Concentrations of trace elements in human hair as a biomarker expose to environmental contamination

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Abstract:

Scalp hairs have been recognized as a biological tissue indicator for toxic elements in the human body in the last decade. In this work scalp hair samples were collected from workers employed in industry workshops and perfume factory in Omdurman, Sudan considered the expect difficulty of exposure to environmental pollution. The hairs content determination was performed using XRF of Cd^{109} radioactive source to assess toxic elements Ca, Mn, Fe, Cu, Zn, Hg, Pb and Sr. An alternative approach of hair sample treatment was implemented with grinding in liquid nitrogen at a temperature of $77^{o}K$ to form a dry weight samples in fine powder mode. In a comprehensive assessment of the results are compared with the IAEA and several countries. The data used variable contributions, factor analysis, t-test values and correlation for method validation that shows the elements Ca, Fe and Sr on optimal levels of hairs workers in workshops, and element Ca, Cu and Zn in perfume factory hairs employers within the range of international reference material. Average elements concentrations of 42 hair samples of the employers indicate the Ca, Sr, Cu and Zn are approved fairly on optimum standards hairs references materials in the literature. However, the high levels of Mn, Cu, Zn, and Pb in workshops for employers and the increasing levels of Fe, Hg and Pb in perfume factory workers are possible to be exposed to environmental pollutants.

Keywords: XRF, Employers, Scalps hairs, toxic elements, Environmental pollution.

1. Introduction:

Hair is extra product of human tissue that reflects elements of metabolism in the body and became a subject of interest to environmental and biomedical sciences. Thus, element concentrations in hair are infection of the levels in other tissues. Moreover, the elements in hair can be absorbed from the environment over historical time, which reflects the impact of accumulation of the trace elements in the body (1). The levels of elements in human hair are important implications serve as a useful adjunct biochemical indices for assessing elements the burden in human body(2). Hence, trace element concentrations in scalp hair are affected by various factors such as environmental exposure, foods, gender and geographical location. The determination of impact of substances in blood and urine, hair and other specimens in people relative to exposure to environmental contamination is known as human biomonitoring. Human biomonitoring is defined as the approach to measure the chemical substances or their metabolites in biological tissues and identify the relation between element exposure to contamination sources and disease (3). The biomontering of hair assessment has the advantage of detecting element variation represents the long-term historical exposure trend and recent exposure of the individual when are compared to urine and blood engaged to observe the current element status of the human body. Hair is widely accepted for many advantages to evaluate the relation between essential elements in body burden and disease (4). Moreover, the elements concentrations are at higher levels in hair, so that accurate results of analysis can be obtained (4).

Scalp hair is one of the easier samples to be collected at low cost, which facilitates the storage and transport processes that offer several advantages for analysis including matrix stability in the human body. Trace element in hair is accurate and precise analysis for external contaminations. The analysis of human scalp hair has more effect in environmental monitoring and important to the validity and usefulness of the assessment (4). The scalp hair analysis, investigation has improved the analytical considerations and limitations of heavy metals in a variety of environmental health, which is related to the broad spectrum of pollution, occupational exposure and the geographical distribution of contaminated regions(4). Additionally, hair grows; structure included trace elements that are separated from the metabolic activity of the body, which is influenced by numerous internal and external factors. However, the trace element content of hair being used as an indicator for screening population groups as well as individuals exposed to environmental contaminants and in internal chemical variations in human body balances(5). Analyses of hair are used in different application such as criminal investigation with the determination of doping relevant substances and metabolites of the drug (6). Hair composition analysis of the toxic substance's determination delivers valuable information about the impact of contaminations is strongly correlated with many disorders, certain drugs and some diseases (6). Comparison of the measured and certified values of Fe, Zn, Cu and Ni in the certified reference material (IAEA-85) used as a QC for the AAS.Y. MURAMATSU and R.M. PARR 1988 were observed a highly significant positive correlation between Hg in the hair and kidney cortex of autopsy (7).

In general, hair is a record of metabolic processes in the organism for a long period of time with a lower metabolic activity of protein tissue. Scalp Hairs characterization, properties and element concentrations are the mirror of individual peculiarities of a human being such as sex, age, diet, cosmetics and pharmacological effects (Vazina et al., 1998). The samples of hairs can be collected frequently and stored for an unrestricted time used for repeated analyses without damage, which uses occupational potential exposure and environmental conduction's investigation flows up (8). The heavy metal's exposure As, Cd, Cr, Cu, Mn and Zn

have been assessed in hair of two different communities at the South and North of the mine area related to about potential exposure pathways to these elements, which were found, no significant differences were found in the average concentration of these elements between villages, R.Per eiraa,b, , R.Ribeir oc, F.Gonc¸alves(8). X-ray fluorescence energy dispersive technique has been used to analysis the elements Cr, Mn, Ni, Cu, Zn and Mo in scalp hair samples of a group of both genders may provide an indirect screening test for deficiency of elements in the body, Peter O. Onuwa2012(10). Hair is a site of excretion for essential, non-essential and potentially toxic elements. The hair element's contents and amount are incorporated with growing that proportional to the level of the element in other body tissues (10). Therefore, elements cadmium, lead and mercury are toxic heavy metals can be exposed to the hairs via a continuous daily process in the place of work, water, food and in the air (GOYER 1996) (11,12). Trace elements have a wide range of roles of the living system of the human body, with some elements of toxic effects, if inhaled at sufficiently high levels for long enough times (13). The objective of research, evaluation will assist to demonstrate the element's toxicity in scalp hairs of Sudanese workers, mainly as data recording and XRF method validation and results reliability compared to the certified international standards literatures.

2. Material and Method:

Data for this study were retrospectively collected from workshops for cars maintenance, iron welding workshop and perfume factory in Omdurman city. The samples of the scalp hairs were collected from different ages of Sudanese's workers in two sites of both genders for measurement utilizing X-ray fluorescence (XRF) spectrometer in energy dispersive mode. Generally, scalp hairs are influenced with numerous external contaminations such as exogenous contamination, fats, oils and assorted types of organic and inorganic substances (14). These hair samples were cleaned by implementing the procedure recommended by the International Atomic Energy Agency (IAEA, 1985), using water-acetone solution of water 50% and acetone 50% to remove external impurity (Chen et al., 1999), Mikasa et al. (1988) and then dry in an oven (5, 15).
Traditionally, the method of preparing the sample for XRF measurement in simple pellet press solid sample with geometrical dimensions for the X-ray absorption and transmission via homogeneous shape. The new approach of hair samples was prepared in fine mode powder using liquid nitrogen at low temperature of 77 ^{o}K. The solid hair immersed in liquid nitrogen was crushed into a fine powder with a hand grinder rod and tray of Teflon prepare specially for this work. The samples powder was prepared in pellet form using a pressing machine that compress to a manual pressure up to 15 tons to form the sample on a dry weight basis. Hair standard reference material sample from IAEA has been applied for measurement and result calibration. The standard reference sample and the hair samples collected from workers were prepared according to the procedure used for XRF measurement geometry. Samples were analyzed for elements of determination and concentration obtains relative to the data and reference certificate of the standard sample. The experiment was run using radioactive Cd^{109} source X-ray fluorescence spectrometer to utilize the elemental analysis in hairs samples. The X-ray spectra was collected by Si (Li) detector with energy resolution of 180 eV at Ekα (5.8 KeV) of manganese (Mn) linked to a Canberra 35 plus (MCA) system that connected to the computer to obtain acquiring data. A quantitative approach was employed for elements concentration in hairs using a calibration comparative approach to the certified standard sample (16).

3.1 Results:

A number of 22 hair samples of men in different types of workshops and 20 samples from both genders males and females in perfume factory were collected for the elements calcium (Ca),manganese (Mn), iron (Fe), copper (Cu), Zinc (Zn) mercury (Hg) , lead (Pb) and strontium (Sr) assessment. The results of the X-ray intensity of the element's concentration in both standard and samples were obtained after calibration and comparison with standard data using Axil package program. Fig.1 shows the average element's contents in scalp hair of the workers in the workshops in industry area. From the data of workers in the factory of the elemental concentration is displayed in the fig.2. Table (1) shows correlations of the elements in the first group men category in the workshops of ages range between 27 to 50 years old. Element correlations of 15 males (22 – 56 years) and 5 females (40- 50 years) in perfume factory are present in the table (2). Table (3) compares the factors and t-test of the both groups under investigation. Figure (2) provides the results obtained from the hair analysis of workers average elements concentration of the workshops groups. Data on the elemental concentration of hairs workers in the factory are displayed in fig (3). Average elements concentration of 42 samples from Sudanese population, compared to the literatures of elements concentration in human scalp hairs of other studies worldwide is shown in table (4).

3.2 Discussion:

The present results are significant in the two major groups of workers, which show the elements Ca, Fe and Sr in the workshop group in optimum values and Mn, Cu, Zn, Pb and Hg are higher levels compared to the International Atomic Energy Agency (IAEA) data and other countries (17). Therefore, the assessment of data indicates the level of Mn is increasing by 5.9 fold, Cu approximately 2 fold, Zn similarly with 1.2 folds; Hg higher by 23 folds and Pb are much higher at 62 fold.

The data on elements concentration of hair workers in perfume factory compared to the international data indicates the elements Ca, Cu and Zn in optimizing value, while Fe is indicate 4.7 fold, Hg of 26 fold higher and Pb shows higher values of 23 fold. However, Mn and Sr were not detected in a perfume factory hairs samples that likely to be impact of environmental contamination in the workshops. In table (1) the elements in hair demonstrate the Cu is correlated with Mn, Pb and is highly correlated with Zn and Hg, while Pb is correlated with Mn, Zn and Hg in group one. The observed correlation between elements Cu, Mn, Zn, Pb and Hg of high levels in the hairs might be explained that are related to external source of contamination. The correlations of elements in table 2 shows that Fe is correlated Pb and Hg, which are indicated high level of concentration in hair and possible to be an impact of contamination in the area.

Statistical significance was analyzed using analysis of initial eigenvalues of total variance and t-tests as appropriate to provide the difference in variation of element concentrations in each site. Table (3) present t-tests were used to analyze the relationship between the elements that possible to be related to sources of contamination, which provides the values of Mn, Pb and Hg in the range of 4.572- 5.570 and values of Cu, Zn 6.877-6.957 in the same range, respectively. Initial eigenvalues of the total variance of the workers 67.68% in the workshops group and 74.07% are total variance of the workers in perfume factory.

The results of factor analysis of variance contributions in table 3 indicate the contents of the element in hairs of high level Cu and Hg in factor 1 and Mn, Zn in Factor 2, while Pb in factor 3 relates to many types of contamination in workshops workers. From this data in table 3, we can see that factors analysis of variance contributions resulted in an optimum level value of elements Ca, Cu and Zn in factor 1 and the high level elements Fe and Hg in factor 2, while Pb in factor 3. Comparisons between the two figures (3, 4) that the projection of variable in fig.3 is revealed the Mn and Pb at the upper section of the graph and Cu, Zn and Hg in the lower section that may be due to different types of impact sources. From the result of the projection of variation in figure 4, it is apparent that the elements Fe, Hg and Pb not in the same position in the graph that indicates different levels of values of effect of contamination in hairs workers in a perfume factory.

The data for evaluation of the elements concentration in hairs in the two sites under study using statistical analysis, correlation, and t-test value factor analysis are compared to International Atomic Energy Agency hairs standard(IAEA) and several countries (table 5) that provides a possible suggestion of contamination in the area (16,18.19.20). The assessments of elements of hairs content in an industrial area in Omdurman in two different sites are indicated by high values Pb and Hg in both sites that possible to be impacted by environmental pollution. It is apparent from this result obtained that Mn, Cu, Zn in hairs of workshops worker and Fe in a perfume factory might be the indoor environmental exposure on both sites.

4. Conclusion:

The purpose of the work was measured to determine the effect on the element concentration in hairs of workers in two sites in the industrial area of Omdurman city using XRF analysis. This work was accepted to use liquid nitrogen to grind the hairs at the lower temperature basis of dry weight sample in the fine mode powder form. The results of this assessment show that industrial workshops, workers are affected by higher levels of Mn, Cu, Zn, Hg and Pb; while perfume factory influence environmental contamination that is increasing the level of Fe, Hg and Pb comparable to the trace elements human hair of IAEA-086 reference material. Therefore, the results of this analysis show that heavy metals are accumulated in the hairs workers relate to the indoor and outdoor environmental exposure. Consequently, Hg and Pb elements are higher in both situations that may be connected to external contamination exposure in the industrial site. However, the high levels of Mn, Cu and Zn in the hair of the workers in the workshops and the Fe in the perfume factory are connected to the indoor contamination in both sites respectively. The results of this research are assessed using statistical analysis, correlation, t-test value and factor analysis to obtain the relation between elements hairs and the sources of pollution that accumulated in the hair that probable to be linked to the indoor or outdoor contamination with heavy toxic metals. This assignment has explained the average elements Ca, Cu, Zn, Sr concentrations in hairs of Sudanese workers are more strongly coinciding with international data of hairs standards for several countries. The outcomes of hair analysis have detected toxic metals such as Mn, Fe, Hg and Pb of high concentrations probably associated with exposure by environmental contaminations, which indicates potential health problems of the workers.

6. Acknowledgement:

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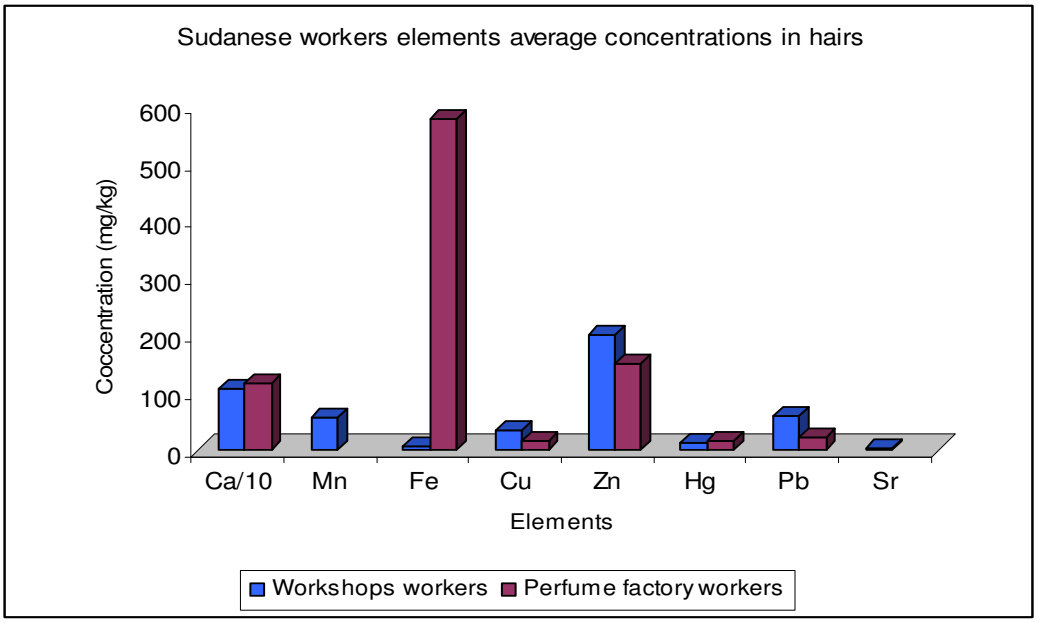

Fig(1) Average elements concentration of Sudanese workers at the two sites.

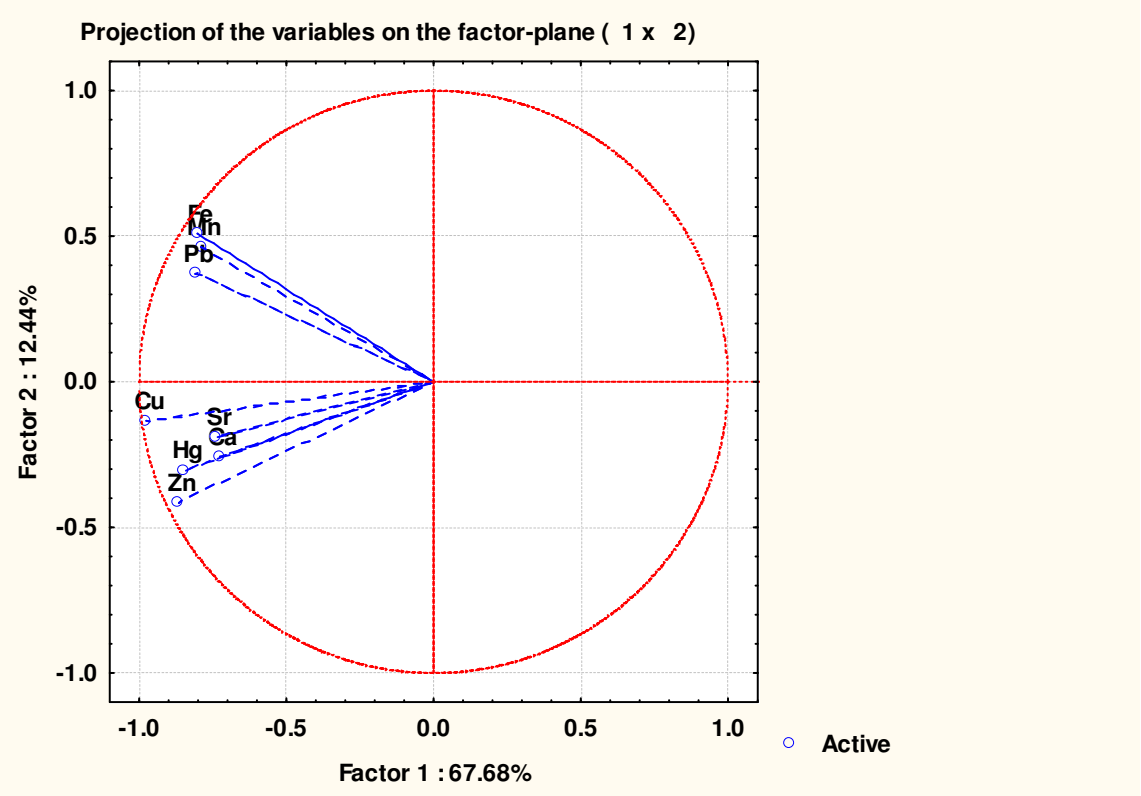

Fig.(2) Elements variation contribution in industry workshops.

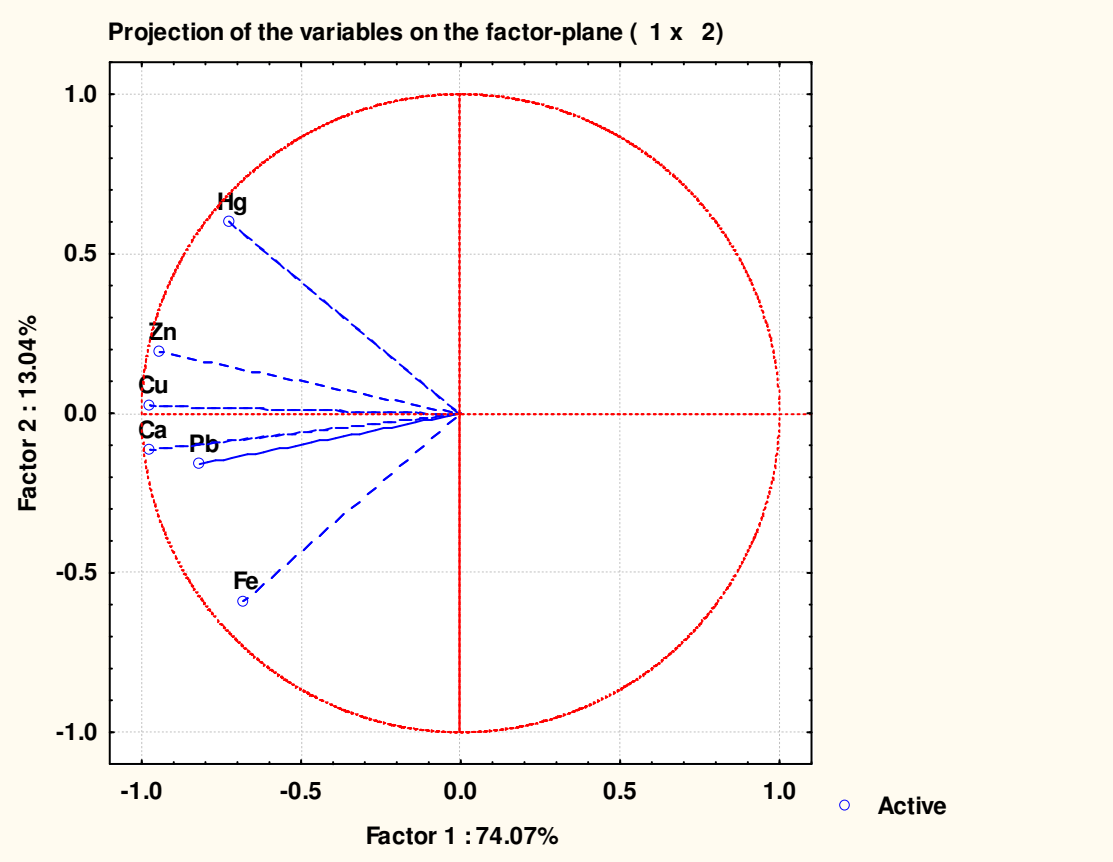

Fig.(3) Elements variation contribution in perfume factory.

Table (1) correlation of elements in workers hairs.

Elements	Ca	Mn	Fe	Cu	Zn	Hg	Pb	Sr
Ca	1.00							
Mn	0.41	1.00						
Fe	0.45	0.81	1.00					
Cu	0.71	0.70	0.70	1.00				
Zn	0.65	0.47	0.50	0.90	1.00			
Hg	0.51	0.52	0.50	0.90	0.90	1.00		
Pb	0.55	0.69	0.80	0.76	0.56	0.63	1.00	
Sr	0.53	0.61	0.53	0.71	0.65	0.54	0.32	1.00

Table (2) correlation of elements in hair workers of perfume factory groups.

Elements	Ca	Fe	Cu	Zn	Hg	Pb
Ca	1.00					
Fe	0.77	1.00				
Cu	0.93	0.56	1.00			
Zn	0.86	0.53	0.92	1.00		
Hg	0.68	0.27	0.66	0.77893	1.00	
Pb	0.75	0.42	0.88	0.73	0.34	1.00

Table (3) significant statistical result of elements variable contributions are based on correlations & t -test values.

	Workshop workers Hairs				Perfume factory hairs			
Elements	Factor 1	Factor 2	Factor 3	t-test	Factor 1	Factor 2	Factor 3	t-test
Ca	0.097	0.066	0.003	6.382	0.213	0.017	0.021	3.979
Mn	0.115	0.215	0.086	4.572	*	*	*	*
Fe	0.119	0.260	0.003	4.789	0.104	0.443	0.297	3.055
Cu	0.175	0.0180	0.005	6.877	0.214	0.001	0.051	4.296
Zn	0.138	0.174	0.015	6.957	0.200	0.047	0.001	3.956
Hg	0.132	0.092	0.078	5.120	0.119	0.461	0.157	2.685
Pb	0.121	0.138	0.227	5.570	0.149	0.032	0.474	3.762
Sr	0.100	0.036	0.583	7.246	*	*	*	*

Table (4) literatures of elements concentration in human scalp hairs in Other Worldwide Studies with comparison with average results of this work (mg/kg- dry weight basis).

Countries(Worldwide Studies)	Ca mg/kg	Mn mg/kg	Fe mg/kg	Cu mg/kg	Zn mg/kg	Hg mg/kg	Pb mg/kg	Sr mg/kg
Present study(samples 42)	1098.7	56.61	593.25	25.22	177.29	14.1	42.41	3.41
I.A.E.A (dry weight) 2000	1120	9.6	123	17.6	167	0.573		
USA, Women Shamberger, 2003				19.8	116.8	0.48	0.97	4.79
Brazil Cameiro et al. 2002 M. I. Szynkowska,2009		0.37		23.5	190	1.28	5.91	5.1
India Samanta et al, 2004		15.48		14.76	152.4	0.88	8.03	
France Goulle et al, 2005		0.41		20.3	162	0.66	0.41	
Poland Y. Takagi et al., 1986 M. I. Szynkowska,2009	1139	0.82	22.1	9.41	160	0.28	4.81	7.50
Japan Y. Takagi et al., 1986	700	2.4	15	10.7	114	2.2	3.62	
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Sweden, M. I. Szynkowska,2009 Y. MURAMATSU,1988			11.7		137	1.23	0.960	1.20
Libya, Shah *et al*., (2006);		1.73			190.3		24.95	
Egypt, [6]Rashed and Hossam, (2005);				10.6	172		5.95	