRYSHYN, *Journal of Radioanalytical and Nuclear Chemistry*, 276(1), 15-21 (2008).
5. B.M. PEAKE, I.D. MARSDEN, A.M. BRYAN, *Environmental Monitoring and Assessment*, 115(1-3), 119-144 (2006).
6. S. TEKIN-OZAN, *Environmental Monitoring and Assessment*, 145(1-3), 295-302 (2008).
7. J. KIM, T.H. KOO, *Archives of Environmental Contamination and Toxicology*, 55(1), 122-128 (2008).
8. R. PEREIRA, M.L. PEREIRA, R. RIBEIRO, F. GONCALVES, *Environmental Pollution*, 139(3), 561-575 (2006).
9. M. WILHELM, C. SCHULZ, M. SCHWENK, *International Journal of Hygiene and Environmental Health*, 209, 301-305 (2006).
10. M. ESTEBAN, A. CASTANO, *Environment International*, doi, 10.1016/j. envint. 2008.09.003 (2008).
11. M.J. GONZALEZ-MUNOZ, A. PENA, I. MESEGUER, *Food and Chemical Toxicology*, 46, 3048-3052. (2008).
12. H. ZHANG, Z. CHAI, H. SUN, *Environment International*, 33, 685-693 (2007).
13. F. PETRUCCIA, N. VIOLANTEA, O. SENOFONTEA, M.D. GREGORIOA, A. ALIMONTIA, S. CAROLIA, G. FORTEA, A. CRISTAUDOB, *Microchemical Journal*, 76, 131-140 (2004).
14. D.B. HRDY, *American Journal of Physical Anthropology*, 49(2), 277-282 (1978).
15. J.D. CAMPBELL, *Journal of Orthomolecular Psychiatry*, 14(4), 276-280 (1985).
16. I.M. KEMPSON, W.M. SKINNER, *Science of the Total Environment*, 338, 213-227 (2005).
17. K.W. SCHRAMM, *Chemosphere*, 72, 1103-1111 (2008).

18. F. KARGIN, K. SEYREK, A. BILDIK, S. AYPAK, *Turkish Journal of Veterinary & Animal Sciences*, 28(3), 609-612 (2004).
19. A. YENIGUN, F. OZKINAY, O. COGULU, C. COKER, N. CETINER, G. OZDEN, O. AKSU, C. OZKINAY, *Down Syndrome Research and Practice*, 9(2), 53-57 (2004).
20. A.R. MEMON, T.G. KAZI, H.I. AFRIDI, M.K. JAMALI, M.B. ARAIN, N. JALBANI, N. SYED, *Clinica Chimica Acta*, 379, 66-70 (2007).
21. A. SUKUMAR, R. SUBRAMANIAN, *Science of the Total Environment*, 372, 474-479 (2007).
22. H. ULVI, R. YIGITER, T. YOLDAS, Y. DOLU, A. VAR, B. MUNGEN, *Eastern Journal of Medicine*, 7(2), 31-35 (2002).
23. Y. TUZUN, N. ARZUHAL, *Dermatose*, 2, 84-91(2004).
24. O. YORBIK, A. OLGUN, P. KIRMIZIGUL, S. AKMAN, *Klinik Psikiyatri*, 7, 80-84 (2004).
25. O. YORBIK, A. OLGUN, P. KIRMIZIGUL, S. AKMAN, *Türk Psikiyatri Dergisi*, 15(4), 276-281 (2004).
26. H.I. AFRIDI, T.G. KAZI, M.K. JAMALI, G.H. KAZI, G.Q. SHAR, *Turkish Journal of Medical Sciences*, 36(4), 223-230 (2006).
27. I. CAKMAK, M. KALAYCI, H. EKIZ, H.J. BRAUN, Y. KILINC, A. YILMAZ, *Field Crops Research*, 60, 175-188 (1999).
28. http,//www.pendik.bel.tr, Pendik Belediyesi Resmi Web Sitesi (The Official Web Site of Pendik Municipality, last access, February - 2009).
29. http,//www.pendik.gov.tr, Pendik Kaymakamlığı Resmi Web Sitesi (The Official Web Site of Pendik District, last access, February - 2009).
30. http,//tuikapp.gov.tr, T.C. Başbakanlık Türkiye İstatistik Kurumu Resmi Web Sitesi (The Official Web Site of Turkish Republic Office of Prime Ministry Statistics Institution, Last Access, February - 2009).
31. G.S. ANDREWS, *Journal of Clinic Pathology*, 32, 325-33 (1979).
32. P.M. NEWBERN, T.F. SCHRAGER, S. BROITMAN, *Pathologie Biologie*, 65, 39-45 (1997).
33. S.K. GUPTA, V.K. SHUKLA, M.P. VAIDYA, S.K. ROY, S. GUPTA, *Journal of Surgical Oncology*, 46, 178-82 (1991).
34. A. PRASAD, *Trace Elements in Human Health and Disease*, Vol. 1. Zinc and Copper and Vol. 2. Essential and Toxic Elements I and II, Academic Press, New York, (1977).
35. M.T. LECCIA, M.J. RICHARD, A. FAVIER, J.C. BEANI, *Biological Trace Element Research*, 69, 177-90 (1999).
36. N. AKGUC, II. OZYIGIT, C. YARCI, *Pakistan Journal of Botany*, 40(4), 1767-1776 (2008).
37. L. GERHARDSSON, V. ENGLYST, N.G LUNDSTROM, S. SANDBERG G. NORDBERG, *Journal of Trace Elements in Medicine and Biology*, 16, 261-266 (2002).
38. I.C. NNOROM, J.C. IGWE, J.C. EJIMONE, *African Journal of Biotechnology*, 4(10), 1124-1127 (2005).
39. B. NOWAK, J. CHMIELNICKA, *Ecotoxicology and Environmental Safety*, 46, 265-274 (2000).
40. I.A. AL-NASEER, A.R. HASHEM, *Journal of King Saud University*, 10(2), 95-100 (1997).
41. http,//www.doctorsdata.com/repository.asp?id=1270, Fully licensed and certificated clinic laboratory, Doctor's Data, Inc. 3755, Illinois Ave. St. Charles, IL (last access, February - 2009).
42. F. EYUPOGLU, N. KURUCU, U. SANISA, *Status of plant available micronutrients in Turkish soils, in Turkish*. In, Annual Report. Report No. R-118. Soil and Fertilizer Research Institute, Ankara, 25-32 (1994).
43. C.S. TORREJO´N, C. CASTILLO-DURA´N, E.D. HERTRAMPF, M. RUZ, *Nutrition*, 20(2), 177-180 (2004).