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Water Quality and Level of Some Heavy Metals in Water and Sediments of Kpeshie Lagoon, La-Accra, Ghana

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Abstract: The water quality and levels of some trace metals in water and sediments of the Kpeshie Lagoon located in Accra, Ghana were studied in March, 2009. Water and sediment samples of the lagoon were analyzed for various parameters. The water quality parameters included pH, temperature, conductivity, Total Dissolved Solids (TDS), salinity, Dissolved Oxygen (DO), and nutrients. The results showed that conductivity (19370-28500 μS/cm), total dissolved solids (9750-14180 mg/L), chlorine (5725.2-8277.6 mg/L) and total alkalinity (800-2000 mg/L) were at an intermediate state between fresh and saline waters. However, the studied nutrients contents of the water were at levels within regulatory limits for natural waters. The heavy metals in the sediment especially nickel (71.8-1568 μg/g), lead (0.5-27.10 μg/g) and chromium (190-26328 μg/g) was adjudged a potential health risk to humans and the aquatic life of the lagoon's ecosystem. The contamination status of the sediment's heavy metals was confirmed on the basis of Enrichment Factor (EF) and geoaccumulation index (I_{geo}). The EF and I_{geo} results supported the fact that the sediments were highly enriched with Ni, and Cr and to a lesser extent Pb. The sediment was found to be practically unpolluted with Zn and that the source of contamination was natural.

Key words: Conductivity, Ghana, Lagoon, metals, sediments, water quality

INTRODUCTION

The coastal line of Ghana is abundantly endowed with many lagoonal resources and is of major significance for domestic, spiritual and economic activities. In recent times, the coast of Ghana is encountering serious environmental challenges. These problems are in response to rapid demographic changes and growth of industrial activities along the coast. This development has coincided with the establishment of human settlements which lack credible sanitary infrastructure to give adequate support to waste disposal (Karikari, 2007a). This has led to degradation of water quality leading to loss of the ecological integrity of the lagoons.

For instance, the heavy concentration of activities in the coast combined with pollutants flowing from streams and storm waters, far inland are the primary causes of nutrient enrichment, toxic chemical contamination, sedimentation and other problems that plague coastal waters. Nutrient pollution lead to a host of ecological and economic impacts to oxygen depletion, loss of important and coastal habitats, changes in marine biodiversity etc. Chemical pollution on its own is directly associated with heavy trace metal pollution and may adversely affect the physical, chemical and biological water characteristics.

Trace metals, which are toxic or poisonous at low concentrations, and many other organic substances, tend to accumulate in certain reservoirs (soil, sediments, etc) from which they may be released by various processes of remobilisation. They may also change form or speciation and become available to the biological food chain, thereby affecting life, including human life by causing chronic and acute disorders. Heavy metals are not usually eliminated from the ecosystems by natural processes, in contrast to most organic pollutants. Therefore, they have the potential to bioaccumulate and biomagnify. Toxicity and other related parameters of the substances such as mutagenity and teratogenity also determine their potential threat (Friberg *et al*., 1986).

The current report documents the water physico-chemical characteristics profile and heavy metal contamination status of the bottom sediments of the Kpeshie Lagoon. The Kpeshie lagoon, though relatively small in size, contributed significantly to the national fish production stock in the past. Major features in the lagoon's catchment area include two major hotels

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(La-Palm Royal Beach and La Beach), a Trade Fair Site (TFS) and the Teshie Military barracks. It is the host of drains from several residential communities including the La Township. Apart from the natural factors influencing the water quality, human activities from domestic and industrial practices have also negatively affected the lagoon. What has become of major concern is the scanty information on the water limnology and heavy metal contamination status of the lagoon. The need to assess the physico-chemical water characteristics and sediments in terms of their heavy metallic load has become imperative. This is because a highly contaminated coastal resource environment has health implications (Awofulu *et al*., 2005).

The study serves to determine the physico-chemical water characteristics and the heavy metal contamination status of the water and bottom sediments of the Kpeshie Lagoon. Several investigations have determined that heavy metals concentrate in the sediment samples (Nihtigale, 1987; Barlas, 1999). On that basis, the current study has employed enrichment factor and geoaccumulation index approach to investigate the source of heavy metals in the sediment of the Kpeshie lagoon. The findings of the study would be informative for future scientific work as the results would serve as a baseline data for the lagoon's aquatic environment.

MATERIALS AND METHODS

Sampling and analysis: Water and sediment samples were simultaneously collected from the Kpeshie Lagoon at six selected sites (Fig. 1) for 3 days i.e., 25th, 27th and 29th March, 2009. The daily duration of sampling was the hours (from 07.00 to 17.00) with a time interval of 5 h between each observation. The six sampling sites were strategically selected to account for all the main drains hosted by the lagoon. Three sampling sites namely A, B and C were located south of the Accra-Tema Road Bridge towards the sea, whilst sites D. E, and F were spotted towards the northern part of the lagoon where all the major drains seemed to confluence.

The water samples for the physico-chemical analysis were taken just below the surface at each sampling location into two polyvinyl bottles and labeled according to the sampling sites. The samples for the trace metal analysis were acidified to pH <2 using 10% analytical grade HNO_3. This was to keep the metals in dissolved state and to prevent bacteria action on them. The samples were placed in an ice-chest and later refrigerated in the laboratory prior to analysis.

Temperature, pH, and electrode potential were determined immediately after sampling using a Fisher Scientist Accumet Portable AP6 pH/mV/ºC Meter. In the laboratory, a Seven Multi-Mettler Toledo was used in the determination of the conductivity and salinity. Total Dissolved Solids (TDS) was determined gravimetrically by filtering 100 cm^3 sample through a weighted filter paper followed by evaporation and ignition (Standard Method, 1998). Total alkalinity was determined by titration using methyl orange indicator with 0.2M HCl as acid. Dissolve Oxygen (DO) was determined using Winkler's Modification Method (Standard Method, 1998). Flame Emission Photometric Method (Standard Method, 1998) was employed to evaluate the water concentration of K, Mg and Na ions.

Chloride ions concentration in the water samples was ascertained by titration using 0.27 M K_2CrO_4 indicator and 0.1 M $AgNO_3$ as titrate solution. Sulphate ion solution was converted to barium sulphate suspension under controlled conditions. The resulting turbid solution was established by spectrophotometer at maximum absorbance of 420 nm wavelength (USEPA, 1983). The concentration of the sulphate ions was then determined from a calibrated curve prepared from standard Na_2SO_4 solution. The nutrients (NO_3^-, NO_2^- and PO_4^-) contents of the water samples were determined with the aid of spectrophotometer using the Cadmium reduction method (HACH, 1992).

For the sediment samples, three replicates of the surface substratum at each sampling site were collected using a Petite Ponar Grab Sampler. The samples were emptied into polyethylene bags and stored in a separate ice-chest and transferred to the Chemistry Department of GAEC. The samples were air dried and sieved in 500 μm mesh. 1.5 g of the fine sediment were weighed into Teflon vessels and 3.0 mL of 37%HCl, 6 mL of 65% HNO_3 and 0.25 mL of 30% H_2O_2 were added and thoroughly mixed. The mixtures were then digested in ethos 900 microwave digester for 26 min. The digested samples were allowed to cool in a water bath for 30 min and the concentrations of the Cd, Co, Cr, Ni, Pb and Zn were determined using Varian AA.240FS atomic absorption spectrometer. For heavy metal analysis of the water samples, 5 mL of the water samples, blank and standards were measured into individual Teflon vessels. The sample preparation for the determination of heavy metals in the sediments was repeated for the water samples and the heavy metal concentrations were determined just was done for the sediments.

The concentrations of $SO4^{2-}$, NO_3-N and PO_4^{3-} were determined spectrophotometrically in the laboratory using potable HACH DR/890 Datalogging colorimeter. Again, for analytical quality assurance, Standard Reference Material (SRM), Oyster tissue was also prepared and analysed under the same conditions.

For the purpose of convenience all the results of the analysis were averaged out. Hence the results presented represent the mean concentrations for the duration of the study.

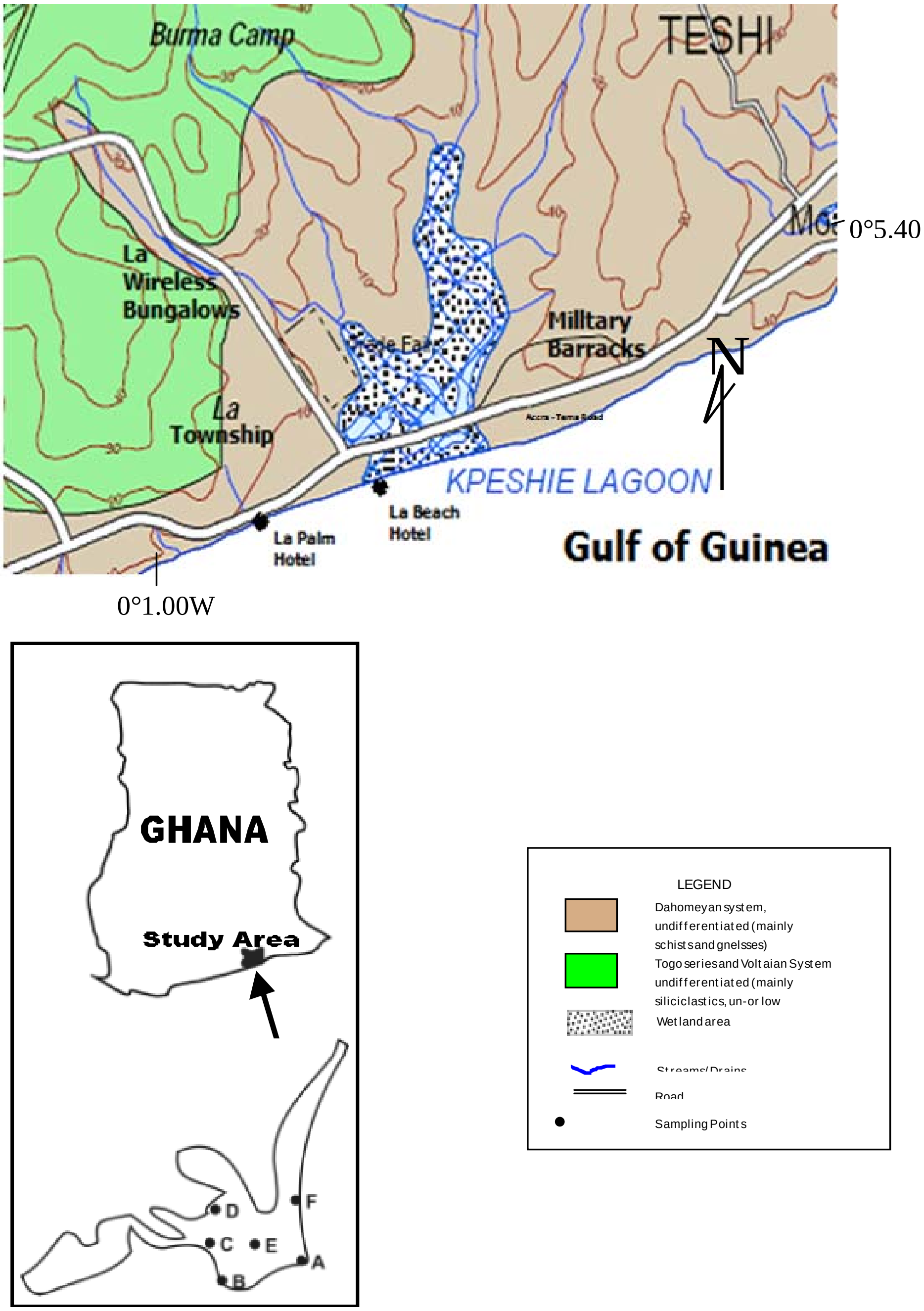

Fig. 1: Drainage map of Kpeshie Lagoon. Inset: Ghana map and sampling locations

Study area: The Kpeshie Lagoon is located between The La Trade Fair (LTF) site to the west and the Teshie Military Barracks to the east. The drainage system of the lagoon has been designed to receive all storm-water from the entire catchments. The Lagoon is an open one with only one broad opening to the sea. The drainage system consists of: domestic wastewater from the La Community; stream waters from Burma Camp. The close proximity of the LTF and two major hotels (La Palm Royal Beach and La Beach) has affected the aquatic life of the lagoon through the discharge from several sewage facilities. The lagoon is gradually being converted into a waste receptacle from both solid and sewage waste from urbanized pressure. The major environmental stress has been the problem of siltation which to a large extent caused by run-off which erode unpaved areas in the catchments, and transport the silt into the lagoon. At present, areas at and adjacent to the northern drains which used to be farmlands of the La people are being converted into residential facilities. These ultimately flush toxic chemicals into the lagoon from remnants of fertilizer and agro-chemical applications. Furthermore, an important vehicular road which enjoins two twin cities (Accra and Tema), runs across the main body of the lagoon. This route experiences intensive traffic jam, therefore occurrence of metals like Pb and Cr in the lagoon might be attributed to vehicular emissions into the atmosphere from where they are deposited unto the streets to be washed into the lagoon by rainfall.

Contaminated assessment methods of some heavy metals in the bottom sediments: The assessment of soil or sediment enrichment can be carried out in many ways. The most common ones are the index of geoaccumulation and enrichment factors (Lu *et al*., 2009). In the study, geoaccumulation index and enrichment factor have been applied to assess Cd, Co, Cr, Ni Pb and Zn contamination of bottom sediments located in the kpeshie Lagoon. The index of geoaccumulation index (I_{geo}) was originally used with bottom sediment by Muller (1969). It is computed by the following equation:

$$I_{geo} = \log_2\left[\frac{C_n}{1.5B_n}\right]$$

where,

C_n = concentration of element of interest in the tested sediment,

B_n = geochemical background value of the element in fossil argillaceous sediment (average shale).

The constant 1.5 is introduced to minimize the effect of possible variations in the background values which may be attributed to the lithologic variations in the sediments. Lu *et al*. (2009) gave the following interpretation for the geoaccumulation index: I_{geo} <0 = practically unpolluted; 0< I_{geo} <1 = unpolluted to moderated polluted; 1< I_{geo} < 2 = moderately polluted, 2< I_{geo} <3 = moderately to strongly polluted; 3< I_{geo} <4 = strongly polluted; 4< I_{geo} <5 = strongly to extremely polluted; and I_{geo} >5 = extremely polluted.

Enrichment factor (EF) has been employed for the assessment of contamination in various environmental media by several researchers (Loska *et al*., 2003; Lu *et al*., 2009; Al-Khashman, 2004; Manno *et al*., 2006). Its version adapted to assess the contamination of various environmental media is as follows:

$$EF = \frac{\left[C_x / C_{ref}\right]_{Sample}}{\left[C_x / C_{ref}\right]_{Background}}$$

where;

C_x = content of the examined element in the examined environment

C_{ref} = content of the examined element in the reference environment

B_x = content of the reference element in the examined environment

B_{ref} = content of the reference element in the reference environment

An element is regarded as a reference element if it is of low occurrence variability and is present in the element in trace amount. It is also possible to apply an element of geochemical nature whose substantial amounts occur in the environment but has no characteristic effects i.e. synergism or antagonism towards an examined element.

Five contamination categories are recognized on the basis of the enrichment factor: EF < 2 states deficiency to minimal enrichment; EF = 2-5 moderate enrichment; EF = 5-20 moderate enrichment; EF = 20-40 very high enrichment; and EF > 40 extremely high enrichment (Loska *et al*., 2003). Despite certain short comings (Reimann and De-Caritat, 2000), the enrichment factor, due to its universal formula, is relatively simple and easy tool for assessing enrichment degree and comparing the contamination of different environment.

RESULTS AND DISCUSSION

Physical and chemical characteristics: The physic-chemical parameters of water are considered as the most important principles in the identification of the nature, quality and type of the water (fresh, brackish, saline) for any aquatic ecosystem (Abdo, 2005). Table 1 shows the water quality parameters for the water samples.

Water temperature recorded during the sampling period (March, 2009) for the various sites did not differ significantly. Temperature ranged from 28.4 to 29.6ºC with an average of 28.9ºC. Temperature is a factor of great importance for aquatic ecosystem, as it affects the organisms, as well as the physical and chemical characteristics of water (Delince, 1992). Thus, the average temperature (28.4ºC) was within the range of 25 and 30ºC needed by fish to grow well (Abulude *et al*., 2006). Thus, dwindling fishery resources of the lagoon could be ascribed to other physico-chemical parameters, since the recorded temperature range is favourable for fish life.

The pH values of the lagoon waters were found to be between 7.73 and 7.93 with a mean value of 7.78. The mean value obtained in the water samples was good for the lagoon, since pH range of 6.50-9.00 is an indicator of a good fish population (Alabaster and Lloyd, 1980; Abulude and Lawal, 2002).

DO levels varied between 1.57 and 4.31 mg/L. When DO is below 2 mg/L, many aquatic organisms perish and

Table 1: Some physico-chemical properties of lagoon water analyzed

Sites	pH	Temp. ºC	DO (mg/L)	Conductivity µS/cm	TDS (mg/L)	Salinity $o/_{oo}$	Total alkalinity (mg/L)	Total hardness (mg/L)
A	7.73	29.6	3.69	28500	14180	17.14	1500	700
B	7.90	29.1	1.57	20800	10340	12.29	800	532
C	7.93	28.4	1.62	20900	10460	12.45	900	487
D	7.83	28.6	1.70	20500	10230	12.12	1200	514
E	7.80	28.7	1.60	20400	10070	11.91	1000	495
F	7.50	28.9	4.31	19370	9750	11.43	2000	481

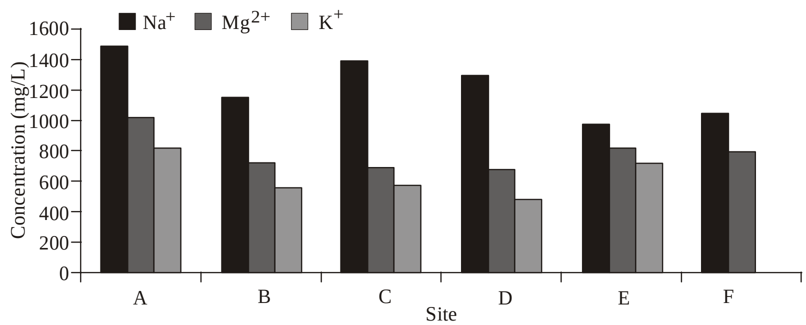

Fig. 2: Major cations in water samples

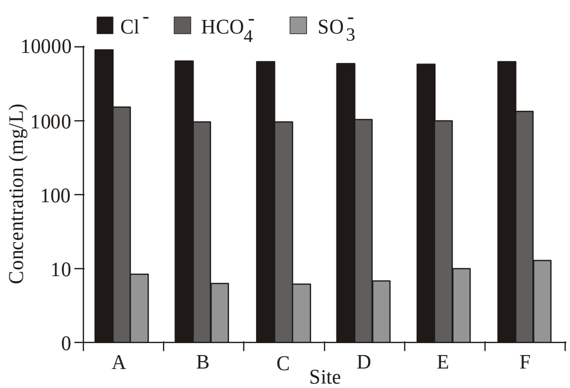

Fig. 3: Major Anions in water samples

it is as a result of biological respiration including those related to decomposition processes which reduces the concentration of DO in water bodies (Cunningham and Saigo, 1995). The mean value of 2.42 mg/L recorded for the study was not encouraging for the biological productivity of the lagoon. The low level of DO recorded can be attributed to less wave action at the period of sampling or the sewage discharges from the catchment area are gradually affecting the aquatic life of the lagoon.

The levels of total alkalinity and total hardness for good fish culture were within 20 to 300 mg/L (Boyd and Lichtkoppler, 1979). The results of the present study fell outside this range. The range of 800-1500 mg/L for total alkalinity and 481-700 mg/L for total hardness were what was recorded for the study. This situation should be a great concern to local wetland experts to trace the source of this aquatic problem.

Conductivity of the water samples ranged from 19370 to 28500 µS/cm. These values far exceed the local Environmental Protection Agency (EPA) effluent guideline limit of 1500 µS/cm (Addo, 2002), indicating relatively high salt contents. Conductivity is related to the concentration of Total Dissolved Solids (TDS). According to Chapman (1992), TDS may be obtained by multiplying the conductivity by a factor between the ranges of 0.55 to 0.75. Given these high conductivity values, it is not surprising that the TDS, which is an index of the amount of dissolved solids in water, which also determine the degree of salinity, would be high. Thus, the TDS which ranged between 9750 to 14180 mg/L according to the study is directly an average multiplication factor of 0.5 of the conductivity values measured across all the sampling points investigated. There is currently no official guideline as to what is considered safe level for conductivity (Karikari, 2007b). However, the conductivity of most freshwaters ranged from 10 to 1000 µS/cm, but many exceed 1000 µS/cm. especially in polluted waters, or those receiving large quantities of land run-off (Chapman, 1992).

The water concentrations of the major ions, Na^+, K^+, Mg^{2+}, Cl^-, SO_4^{-}, and HCO_3^- were measured. The concentration of the major cations were generally in the order of Na>Mg>K (Fig. 2). The major anion concentration followed the order $Cl^->HCO_3^->SO_4^-$ (Fig. 3). The cationic dominance pattern was similar to that of seawater but the anionic dominance pattern was a blend between those of seawater and freshwater (Karikari *et al*., 2007b). The chlorine level in the samples averaging 6307.24 mg/L was too high. Chloride level in water is a useful measure in water sample. However, high

Table 2: Concentration of heavy metals in surface water (mg/L) and sediment (μg/g)

Element sites	Cd		Co		Cr		Ni		Pb		Zn	
	Water	Sed.	Water	Sed.	Water	Sed.	Water	Sed.	Water	Sed.	Water	Sed.
A	0.003	2.80	0.028	5.95	0.010	356.0	0.037	174.0	0.005	8.12	0.048	0.001
B	0.002	0.20	0,075	5.94	0.010	1353.0	0.056	247.0	0.005	6,86	0.095	0.001
C	0.002	0.20	0.020	0.36	0.053	190.0	0.046	71.8	0.005	0.50	0.019	0.002
D	0.003	0.20	0.025	2.12	0.019	2482.0	0.079	229.0	0.058	0.50	0.019	0.001
E	0.008	0.25	o.o17	7.36	0.010	150.0	0.087	54.6	0.005	27.05	0.019	0.001
F	0.003	0.24	0.010	29.2	0.740	26328.	0.051	1568.0	0.005	13.30	0.162	0.001

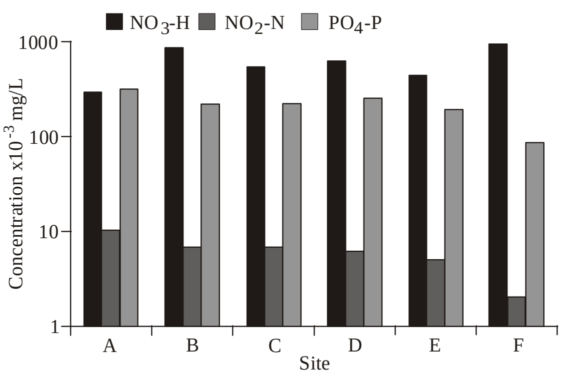

Fig. 4: Nutrients in water samples

level is known to be injurious to water organisms (Abulude *et al*., 2006).

Figure 4 shows the concentration levels of nutrients in the water samples. Nitrates and Nitrites are veritable indication of biological pollution in natural waters. The presence of nitrates and nitrites in elevated concentrations is an indication of organic pollution in the water body. Levels in excess of 5.0 mg/L NO_3-N and concentration exceeding 0.50 mg/L NO_2-N indicate pollution (McCutcheon *et al*., 1989). Nitrate levels averaged 0.64 mg/L and varied between 0.28 to 0.83 mg/L, whilst NO_2-N varied between 0.002 to 0.010 mg/L with mean concentration of 0.006 mg/L. The concentration levels for both NO_3-N and NO_2-N, according to McCutcheon *et al*. (1989) were not alarming and therefore the lagoon was free from organic waste contamination.

Phosphorous is a limiting nutrient for algal growth and therefore controls the primary productivity of a water body (karikari *et al*., 2007a). It is also an essential nutrient and another indicator of anthropogenic biological pollution. In most natural waters, Phosphorous ranges from 0.005 to 0.020 mg/L PO_4-P (Chapman, 1992). In some pristine waters, concentrations as low as 0.001 mg/L may be found (karikari *et al*., 2007a). Levels of PO_4-P varied between 0.09 and 0.31 mg/L with a mean concentration of 0.22 mg/L. The mean value for the study was comparable to what Chapman (1992) observed for natural waters. High concentrations of Phosphate are largely responsible for eutrophic conditions in a water body. Eutrophication-related problems in warm water systems begin at phosphate concentration of the order 0.34 to 0.70 mg/L phosphate (Rast and Thornton, 1996).

Heavy metals in water and sediments: Results of trace heavy metals analysis in the Kpeshie Lagoon water and sediments are presented in Table 2.

The mean concentration of Cd in water ranged from 0.002 to 0.003 mg/L while that in the sediment varied between 0.020 and 2.80 μg/g. The range obtained for the water is in good agreement with US EPA (USEPA, 1983) tolerance level of <0.01 mg/L for wastewater as well as 0.05 mg/L Maximum Contaminant Level (MCL) (USEPA, 1986) for natural waters. The level of Cd obtained in the sediment samples were within South African Target Water Quality Range (TWQR) for irrigation purposes (DWAF, 1996a). Cadmium used to be an important factor in aquatic monitoring studies, because it has been found to be toxic to fish and other aquatic organisms (Woodworth and Pascoe, 1982). Also Cd has been implicated in endocrine disrupting activities which could pose serious health problems (Awofulu *et al*., 2005). The high level of Cd in the sediment relative to levels in the water is expected since sediments have been described as a sink or reservoir for pollutants in water (Samir *et al*., 2006). Apart from natural sources like run-off from agricultural fields where phosphate fertilizer might be in use, other sources may include leachate from Ni-Cd based batteries (Hutton *et al*., 1987). Thus, the dumping of metal waste around the banks of the lagoon poses a potential danger to metal toxicity.

Concentration of Co in lagoon water ranged from 0.020 to 0.075 mg/L with average value of 0.029 mg/L, while in sediment, it varied from 0.36 to 29.2 μg/g accounting averagely as 9.572 μg/g. Levels of $2.0x10^{-4}$ mg/L is a typical concentration of Co in unpolluted surface water (DWAF, 1996b). The average value exceeds this amount. However, the water could be said to be environmentally sound as the value obtained is comparable to the USEPA (1995) tolerance limit for wastewater. According to Samir *et al*. (2006), the background level of Co in sediment is 13.0 μg/g. All the sampling sites recorded less than this value except site F where most debris from run-off accumulates.

Lead is a highly toxic metal to man since it causes brain damage, particularly to the young and induces aggressive behaviour (Ramadan, 2003). The major ways of toxicity by lead to man are caused through air respiration (inhalation), water contamination from lead piping and from polluted fish stuff. Lead toxicity is due to it mimics many aspects of metabolic behaviour of Ca and inhibit many enzyme systems (Mengel and Kirkby, 1982). Lead level in lagoon water varied between 0.005 to 0.058 mg/L and between 0.50 to 27.05 μg/g in sediment. The level of Pb obtained in the sediment were higher than those in the lagoon water, hence the sediment could be an influencing factor on the level of Pb in the lagoon water with other enhancing factor like pH since water acidity is known to influence the solubility and availability of metals. The high levels of Pb in the sediments and low level in the water at sites E and F may be due to the calm (undisturbed) nature of the area and therefore the particles are bound to settle.

Level of Zn in the lagoon water ranged from 0.019 to 0.095 mg/L. The TWQR for Zn in water for domestic supply is 3.0 mg/L (DWAF, 1996a). Hence according to the study there is no detrimental effect on the aquatic ecosystem. Extensive literature on aquatic toxicity of Zn and especially its toxicity to fish has been reviewed by Alabaster and Lloyd (1980) and by Spear (1981). Zinc is unusual in that it has low toxicity to man, but relatively high toxicity to fish (Alabaster and Lloyd, 1980). It was surprising that Zn could not be detected in significant amount in any of the sediment samples. The presence of Zn in the water and the insignificant concentration in the sediments was surprising and interesting. The situation could be attributable to the coincidence of the period of sampling to the period when the lagoon was receiving the metal and that time was needed for the metal to settle out of the water unto the lagoon floor.

Levels of Ni in the lagoon water ranged from 0.037 to 0.079 mg/L with a mean of 0.059 mg/L, whilst sediment concentration of Ni varied from 54.6 to 1568 μg/g with a mean value of 390.7 μg/g. According to Mckenzie and Symthe (1998) more attention has been focused on the toxicity of Ni in low concentration, such as the fact that Ni can cause allergic reaction and that certain Ni compounds may be carcinogenic. The typical concentration of Ni in unpolluted waters is given as 0.015 to 0.020 mg/L (Salnikow and Denkhaus, 2002). The study recorded much higher value, indicating that the lagoon water is contaminated. The high level of Ni in the sediment samples, especially at site F (1568 μg/g) is of concern. Possible contamination of the metal in some traditional fishes cannot be ruled out, since Pane *et al*. (2003) has reported Ni toxicity in rainbow trout. Although Ni is considered an essential element to plants and some animals (Ni is present in the enzyme urease), its essentiality to man is yet to be demonstrated (Teo and Chen, 2001). However, Ni related health effects such as renal, cardiovascular, reproductive and immunological effects have been reported in man.

Chromium concentration in the lagoon water varied from 0.010 to 0.074 mg/L with an average value of 0.029 mg/L. The World Health Organization (WHO, 1998) recommended limit for Cr in drinking water is 0.050 mg/L and most (70%) of the water samples were less than this limit. It must be borne in mind that the biological effect of Cr depends on its valency. In the trivalent form, Cr is an essential element, in the hexavalent form, it is carcinogenic (Chiba and Masironi, 1992). Though an essential trace nutrient and a vital component for glucose factor, Cr toxicity damages the liver, lungs and causes organ hemorrhages (WHO, 1998; O'Flaherty, 1995). Katz and Salem (1994) have reported that Cr contamination is common in soils and in both ground and surface waters in industrial areas. The concentration in the sediment, according to the study, ranged between 150.0 to a walloping level of 13,228.54 μg/g. Unfortunately, the area of reference is not heavily industrialized and so the high level of contamination in the sediment needed detailed investigation to locate the high source of contamination. However, small-scale industrial activities might be operating from some residential areas including the Wireless Bungalows. The production of batik and Tye and dye clothing in such areas could be a possible contributing factor to this high sediment contamination with the metal (ABP Consult Ltd., 1999). In this situation, an elevation of Cr concentration in the water is expected when the sediment is slightly disturbed. Benthic organism and other biological communities like the Tilapia, melanotheron/heudeloti, which have been identified as good biological makers (Ramadan, 2003) stand a high risk of possible contamination.

The results of the study have shown that heavy metals are highly concentrated in the sediment than the lagoon water. In addition, elevated levels in conductivity, TDS, Cl, total hardness and poor concentration of oxygen were observed during the study. Zabetoglou *et al*. (2002) had observed that concentration of heavy metals in sediments usually exceed those in the overlying water by 3-5 order of magnitude. The current study has shown a complete departure from this observation in that the least order of magnitude of sediment/water ratio is 100. A correlation matrix constructed (Table 3) for elements in the sediment show positive correlation between Cd and Co (0.71), Cd and Pb (0.79), Co and Pb (0.93), and Cr and Ni (0.94). This is an indication that they were likely contributed simultaneously from their source. Some of the elements were poorly correlated indicating that they might have different geochemical factors influencing their concentration in the sediment samples.

Assessment of heavy metal contamination in sediments: Sediments represent one of the ultimate sinks for heavy metal discharge into the environment (Gibbs, 1977; Luoma and Bryan, 1981). In order to protect the aquatic life community comprehensive methods for identifying and assessing the severity and soil contamination have been introduced over the past decades (Loska *et al*., 1997; Chapman, 2000; Ghrefat and Yusuf, 2006). In this study, the index of geoaccumulation (I_{geo}) and Enrichment Factor (EF) have been applied to assess

Table 3: Correlation matrix showing inter-elemental relationship in the sediment samples

	Cd	Co	Cr	Ni	Pb	Zn
Cd	1.00					
Co	0.714	1.00				
Cr	-0.029	0.20	1.00			
Ni	-0.20	0.26	0.94	1.00		
Pb	0.79	0.93	-0.22	-0.07	1.00	
Zn	0.09	0.14	0.03	0.03	0.02	1.00

Table 4: Minimum, maximum, mean concentrations (mg/kg) and EF and I_{geo} values of metals in the Kpeshie Lagoon Sediments

Element	Min.	Max.	Mean	Av. Value in Shale	I_{geo}	EF
Cd	0.20	2.80	0.65	0.3	0.53	43.57
Co	0.36	29.2	8.49	19	- 1.74	8.99
Cr	150.0	13228.54	2959.83	90	4.46	661.29
Fe	1486.6	2971.5	2347.3	47200	-	-
Ni	54.6	1568.0	390.73	65	2.01	118.89
Pb	0.50	27.05	9.42	20	- 1.64	10.03
Zn	0.001	0.002	0.0015	95	- 13.29	0.0002

heavy metals (Cd, Co, Cr, Ni, Pb and Zn) contamination in the sediment samples of the Kpeshie Lagoon.

For a better estimation of anthropogenic inputs, EF was calculated for each metal by dividing its ration to a normalized element by the same ration found in a baseline. The use of EF for identification of anomalous metal concentration requires geochemical normalization of the heavy metal data to a conservative element such as Al, Fe, Si (Ghrefat and Yusuf, 2006). Several authors have successfully used Fe or suggested the used of Fe to normalized metal contamination (Schiff and Weisberg, 1999; Loska *et al*., 2003; Chakravarty and Patgiri, 2009; Bhuiyan *et al*., 2010). The current study has also employed Fe as a conservative tracer to differentiate natural from anthropogenic source of metal contamination in the Kpeshie Lagoon bottom sediment. In order to estimate quantitatively, the anthropogenic trace metals in the sediment samples, their background concentration must be known. Previous researchers often used an average lithogenic background value (Muller, 1969), an average concentration in shale (Ghrefat and Yusuf, 2006; Bhuiyan *et al*., 2010) or an average value of measured concentration before industrialization (Hakanson, 1980) to assess trace metal concentration in sediment. In this study the background value was taken from average shale (Turekian and Wedepohl, 2010).

The EF values for metals under the current study in the lagoon sediment along with their background value are shown in Table 4. EF close to one points to a crustal origin while those with a factor more than 10 are considered to have a non-crustal source (Ong and Kamaruzzman, 2009). The results of the study show that Cr, Ni and Cd are extremely enriched in the sediment with these elements greater than 40. This strongly suggests that the sources of these metals contamination are the result of anthropogenic input. Previous agricultural activities upstream and dumping of solid waste as well as effluents from the adjacent hotels might account for this. Zinc is the only deficient metal and therefore contamination may be traced to a natural source.

In order to compare the status of heavy metals concentration with background values, index of accumulation (I_{geo}) was computed for each metal under the current study. I_{geo} describes the relationship between the measured element in the fraction of the sediment and the geochemical value in fossil argillaceous sediment (average shale). Table 4 present the I_{geo} values of the metals in the sediment samples where Co, Pb and Zn have calculated values less than zero and therefore can be classified as practically unpolluted. Truly the measured values of these metals are less than their background in average shale. Cadmium exhibited I_{geo} value less than one to suggest unpolluted to moderate pollution. The I_{geo} values in Table 4 confirms the strongly to extremely pollution of Ni and Cr indicating that they far exceeds the background levels in the measured sediments. Based on the EF and I_{geo} values, it can be suggested that the source of Zn in the sediment is solely natural which came from the earth's surface.

The presence of toxic elements such as Cd, Cr, Ni and Pb in the lagoon water could be detrimental to human beings and aquatic life. Although, our results showed that the toxicity status of the metals studied could not very serious in the lagoon waters, it should be noted that there is still a massive danger of contamination should the benthic materials got disturbed. We recommend that combating all kinds of pollution in the lagoon become eminent. This can be achieved through prevention, controlling or by applying treatment on drainage load which or discharged into the lagoon. It is about time that small-scale industrial developments in residential areas be identified, monitored and factored into a well-designed action plan executable through intensive rehabilitation programmes, not only for the Kpeshie, but for all lagoons of the non-Ramsar category. The action plan should be competent enough to free the lagoon from the siltation problems facing it currently because the lagoon is of great importance to the surrounding communities. Besides, large human populations depend mostly on the food fish from it.

CONCLUSION

This study has established that some physico-chemical parameters like conductivity, TDS, Cl, total alkalinity and total hardness in the Kpeshie Lagoon were above specified guideline limits for natural waters. In addition, the presence of toxic metals in sediment and water in the aquatic environment of the lagoon were also established. The identification and quantification of the heavy metal sources are important environmental issues. Therefore, the employment of EF and I_{geo} as tools for evaluation of the heavy metals contamination in the sediment in the study has proven useful. The study identifies Zn to posing a low environment risk, whereas Cr and Ni pose a high risk. The information gathered suggest that the pollution of the lagoon is on a high side. Therefore, a follow up investigation is needed to determine the extent to which some of the biotic species including the tilapia melanotheron/heudeloti have been affected by the present status of the lagoon.

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REFERENCES

Abdo, M.H., 2005. Physico-chemical characteristics of Abu Za'baal pond. Egypt. Egypt. J. Aquatic Res., 31(2): 1-15.

ABP Consult Ltd., 1999. Environmental Impact Assessment for Export Processing Zone, Tema. Consulting Engineers, 1 Mile Close off Amilcar Cabral Road, Airport, Accra.

Abulude, F.O. and L. Lawal, 2002. Analysis of selected nutrients of wine obtained from felled palm tree. Pak. J. Sci. Int. Res., 45: 386-387.

Abulude, F.O., O.O. Fapohunda and Awanlenhen, 2006. Determination of some heavy metals in *Procambaris clakii*, *Paleanon* sp., *Macrobrahium vollenhovenii* and *Penaeus notalis* from the coastal water of Ondo State, Nigeria. J. Anim. Vet. Adv., 5(1): 38-41.

Addo, M.A., 2002. An assessment of aspects of environmental impacts of the proposed 'West African gas pipeline project in Ghana'. Thesis, Department of Environmental Science Programme, University of Ghana, Legon-Ghana, pp: 115-116.

Alabaster, J.S. and R. Lloyd, 1980. Water Quality Criteria for Fish. 2nd Edn., Butterworth, London.

Al-Khashman, O.A., 2004. Heavy metal distribution in dust, street dust and soils from the work place in Karak Industrial, Jordan. Atmos. Environ., 38: 6803-6912.

Awofulu, O.R., Z. Mbolekwa, V. Mtshemia and O.S. Fatoki, 2005. Levels of trace metals and sediment from Tyume River and its effects on an irrigated farmland. Water SA., 31(1): 87-94.

Barlas, N.E., 1999. Histopathological examination of gill, liver and kidney tissues of (Cyprinus Carpio L. 1758) fish in the Upper Sakarya River Basin'. Turk. J. Vet. Anim. Sci., 23: 277-264.

Bhuiyan, M.A.H., L. Parvez, M.A. Islam, S.B. Dampare and S. Suzuki, 2010. Heavy metal pollution of coal mine-affected agricultural soils in the Northern Part of Bangladesh. J. Hazard. Mater., 173: 384-392.

Boyd, C.E. and F. Lichtkoppler, 1979. Water quality management in pond fish culture. Research and Development Series No. 22, Auburn University, Auburn.

Chakravarty, M. and A.Dd. Patgiri, 2009. Metal pollution assessment in sediments of the Dikrong River, N. E. India. J. Hum. Ecol., 27(1): 63-67.

Chapman, D., 1992. Water Quality Assessment: A Guide of the use of Biota, Sediments and Water in Environmental Monitoring. University Press, Cambridge, pp: 585.

Chapman, P.M., 2000. The sediment quality triad: Then, now and tomorrow. Int. J. Environ. Pollut., 13: 351-360.

Chiba, M. and R. Masironi, 1992. Toxic and trace elements in tobacco and tobacco smoke. Bull. WHO, 70(2): 269-275.

Cunningham, W.P. and B.W. Saigo, 1995. Environmental Science, A Global Concern. 3rd Edn., WNC Brown Publishers.

Delince, G., 1992. The Ecology of the Fish Ecosystem with Special reference to Africa. In: Addo, M.A., 2002. Probable impact of the West African gas pipeline project at Tema New-Town, Ghana'. Thesis presented to the Environmental Science Programme, University of Ghana, Legon.

Department of Water Affairs and Forestry (DWAF), 1996a. Water Quality Guidelines for Domestic Use. Vol. 1, 2nd Edn., DWAF, Pretoria.

Department of Water Affairs and Forestry (DWAF), 1996b. South Africa water Quality Guidelines, Field Guide. Vol. 8, 1st Edn., DWAF, Pretoria.

Friberg, L., C.G. Elinder, T. Kjelltroem and G.F. Nordberg, 1986. Cadmium and Health: A Toxicological and Epidemiological Appraisal. Vol. 2, Effect and Response. In: Fatoki, O.S., N. Lujiza and A.O. Ounfowokan, 2002. Trace Metal Pollution in Umtata River. J. Water Soil Air, 28(2): 183-189.

Ghrefat, H. and N. Yusuf, 2006. Assesssing Mn, Fe, Cu, Zn and Cu, Pollution in Bottom Sediment of Wadi Al-Arab Dam. J. Chemspeheric, 6: 043.

Gibbs, R.J., 1977. Transport phases of transition metals in the Amazon River. Geol. Soc. Am. Bull., 88: 829-843.

HACH, 1992. Water Analysis Handbook. Hach Company, Loveland, Colorado, USA, pp: 401-402, 427-428, 537-538.

Hakanson, L., 1980. An Ecological risk index for aquatic pollution control: A sedimentological approach. Water Res., 14: 975-1001.

Hutton, M., R.L. Chaney, C.R. Krishna, M. Murti, A. Olade and A.L. Page, 1987. Group Report. In: Hutchson, T.C. and K.M. Meena, (Eds.), Lead, Mercury, Cadmium and Arsenic in the Environment. John Wiley, New York, pp: 35-41.

Karikari, A.Y., J.K. Bernasco and E.K.A. Bosque-Hamilton, 2007a. An Assessment of Water Quality of Augaw River in South-Eastern Coastal Plain of Ghana. Unpublished paper, CSIR-Water Research Institute, P.O. Box M32, Accra-Ghana.

Karikari, A.Y., K.A. Asante and C.A. Biney, 2007b. Water Quality Characteristics at the Estuary of Korle Lagoon in Ghana. Unpublished paper. CSIR-Water Research Institute, P.O. Box M32, Accra-Ghana.

Katz, S.A. and H. Salem, 1994. The Biological and Environmental Chemistry of Chromium. VCH: New York. In: Adaikpoh, E.O., G.E. Nwajei and J.E. Ogala, (Eds.), 2005. Heavy Metal Concentration in Coal and Sediment from River Ekulu, Coal City of Nigeria. J. Appl. Sci. Environ. Manage., 9(3): 5-9.

Loska, K., J.J. Cebula, J. Pelczar, D. Wiechhla and J. Kwapulinski, 1997. Use of enrichment and contamination factors together with geoaccumulation indexes to evaluate the content of Cd, Cu, and ni in the rybnik water reservoir in Poland. Water Air Soil Pollut., 3: 347-365.

Loska, K., D. Wiechula, B. Barska, E. Cebula and A. Chojnecka, 2003. Assessment of arsenic enrichment of cultivated soils in Southern Poland. Polish J. Environ. Stud., 12(2): 187-192.

Luoma, S.N. and G.W. Bryan, 1981. A statistical assessment of the form of trace metals in oxidized estuarine sediments employing chemical extractants. Sci. Total Environ., 17: 165-196.

Lu, X., L. Wang, K. Lei, J. Huang and Y. Zhai, 2009. Contamination assessment of copper, lead, zinc, manganese and nickel in street dust of Baoji, NW Chine. J. Hazard. Mater., 161: 1058-1062.

Manno, E., D. Varrica and G. Dongarra, 2006. Metal distribution in road dust samples collected in an Urban area close to a petrochemical plant at gela, sicily. Atmos. Environ., 40: 5929-5941.

McCutcheon, S.C., J.L. Martin and T.O. Barnwell, 1989. Water Quality. In: Maidment, D.R., (Ed.), 1993. Handbook of Hydrology. McGraw-Hill, INC, NY, Singapore, Sydney, 11: 48-11.50.

Mckenzie, H.A. and L.E. Symthe, 1998. Quantitative Trace Analysis of Biological Material. Elsevier, Amsterdam.

Mengel, K. and E.A. Kirkby, 1982. Principles of Plant Nutrition. 3rd Edn., Int. Pot. Inst. P.O. Box CH-3048, Worblaufen-Bern., Switzerland, pp: 655.

Muller, G., 1969. Index of geoaccumulation in sediment of the Rhine River. Geol. J., 2: 109-192.

Nihtigale, H.I., 1987. Accumulation of As, Ni, Cu and Pb in retention and recharge basin soil from urban run-off. Water Res. Bull., 23: 663-672.

O'Flaherty, E.J., 1995. Chromium Toxicokinetics. In: Asonye, C.C., N.P. Okolie, E.E. Okenwa and U.S. Iwanyanwu, 2007. Some Physico-chemical characteristics and heavy metal profile of Nigerian Rivers, streams and water ways. Afr. J. Biotechnol., 6(5): 617-624.

Ong, M.C. and B.Y. Kamaruzzman, 2009. An assessment of metals (Pb and Cu) contamination in bottom sediment fron South China Sea Coastal Waters, Malaysia. Am. J. Appl. Sci., 6(7): 1418-1423.

Pane, E.F., J.G. Richard and C.M. Wood, 2003. Acute water borne nickel toxicity in the rainbow trout (*Oncorhychus mykiss*) occurs by respiratory rather than ionoregulatory mechanism. Aquatic Toxicol., 63(1): 65-82.

Ramadan, A.A., 2003. Heavy metal pollution and biomonitoring plants in Lake Manzala, Egypt. Pak. J. Biol. Sci., 6(13): 1108-1117.

Rast, W. and J. Thornton, 1996. Trend in eutrophication research and control. Hydrol. Proc., 10: 295.

Reimann, C. and P. De-Caritat, 2000. Intrinsic flaws of element Enrichment Factors (EFs) in environmental geochemistry. Environ. Sci. Technol., 34: 5084.

Salnikow, K. and E. Denkhaus, 2002. Nickel essentiality, Toxicity and carcinogenicity. Crit. Rev. Oncol. Haematol., 42(1): 35-56.

Samir, M.N., A.O. Mohamed and M.K. Shaif, 2006. Environmental assessment of heavy metal pollution in bottom sediments of Aden Port, Yemen. Int. J. Ocean Oceanogr., 1(1): 99-109.

Schiff, K.C. and S.B. Weisberg, 1999. Iron as a reference element for determining trace metal enrichment in Southern California Coast Shelf Sediment. Mar. Environ. Res., 48: 161-176.

Spear, P.A., 1981. Zinc in the Aquatic Environment: Chemistry, and Toxicology. National Research Council of Canada. Associate Committee on Scientific Criteria for Environmental Quality. Report NRCC No. 17589. Ottawa. In: Fatoki, O.S., N. Lujiza and A.O. Ounfowokan, 2002. Trace metal pollution in Umtata River. J. Water Soil Air, 28(2): 183-189.

Standard Method, 1988. Standard Method for Water and Wastewater. 20th Edn., American Public Health Association. Washington D.C.

Teo, K.C. and J. Chen, 2001. Determination of cobalt and nickel in water using atomic absorption spectrometry after cloud point extraction. Anal. Chim Acta., 434(3): 325-330.

Turekian, and K.L. Wedepohl, 2010. Distribution of the elements in some major units of the earth's crust. Goel. Soc. Am. Bull., 72: 172-192.

United States Environmental Protection Agency (USEPA), 1995. Standard Methods for the Examination of Water and Wastewater, 19th Edn., APHA.

United States Environmental Protection Agency (USEPA), 1986. Quality Criteria for Water. Office of Water Regulation and Standards, Washington DC, USEPA-40015-86-001, 256.

United States Environmental Protection Agency (USEPA), 1983. Method of Chemical analysis of Water and Wastewater, EPA/600/4-79/020, March, 374.3.1-375.4.3.

Woodworth, J.C. and V. Pascoe, 1982. Cadmium toxicity of rainbow trout, salmon gairdneri richardson. A study of eggs and alevine. J. Fish Biol., 21: 47-57.

World Health Organization (WHO), 1998. Guidelines for Drinking Water, WHO Criteria and Other Supporting Information, WHO, Geneva.

Zabetoglou, K., D. Voutsa and C. Samara, 2002. Toxicity and heavy metal contamination of surfucial sediment from bay of thessaloniki (North Western Aegean Sea). Greece Chemosphere, 49: 17-26.