

Recent Applications of Stable Isotopes in  
Environmental Medicine in Germany



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ABSTRACT

In the last few years, a new quality in the application of stable isotopes became manifest. It is the establishment of stable isotopes as a tool in medical routine diagnosis – a novel field of nuclear medicine – and in environmental-medical epidemiological surveys. Owing to missing suitable radioactive isotopes of the bio-elements carbon and nitrogen and because of ethical problems in the human use of some radionuclides, the stable isotopes  $^{13}\text{C}$  and  $^{15}\text{N}$  play a key role in this new field.

A review is given about four new stable isotope-aided methods for *in vivo* organ function test. Three of them were developed in Leipzig, Germany, and one in Houston/Texas. We have validated the tests and then introduced into medical and environmental routine diagnostic use:

- [ $^{15}\text{N}$ ]Methacetin and [ $^{13}\text{C}$ ]methacetin liver function tests to characterize the detoxification capacity of the human liver;
- [ $^{15}\text{N}$ ]Urea and [ $^{13}\text{C}$ ]urea tests to detect the colonisation of the human stomach by the bacterium *Helicobacter pylori*. This bacterium is, as known, responsible for gastritis and ulcer of the gastrointestinal tract. The transmission ways of *H. pylori* are under investigation world-wide.

Our nine-year experience in the research and the application of the methods has shown that they are very well suited not only for clinical routine use but also outside the doctor's practice: Environmental-epidemiological studies were carried out with thousands of clinically healthy people, especially with risk groups of children in kindergartens and schools. Due to the voluntary character of participation, the methods have to be non-distressing, non-invasive and non-radioactive. These premises are fulfilled and, therefore, the methods were accepted by the people.

*Key Words: Breath tests / Carbon 13 // Medicine / Nitrogen 15 // Urine tests*

INTRODUCTION

Since the pioneer work of Rudolf Schoenheimer (1898-1941) <sup>(1)</sup>, stable isotopes have been accepted as an important tool of research in the life sciences. However, owing to the successful development of the use and measurement of radionuclides in medical diagnosis, the use of stable isotopes was limited for decades mainly to agriculture and that to the use of  $^{15}\text{N}$  in fertilization research <sup>(2)</sup>.

In the eighties, the potential of stable isotopes, especially of  $^{15}\text{N}$  and  $^{13}\text{C}$ , as a fruitful tool in medical research was recovered again <sup>(3)</sup>. Routine use of stable isotopes started in Leipzig <sup>(4,5,6)</sup> and in

Houston/Texas <sup>(7)</sup>. Finally, in the last decade we started to use <sup>15</sup>N and <sup>13</sup>C also in environmental medicine and epidemiology <sup>(8)</sup>. All studies we have performed were approved by the Ethics Committee of the University of Leipzig.

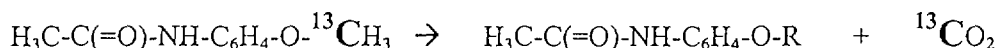
## METHODS, RESULTS AND DISCUSSION

In medical diagnosis, one of the current trends favours highly specialized *in vivo* tests investigating a specific enzyme-catalyzed elementary biochemical reaction as a characteristic indicator of an organ function. The tests are expected to be very sensitive, very specific and also non-distressing, non-invasive, non-radioactive and simple. Apparently, stable isotopes can help to fulfill the premises. Therefore, some stable isotope-aided *in vivo* tests aroused great interest for medical diagnosis.

### Liver function tests

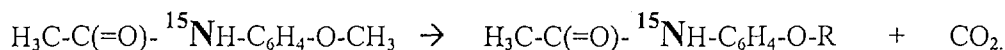
Twenty years ago, <sup>14</sup>C became usual for an *in vivo* liver function test to characterize the capacity of the cytochrome P450-aided mono-oxygenation as a first step to eliminate xenobiotics. The substrate used was [<sup>14</sup>C]aminopyrine. For research purpose, the substrate aminopyrine was additionally labelled with <sup>13</sup>C to compare the influence of either oral or intravenous application of the test substrate on the test results <sup>(9)</sup>. The investigators found large interindividual variation in the results.

In Germany, the use of <sup>14</sup>C in routine diagnosis was restricted more and more. Also for the drug aminopyrine some admonitions were published. Therefore, phenacetin was proposed to be used as an alternative diagnostic drug. However, we decided to use methacetin as a diagnostic agent and to substitute the stable isotope <sup>13</sup>C for the radioactive isotope <sup>14</sup>C <sup>(4)</sup>. Methacetin was seen to be more suitable because of its structure with one CH<sub>2</sub>-group less in the molecule than phenacetin yielding in a shorter elimination half life. That means a shorter investigation time. This was the beginning of routine organ function tests with stable isotopes in Germany in the year 1985.



Catalyzed by cytochrome-P540-activated mono-oxygenases, methacetin is demethylated and then conjugated to get hydrophile and to be eliminated via urine. The splitted methyl group is excreted as <sup>13</sup>CO<sub>2</sub> via breath ([<sup>13</sup>C]methacetin breath test). Because mono-oxygenation is the rate-limiting elimination step, the <sup>13</sup>CO<sub>2</sub> excretion rate is a measure of the capacity of the mono-oxygenases.

Also in 1985, we proposed an alternative liver function test with the same diagnostic agent but labelled with <sup>15</sup>N ([<sup>15</sup>N]methacetin urine test) <sup>(5)</sup>:



In this case, not the breath is analyzed for <sup>13</sup>C but is urine for <sup>15</sup>N. We proved that all <sup>15</sup>N excess found in urine originated from methacetin metabolites. The portion of unchanged methacetin in urine was less than 1%. The test protocol prescribes the oral administration of 3 mg [<sup>15</sup>N]methacetin / kg b.m. and the estimation of the urinary <sup>15</sup>N elimination kinetics over 9 hours: disturbed detoxification is reflected in retarded <sup>15</sup>N elimination.

In a comparison study with triply <sup>13</sup>C-, <sup>14</sup>C- and <sup>15</sup>N-labelled methacetin, we found that the urine test is more reliable than the breath test <sup>(6,10)</sup>. The portion of endogenous <sup>12</sup>CO<sub>2</sub> cannot be determined

exactly and is fluctuating in dependence on physical activity. Therefore, the  $^{13}\text{CO}_2$  in breath is diluted with fluctuating extent. Especially in the case of testing children, we used to prefer the  $^{15}\text{N}$  urine test. The urine test is also recommendable with small children who not yet can fill a breath bag. The use of breath masks would again provoke higher energy requirement and higher endogenous  $\text{CO}_2$  production.

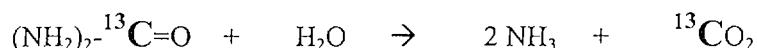
The [ $^{15}\text{N}$ ]methacetin urine test has been used in several environmental-epidemiological studies in Germany<sup>(11)</sup>. As an example, we determined the liver detoxification capacities of groups of kindergarten children to estimate the effect of air pollution on the hepatic detoxification capacities of the children. We found that the groups living near to industrial plants have slightly diminished capacities in comparison to groups in a greater distance. Moreover, the estimated mean  $^{15}\text{N}$  elimination rate was correlated to the mean  $\text{SO}_2$  emission measured there and both fluctuated seasonally<sup>(12)</sup>.  $\text{SO}_2$  served as an indicator of the general air pollution situation in the area under investigation. In another study we found that the [ $^{15}\text{N}$ ]methacetin liver function test is also suited to estimate environmental effects on the maturity of neonates<sup>(13)</sup>.

### Helicobacter pylori tests of the stomach

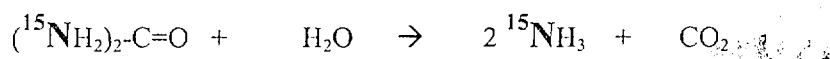
Only about ten years ago scientists and physicians agreed definitively that the bacterium *Helicobacter pylori* is the main source of gastritis, ulcers and, probably, even of cancer of the stomach. If the bacterium can be detected, it can be eradicated. Early detection means chances of early prevention and of therapy.

There are excellent diagnostic methods basing on endoscopic investigations. However, the methods are invasive and not well suited for screening purpose, for example for epidemiologic surveys. One of the invasive methods uses the special ability of this bacterium to produce the enzyme urease in order to split urea for the neutralization of the acidic environment in the stomach: A tissue sample is taken from the stomach and is mixed *in vitro* with urea and a pH value indicator. If *H. pylori* are present in the tissue sample, some of the added urea is splitted to yield ammonia, and the indicator changes its color. Disadvantages of the method are that it is based on invasive endoscopy and that the tissue sample could, by chance, be negative in spite of *H. pylori* colonization at other places of the stomach surface. Why not let run the chemical reaction *in vivo* to reach the whole surface of the stomach? This would only be possible if added urea and its splitting products can be recovered besides endogenous urea, ammonia and carbon dioxide. The solution of the problem is the use of stable isotope tracer technique.

Within only three years, two stable isotope-aided *H.-pylori* tests were proposed. The first method was developed in Houston/Texas in 1987<sup>(14)</sup>. It is based on oral intake of  $^{13}\text{C}$  labelled urea and the detection of recovered  $^{13}\text{CO}_2$  in breath ( $^{13}\text{C}$ urea breath test):



The other method was developed in Leipzig/Germany and first published internationally in 1990<sup>(15)</sup>. It is based on oral intake of  $^{15}\text{N}$ -labelled urea and the detection of recovered ammonia in urine ( $^{15}\text{N}$ urea urine test):



The  $^{13}\text{C}$  breath test is now the most commonly used clinical diagnostic test to detect *H. pylori* in the stomach. We see in the  $^{15}\text{N}$  urine test an alternative method which is suited, for example, for small children who are not yet able to fill breath bags. As known, children learn to fill balloons only in the age of about four years.

Our  $^{13}\text{C}$  *H. pylori* test protocol prescribes filling a breath bag, the oral administration of 75 mg [ $^{13}\text{C}$ ]urea with orange juice and filling a second breath bag after 30 minutes. Our  $^{15}\text{N}$  *H. pylori* test protocol prescribes the administration of 150 mg [ $^{15}\text{N}$ ]urea with orange juice and delivery of a urine sample of the second hour after test start.

Using both tests side by side with groups of identical probands, we could demonstrate advantages of the  $^{15}\text{N}$  urine test: Whereas physical activities during the test time provoke fluctuations of the  $^{13}\text{C}$  test result, they do not alter the  $^{15}\text{N}$  test results. As was demonstrated already for the methactin liver function tests, additional endogenous  $\text{CO}_2$  production may dilute the  $^{13}\text{C}$  content of the  $\text{CO}_2$  and falsify the  $^{13}\text{C}$  test result <sup>(16)</sup>. Another advantage of the  $^{15}\text{N}$  test was seen concerning the pre-test overnight fasting which is recommended for the tests. Pre-test fasting is a dilemma for surveys because not all people can be investigated in the morning. We demonstrated that the results of the  $^{15}\text{N}$  *H. pylori* test do not fluctuate considerably, independently on the time of the last meal <sup>(17)</sup>.

The UFZ in Leipzig initiated comprehensive environmental-epidemiological studies to ascertain prevalences and incidences of a certain birth cohort and to get information about transmission and infection pathways. 3350 children, that is more than 90% of the birth cohort 1990/91 of the city and the rural county of Leipzig (657.000 inhabitants) were tested with the  $^{13}\text{C}$  breath test two times with an interval of two years. Questionnaires about living conditions, health status of the family, certain habits et cetera were completed by the parents of the children. The first investigation was 1998 during the school entry medical examination. The second investigation is just going on. It is the largest *H. pylori* study of a defined age group of a defined region so far.

We found that 6% of the Leipzig school starters are already infected. Using cluster analyses and calculating odds ratios we found that there are some environmental vectors provoking the infection of pre-school children in this region: drinking water from sources outside the communal walls and frequent contacts to certain pets (hamsters). Besides these pathways familiar crowding was approved to be also a risk factor of *H. pylori* infection <sup>(18,19)</sup>.

## CONCLUSION

Our nine-year experience in the research and the application of stable isotope methods in environmental medicine has shown that they are very well suited not only for clinical routine use but also outside the doctor's practice. The methods have been accepted by the people who participate voluntarily in environmental studies. Premises such as the non-distressing, non-invasive and non-radioactive character of the methods are fulfilled. The methods are best suited for environmental-epidemiological surveys with large groups of children.

## ACKNOWLEDGMENTS

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TUA-7 TRACE METALS DISTRIBUTION IN ENVIRONMENTAL SAMPLES  
FROM LAKE NASER, EGYPT



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### ABSTRACT

Distribution of heavy metals and trace elements from anthropogenic as well as lithopogenic origin in sediment, soil and water samples from Lake Naser has been investigated. The study reveals information on the characteristic lake-typical mean, value and areal pattern of the investigated variables. Soil and sediment samples were analyzed using Instrumental Neutron Activation Analysis (INAA), whereas water samples analysis were carried out using Inductively Coupled Plasma - Mass Spectrometry (ICP-MS). The distribution Cd, Pb and Cu within water column profile - at surface, 5 m, 20 m and 40 m depth- along the lake shows proportional relation between the concentration of most of the investigated elements and the depth. The average concentrations of Cd, Pb and Cu in water from the previously selected depths along the lake were (0.13, 0.16, 0.51 ng/ml), (26, 22, 41 ng/ml) and (7.8, 19, 99 ng/ml) respectively. The most elevated elemental concentration was found in Argin bottom sediment, while the lowest concentration was found in Toshki shore sediment. The study provides a preliminary base-line data essential for the investigated area that is pre-industrialized area and represents the location of one of the greatest agricultural projects to be performed in Egypt.

### INTRODUCTION

There is considerable interest in trace element concentrations in the environment for a variety of reasons including their role in health, nutrition, and environmental pollution. One of the drawbacks of the industrial revolution is the transformation of lakes, rivers and coastal waters into sewage depots where the natural biological balance is severely upset and in some cases totally disrupted (1). For the evaluation of the present status of our environment with respect to hazardous chemical and toxic elements, base-line data from pre-industrial area would be desirable. The area of Lake Naser and the adjacent regions were chosen for this study, where it is the main water reservoir in Egypt. The area still considered as pre-industrial area, which should be one of the greatest urban regions in the future. These activities are expected to change the present status of the area. Therefore, a systematic monitoring of this area seems to be mandatory to provide representative environmental samples and their characterization.

#### *General feature of Lake Naser*

Lake Naser is one of the greatest man-made lakes in the world. It extends, at 180 m above sea level, along 500 km, of which 350 km are within the Egyptian territory. The reservoir has a total surface area of 6216 km<sup>2</sup>, a mean width of 12.5 km and the length of its shoreline is 9250 km. The volume that held by this reservoir is 157 km<sup>3</sup> (2). The lake is underlain and surrounded by a wide variety of rocks that include granitoids, gneisses, schists in its southern parts and Nubian sandstone and Tertiary and Quaternary basalt in the north. Most of the sediments that settle in the lake are silts and sands derived from the basic and the intermediate volcanic rocks that are representative of the provenance of Ethiopia and Sudan with minor contribution from the underlying and surrounding rocks. According to the hydrological regime of the lake, about 95% of the sediment carried by the annual flood rest in the southern sector of the lake.

## EXPERIMENTAL

**Sampling and Sample preparation** Samples were collected from 8 sites along the lake as shown in Fig.1. *Sediment samples* from the basin of the lake were collected randomly using a steel clamp-shell snapper.

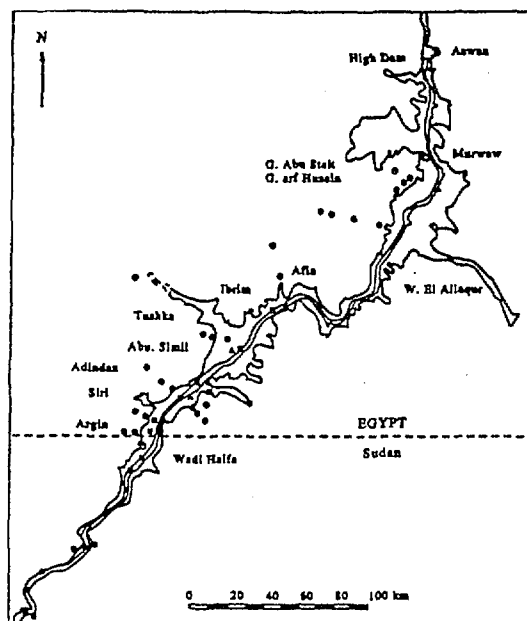


Fig. 1: Investigated area and sampling sites at Lake Naser

Samples were air dried, pulverized, homogenized and sieved to pass through 100 mesh. For Neutron Activation Analysis (NAA), two aliquots each of about 100 mg, were packed in quartz tubes, sealed and irradiated at the FRG2 reactor at Geestacht for 10 h at a thermal beam flux of  $5 \times 10^{13} \text{ n cm}^{-2} \text{ s}^{-1}$ . Following a reasonable period of decay, samples were washed in concentrated HCl, HNO<sub>3</sub> and distilled water. Samples were then counted for 5000 to 50000 s using a well shielded HPGe detector of efficiency 20 % and an energy resolution of 1.9 keV FWHM for the 1332 keV <sup>60</sup>Co transition. For calculation, synthetic standards were prepared from a mixture of liquid standards (Perkin Elmer), evaporated in quartz tubes and irradiated along with reference materials (e.g. CEC, BRC, Ref. No. 176, city incineration ash) to control the quality of the obtained results. More details are given somewhere else (3). *Water samples* Due to variation in depth of the lake at investigated locations, it was difficult to obtain water samples at fixed depths. However, water samples were obtained at the surface, middle depth and the deepest point. For each sample 10 l were collected-with original pH neutral to alkaline - acidified to pH less than 2 with supra pure HNO<sub>3</sub> (Merck) and filtered with 0.45 μm Millipore filter directly after arrival to the lab (4). The volume of filtrate was reduced to 1 l by gentle evaporation. Acidification of water before filtration may lead to leaching of some trace elements from the suspended particulate in the water. Therefore, the concentration of trace elements in water will be regarded here as the concentration in water/suspended matter. Water measurements were performed with ICP-MS, ELAN 5000 PERKIN ELMER SCIEX. The setting parameters were: plasma flow 15 l/min, neublizer cross flow 0.87 l/min, auxiliary flow 0.8 l/min, Rf power 1200 W, sample uptake 2.1 ml/min and 50 ppb <sup>103</sup>Rh was used as internal standard.

## Results and Discussion

*Sediment:* Since the concentration of trace elements in Lake Sediments offers an excellent key to the pollution history of the lake, it is essential to estimate the background level in pre-industrialized area. The minimum, maximum and average concentrations of trace elements in sediment samples taken along Lake Naser are shown in Fig. 2.

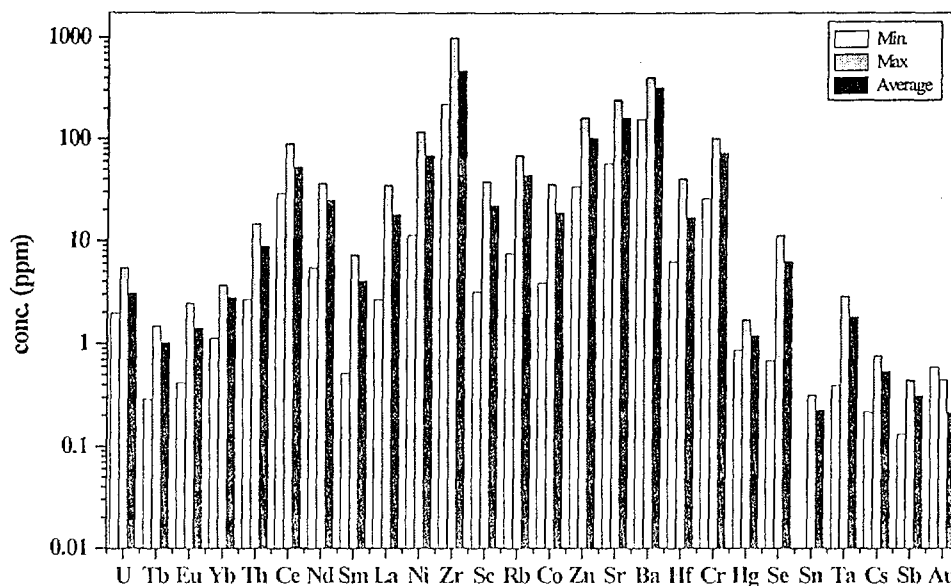


Fig. 2: Minimum, maximum and average concentration of selected trace elements in sediment samples along Lake Naser.

Trace metals have been found to be present mainly in clay / silt particles and due to the fact that their concentration can vary by a factor of 2 or 3 depending on the sediment grain size and the concentration of Al, Fe, Mn and organic carbon (5). So mechanical analysis of shore, bottom sediment and soil samples are given in Table 1. However, the natural background value of heavy metals in sediments can also be highly variable, depending on the bed rock structure of the catchment. Regarding the studied area, after entering Egypt from Sudan at Wadi Halfa, the Nile flows for more than 350 km bordered by abrupt cliffs of sandstone and granite before reaching the first cataract which commences about 7 km upstream of Aswan.

Table 1: Mechanical analysis and limestone content ( $\text{CaCO}_3$ ) content of sediment and soil samples from Lake Naser.

Site	Sample type	$\text{CaCO}_3$ (%)
Ibrim BS	Loamy	5
Tushka BS	Loamy	3.2
Tushka BS	Sandy Clay	10.2
Tushka SS	Sandy Clay	7.8
Abu Simble BS	Clay	2.2
Adindan SS	Sandy	7
Adindan S	Sandy	2.6
Argin BS	Loamy	1.4
Argin SS	Sandy	8.4
Siri BS	Clay Loam	1.8
Siri SS	Sandy	7
Siri S	Sandy	7

SS Shore sediment, SB Bottom sediment, S Soil



Table 2 shows the concentration of various elements in igneous, sedimentary rocks and dried soils (6, 7). Trace metals in recent sedimentary deposits can generally be divided into two categories in accordance with their predominant source of origin, either as lithogenic {geochemical} or anthropogenic {man-made} (8).

Table 2: Concentration ( $\mu\text{g/g}$ ) of various elements in igneous rocks, sedimentary rocks and dried soils (6,7).

Element	Igneous rock	Sedimentary rock	Soils	
			Mean	Range
Ag	0.07	0.05	0.1	0.01 - 5
As	1.8	1 - 13	6	0.1 - 40
Ca	40,000	22,000- 300,000	14,000	7000 - 500,000
Co	25	0.1 - 20	8	1 - 40
Cr	100	10 - 100	100	5 - 3000
Fe	60,000	4000 - 50,000	38,000	7000 - 550,000
Hg	0.08	0.03 - 0.4	0.03	0.01 - 0.3
Mn	1000	50 - 1000	850	100 - 4000
Mo	1.5	0.2 - 2.5	2	0.2 - 5
Ni	75	2 - 70	40	10 - 1000
Sn	2	0.5 - 6	10	2 - 200
Zn	70	15 - 100	50	10 - 300
U	3	0.45		
Se	0.05	0.05		
Ba	420	190		
Sr	440	20		
Zr	15	2		
Sb	0.2	0.04		

Lithogenic metals such as Zr, Rb and Sr, in bottom sediments, which are derived from rock material by natural weathering processes, show an average concentration of 477, 44 and 163  $\mu\text{g/g}$  (dry weight) respectively. Whereas, anthropogenic elements as Zn, Cr, Ni, Co, and Hg show average concentration of 104, 73, 68, 19, 6 and 1.2  $\mu\text{g/g}$  (dry weight) respectively. Reviewing the results obtained from the analysis of sediment samples, the highest concentrations of elements like Eu, Th, Ni, Sc, Co, Zn, Sr, Ba, Cr, Sb, Au and Fe in bottom sediments were found in Argin ( 331 km down stream from Aswan,  $31^{\circ} 05' \text{ E}$  and  $22^{\circ} 00' \text{ N}$ ), while the lowest concentrations were found in shore sediment from Tushka ( $31^{\circ} 09' \text{ E}$  and  $22^{\circ} 45' \text{ N}$ ). Table 3 shows the average geochemical background or "average shale" concentrations of selected heavy metals in pre-industrial or natural environments (9-11).

Comparing the average concentrations of elements like elements like Zn, Cr, Ni, P and Hg with the average natural background levels in pre-industrial sediments from Swedish lakes (11, 12) show that the values found in sediments from Lake Naser are considerably lower except for Hg. However, the enrichment of mobile elements such as Fe may cause elements to accumulate (8). Correlations between some selected elements in sediment samples are given in Fig. 3.

Table 3: Concentrations ( $\mu\text{g/g}$ ) of selected heavy metals in pre-industrial or natural environments.

	Fossil lake sediments <sup>a</sup>	Recent lake sediment, remote area <sup>a</sup>	European and American lakes <sup>b</sup>	Shale standard <sup>c</sup>	Lake Naser
Fe	18200	43,400	26,700	46,700	45,000
Mn	406	760	860	850	
Sr	252	151	-	300	163
Zn	105	118	111	95	104
Cr	59	62	49	90	73
Ni	51	66	50	68	69
Cu	25	45	29	45	-
Pb	16	34	35	20	-
Co	15	16	19	19	19
Hg	0.5	0.35	0.12	0.4	1.2
Cd	0.2	0.4	0.58	0.58	-

a (9), b (10) and c (7).

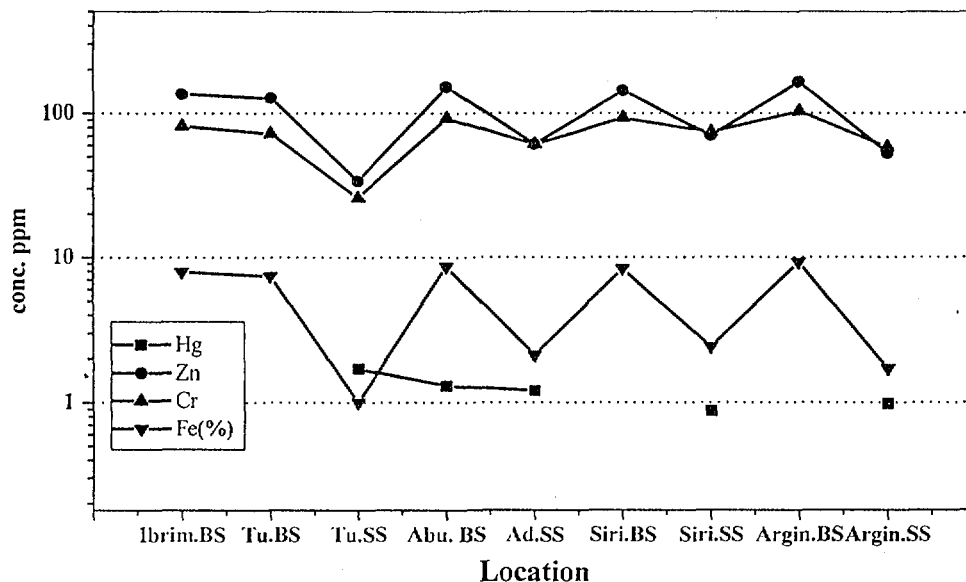


Fig. 3: Distribution of selected trace elements in sediments, BS bottom sediment, SS shore sediment

It should be mentioned that the investigated area contains several mines: iron in Aswan, Cu in Abu Swiel, Cr in Wadi El-Alagi and Au near to Argin. This may explain the elevated levels of Hg and other elements in bottom sediments from Argin. The mechanical analysis showed that Argin bottom sediment is loamy type where it is expected to be rich in minerals and trace elements. An elevated concentration of Sn in Abu-Simbl bottom sediment may be referred to the increasing touristic activities, through the Nile cruises, where the organic compounds of tin are used as antifouling agents.

*Water and suspended matter:* To be able to quantify the degree of anthropogeneous contamination and compare different metals which appears in different ranges of concentration in lake water, it is essential to establish a natural reference or background level. It is somehow problematic to establish global mean values for the individual trace elements in inland waters. This could be, in the first place, due to the variety of rock formations and the fluctuation in water transport. The minimum, maximum and average concentrations of trace elements in water/suspended matter samples taken along Lake Naser are shown in Fig. 4.

Boyle et al. (13) found Cu variations greater than a factor of three (0.56 - 0.185  $\mu\text{g/L}$ ), while Bowen 1966 (6) gave a value of 10 ( $\mu\text{g/L}$ ) as an abundance value for Cu in fresh water. Table 4 compare the abundance values given by Bowen 1966 (6) with those found in this study.

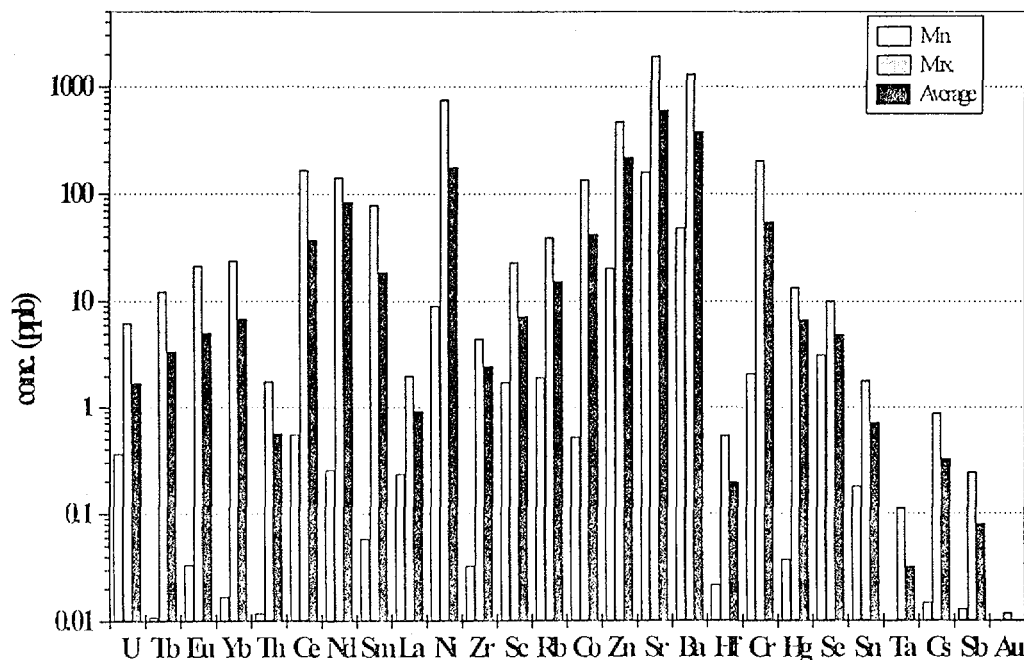


Fig. 4: Minimum, maximum and average concentration of selected trace elements in water/suspended matter along Lake Naser.

Fig. 5 shows the average concentration of Cd, Pb and Cu within the water column profile along the Lake Naser. The average concentrations and ranges for Cd, Pb and Cu were found to be (less than DL - 1.2) 0.4 ng/ml, (0.47 - 96) 44 ng/ml and (1.9 - 161) 35 ng/ml respectively. The highest concentrations were found in the deepest samples, which could be due to the increase in the suspended matter content and the sediment - water interaction. I also should be mentioned that the sampling was carried out during August - flood time- where the water load with particulate matter from the origin and track of the river increases.

Table 4: The abundance value of selected trace elements (ppm) in fresh water, Lake Naser water and dried soil.

Element	Fresh water	Lake Naser	Soil
Ag	0.13	0.16	0.1
As	4	32	6
Cd	< 0.08	0.43	0.06
Co	0.9	43	8
Cr	0.18	55	100
Cu	10	126	20
Fe	670	1677	38,000
Hg	0.08	6.8	0.03 - 0.8
Mn	12	18	850
Mo	0.35	1.3	2
Ni	10	179	40
Pb	5	44	10
Sn	0.04	0.7	10
Zn	10	221	50

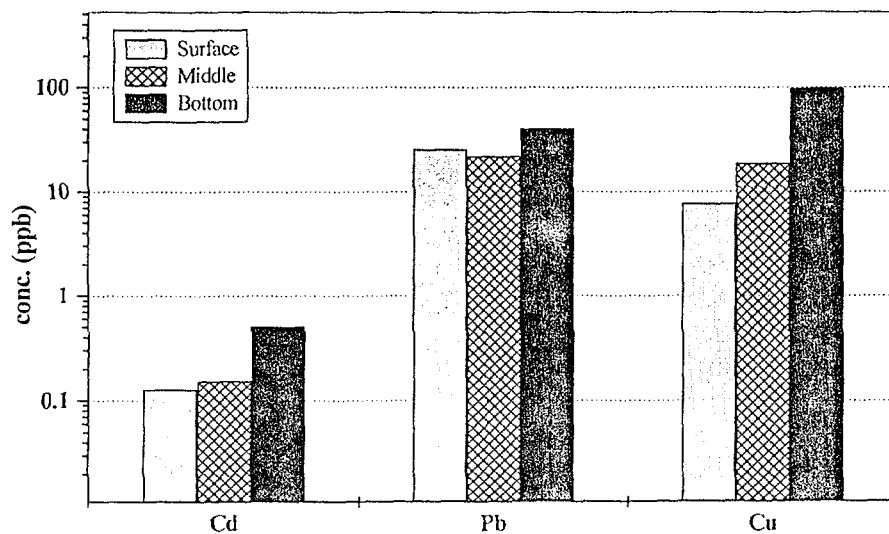


Fig. 5: Average concentration of Cd, Pb and Cu within the water column profile along the Lake Naser

Fig. 6 shows the distribution of the three elements within the water column profile along the Lake Naser. The highest concentrations of Cd, Pb and Cu were found in Adindan deepest water, Afia surface water and Siri deepest water respectively. Fig. 7 represents the horizontal distribution of the three elements along the lake as counter diagram.

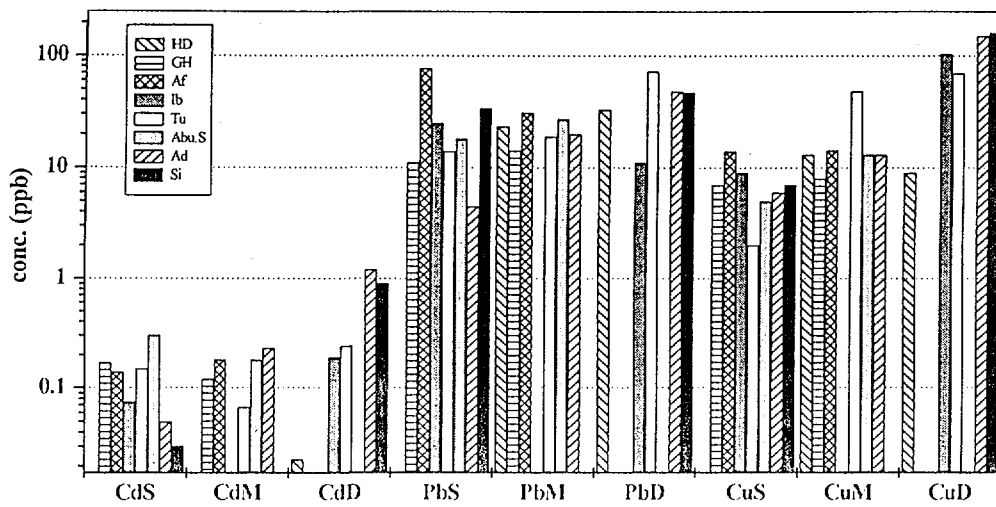


Fig. 6: Distribution of Cd, Pb and Cu within the water column profile along the Lake Naser, HD high dam, GH garf Hussien, Af afia, Ib Ibrim, Tu tushka, Abu S Abu simble, Ad adindan and Si Siri, S surface, M middle and D deep.

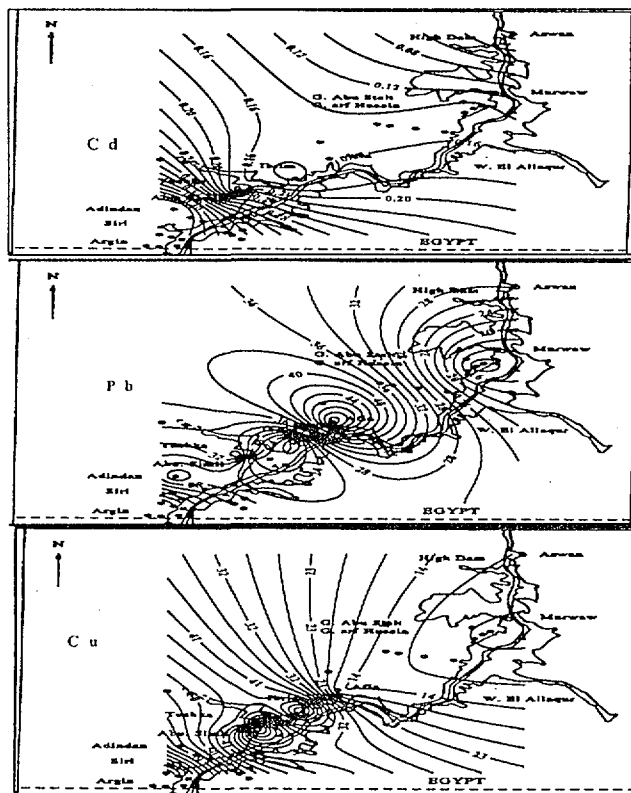


Fig. 7: Counter diagrams illustrating the horizontal distribution of Cd, Pb and Cu along Lake Naser

The study provides background information about the Lake Naser -as pre-industrial area-, which might help in the future evaluating the changes, induced through expected increase human activities. Seasonal monitoring of the lake is recommended to be able to exclude the possible effects of the flood. Detailed investigation should be done for the sites showing high levels of anthropogeneous contamination especially Hg and Sn where the risk of the methylated Hg and butylated Sn on the aquatic environment is much more pronounced when compared to elemental form.

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