Heavy Metal Detection in Soil and Related Health Aspect at Aila Inundated Sundarban Region, Bangladesh

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Abstract: The work was conducted on some soil samples collected from Aila flood water inundated 3 unions of Shamnagar upazila, Satkhira, Bangladesh where Aila flood water inundated and were few months. The soil samples were analyzed to determine elemental contamination by PIXE analysis. The elemental concentration of Ni, Cu, Zn, Hg and Pb in the investigated soil samples is higher than the values obtained from reference soil samples provided from IAEA. The elevated amount of Ni, Cu, Zn, Hg and Pb may affect the geological properties of the soil and thus play some important role of anatomical characters and heavy metal accumulation potentiality during the development and growth of plants in the area which ultimate affect on population health. The present work also will be useful in providing environmental monitoring base data of those particular areas.

Key words: Aila, PIXE, Heavy metal, Environment, Health, Base data

1. INTRODUCTION

Environment issues related to human health have grown as a subject of great concern in recent times. The environment is rapidly changing its nature throughout the world. Tsunami, cyclones, hurricane such as Sidor, Aila, etc are striking especially the coastal areas time to time in Bangladesh. Most public attention related to these storms is focused on the human condition associated with the flooding. Researchers are interested in the environmental impacts as well as health and agriculture resulting from the natural disaster. Within the scientific community and regulatory entities, concern was raised regarding the distribution of contaminants as a result of the natural disaster (Aila) in the environmental ingredients like soil, water, air, plants and vegetables, etc and the subsequent increased potential exposure and potential health hazards to residents of the area of concern. Preliminary investigations quantified a suite of chemical and biological contaminants to determine potential risk to residents in New Orleans after Hurricane Katrina. Extracted data confirmed that As and Pb concentrations in soil and sediment exceeded threshold criteria [1], [2]. In Bangladesh one such incident (Aila) occurred during 2009, which affected our soil and sediment. That got to be tested. In the present day increasing industrialization and introduction of newer practices in agricultural developments the concern of global environmental degradation with ever need for ensuring material's quality in relation to economic developments and human health, have become important issues.

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From 90 naturally occurring elements, 26 are known to be essential for life [3]. The most common heavy metal contaminants are Cd, Cr, As, Cu, Ni, Zn, Hg and Pb. Metals are natural components in soil [4]. Some of these metals are micronutrients necessary for plant growth, such as Zn, Cu, Mn, Ni, and Co, while others have unknown biological function, such as Cd, Pb, and Hg [5]. Heavy metal pollution has harmful effect on biological systems and does not undergo biodegradation. Toxic heavy metals such as Pb, Co, Cd can be differentiated from other pollutants, since they cannot be biodegraded but can be accumulated in living organisms, thus causing various diseases and disorders even in relatively lower concentrations [6]. Heavy metals, with soil residence times of thousands of years, pose numerous health hazards to higher organisms [7].
One of the essential trace elements is Copper and it forms part of a number of enzymes needed for the formation of bone, hemoglobin and red blood cells. But its high presence in the environment can cause of serious health hazards. With the increase in amount of copper in the environment it is essential to monitor the extent of contamination [10] caused by it. Food is the major source of exposure of Ni to biological cell. One may also be exposed to Ni by breathing air, drinking water, or smoking tobacco containing Ni. The most common harmful health effect of Ni in humans is an allergic reaction. Approximately 10-20% of the population is sensitive to Ni. Uptake of high quantities of Ni can cause cancer, respiratory failure, birth defects, allergies, and heart failure [8]. One of the heavy metal Mercury which is toxic even at low concentrations to a wide range of organisms including humans. The organic form of Hg can be particularly toxic, and the methyl-and ethyl-forms have been the cause of several major epidemics of poisoning in humans resulting from the ingestion of contaminated food, e.g. fish. The poisoning became well-known as Minamata disease [9]. Lead is generally known as toxic since the 2nd century BC in Greece. It is a widespread contaminant in soils. Inhaling Pb dust from the air is a common way Pb gets into the body. Pb can also be ingested through the foods we eat and from hand to mouth activity from Pb in dust and soil. Drinking water may contain Pb if it flows through Pb pipes or fittings. Pb poisoning is one of the most prevalent public health problems in many parts of the world.

It was the first metal to be linked with failures in reproduction [9].
In trace element analysis, selection of a particular methodology depends on the nature of the problem. A technique used in the determination of the elemental make-up of a material or sample is PIXE. PIXE is a powerful yet non-destructive elemental analysis technique now used routinely by geologists, archaeologists, art conservators and others to help answer questions of provenance, dating and authenticity.

2. MATERIALS AND METHODS

Sample preparation:
Total 21 soil samples were collected from three unions name as Gabura, Patakhali and Padmapukur of Shamnagar upazila, Satkhira district. 16 samples of them were from cultivable soil (5-20 cm in depth) and 5 samples were deep soil (130-150 cm in depth). After collection of the soil samples, nearly 50 grams of each sample was taken into a porcelain cup and put into a temperature controlled electric oven for a week at 80^0C temperature. After drying this way, the samples were taken into hand grandeur for crushing and thus changing the samples into powder form. Nearly 20 gm of each sample was taken for making a pellet. A manual hydraulic press applying pressure of 250 kg/cm^2 was used to prepare a pellet of 7 mm diameter and about 1 mm in thickness. The reference soil samples provided by IAEA, which is called Soil-7 also used to make pellets of similar dimension for onward irradiation by 3MV Van de Graaff (VDG) accelerator Atomic Energy Center Dhaka (AECD).

Samples Irradiation:
For irradiation of samples at a time 13 soil samples, a quartz and 2 standard samples (Total 16 slides of samples) were set with the wheeler which was then set in the proton beam scattering chamber. Then the chamber was made vacuum by using vacuum pump up to the level of ~10^{-5} Pascal. Achieving the required vacuum, the samples were irradiated by the proton beam of energy 2.2 – 2.5 MeV with a beam current of 10 to 15 nA. The X-ray spectrum were analyzed with the help of well established PIXE technique and by the use of the Si(Li) detector. The obtained data from PIXE technique in 3MV Van de Graaff accelerator at Atomic Energy Center, Dhaka (AECD) were analyzed by MAESTRO-32 PIXE program and the Guelph GUPIX PIXE program with the interface of DAN32. To identify the element, one has to measure the energy of the peak centre accurately and then compare the energy with the PIXE yield database.

Quality control test:
A quality control test was conducted in the work for the measurement of material concentration using 3MV Van de Graaff accelerator. Four standard reference soil samples (of Soil-7) and a thick standard aluminum (Al) sample provided by IAEA were irradiated for this purpose. The obtained results of measurements of elemental concentration of Soil-7 were compared with the IAEA reference values. Ratios between the reference values and obtained values for the selective materials are shown in Fig. 1. The obtained spectrum of standard thick aluminum (Al) and the concentration was measured by using GUPIX/DAN-32 is shown in Figure 2.

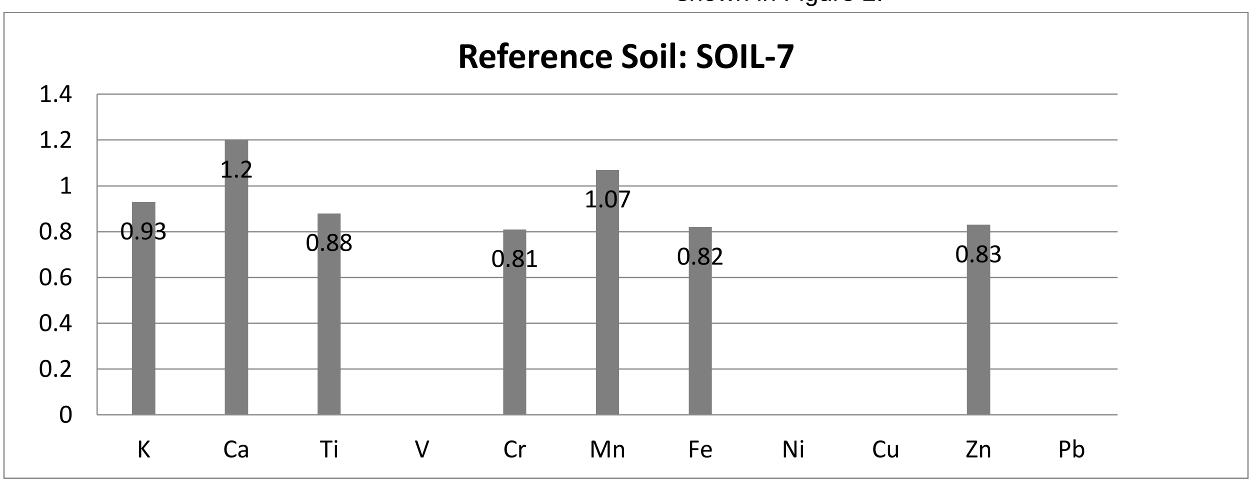

***Figure 1**. Ratio between the reference values and obtained values of the selective material of reference soil: Soil-7*

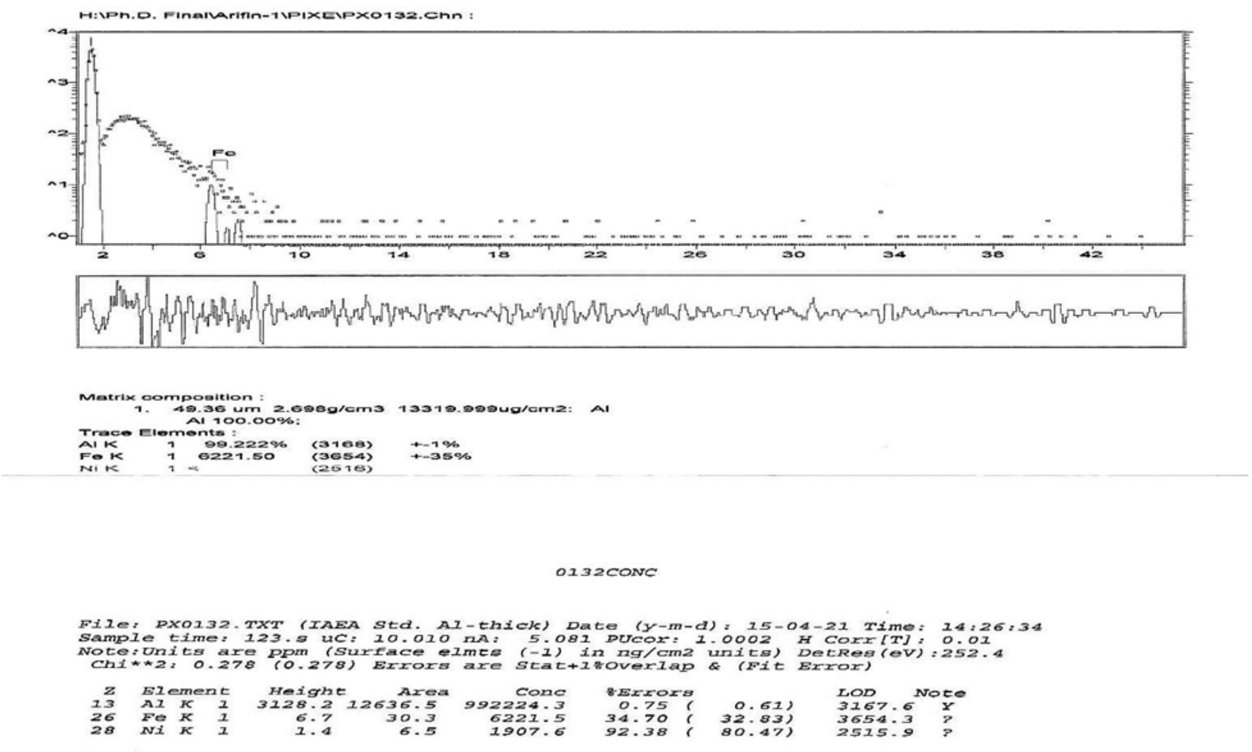

Figure 2: *Snap shoot of IAEA standard thick (Al) energy spectrum and concentration (GUPIX/DAN-32)*

For Soil-7, it is observed that the most of the elements ratios between the obtained results and IAEA provided results are very close to one and the concentration of the standard thick aluminum (Al) is also in the same as IAEA provided concentration (99.99%). Thus, the good consistency between the measured and IAEA values confirms the reliability of our measurements of soil samples using the 3MV VDG accelerator.

3. RESULTS AND DISCUSSIONS

In Shamnagar Upazila, Satkhira in total 21 soil samples were irradiated using the VDG facility: 16 of them are surface soil samples and 5 deep soil samples. Table 5.10 and 5.11 shows the elemental concentrations in soil samples for surface soil samples and deep soil samples respectively. It must noted that the 5 deep soil samples (PX-123, PX-130, PX-116, PX-117 & PX-131) were collected from the same location where from the surface soil samples (PX-113, PX-121, PX-125, PX-129 & PX-134) were collected. Elemental concentrations in soil samples from the detection material Ni, Cu, Zn, Hg and Pb are analyzed here.

Table1: Elemental concentrations in soil samples of Shamnagar Upazila, Satkhira measured using the VDG Facility at AECD

Sample ID	Material Concentration in µg/g									
	K	Ca	Ti	Cr	Mn	Fe	Ni	Cu	Zn	Hg	Pb
PX-113	18429	26132	5318	294	1073	68221	-	-	218	18	924
PX-114	25317	31673	6017	-	2819	45649	-	478	-	-	619
PX-115	18514	23652	5483	-	3019	61664	-	-	-	-	-
PX-118	22202	39505	6975	885	3584	51912	230	0	154	11	1257
PX-119	20337	51011	6149	1053	3712	55715	-	145	177	19	599
PX-120	19833	56351	6202	1499	5561	54636	237	-	223	18	731
PX-121	19088	44097	7112	-	604	50173	314	144	281	15	2226
PX-122	19610	27214	5663	936	4300	51213	0	-	1472	-	806
PX-124	17124	33922	5981	979	4491	63055	0	150	249	24	722
PX-125	18411	10096	7452	902	4036	49905	339	0	143	31	1097
PX-126	21225	44724	6308	-	3930	52922	463	-	-	20	459
PX-127	22202	32318	6732	966	3946	53178	263	-	-	14	-
PX-128	18592	49112	5301	-	3800	57938	321	-	214	-	-

PX-129	20225	26630	6513	1160	6205	51993	-	-	175	0	1307
PX-134	24351	29517	5054	496	3756	46788	214	162	-	11	1612
PX-135	17876	35322	6109	-	2864	49352	-	131	-	-	589

In case of the surface soil, Ni concentration was found to range from 214 to 463 µg/g in 7 samples (Sample ID: PX-118, PX-0120, PX-121, PX-125, PX-126, PX-127, PX-128, and PX-134), Cu concentration ranges from 131 to 478 µg/g in 6 samples (Sample ID: PX-114, PX-0119, PX-121, PX-124, PX-134 and PX-135); that of Zn ranges within 143 to 1472 µg/g in 10 samples (Sample ID: PX-113, PX-0118, PX-119, PX-120, PX-121, PX-124, PX-125, PX-128 and PX-129), Hg within 11 to 31 µg/g in 10 samples (Sample ID: PX-113, PX-118, PX-119, PX-0120, PX-121, PX-124, PX-125, PX-126, PX-129, PX-134 and PX-135) and Pb concentration ranges from 459 to 2226 µg/g in 13 samples (Sample ID: PX-113, PX-114, PX-118, PX-119, PX-0120, PX-121, PX-122, PX-124, PX-125, PX-126, PX-129, PX-134 and PX-135).

Table 2: Elemental concentrations in soil samples of Shamnagar Upazila (Deep Soil), Satkhira measured using the VDG Facility, AECD

Sample ID	Material Concentration in µg/g										
	K	Ca	Ti	Cr	Mn	Fe	Ni	Cu	Zn	Hg	Pb
PX-123	15974	47114	4531	-	6994	63930	0	0	251	22	572
PX-130	17796	57779	5510	1126	6715	48421	246	-	215	25	-
PX-116	21257	39322	5044	646	3984	54319	-	-	-	-	1244
PX-117	18123	29756	6214	1912	3142	89318	-	-	331	11	859
PX-131	18552	31348	7219	659	3424	54265	187	-	-	24	718

Besides these out of the 5 deep samples (Table 5.11) Ni concentration was observed to remain within 187 and 246 µg/g in 2 samples (Sample ID: PX-130 and PX-131), Zn concentration ranges from 215 to 333 µg/g in 3 samples (Sample ID: PX-123, PX-130 and PX-117), Hg concentration ranges from 11 to 25 µg/g (Sample ID: PX-123, PX-130, PX-117 and PX-131) and Pb concentration ranges from 572 to 1244 µg/g (Sample ID: PX-123, PX-116, PX-117 and PX-131). When one considers these results it is obvious that the surface soil samples show the presence of higher level compared to that of the deep soil samples. The actual cause and findings are not obvious, excepting that Aila flooded water for a longer time on that areas increases the presence of heavy metal in the surface soil. In a study Rabito et al. [11] reported the results on Pb concentration level of soil at New Orleans, USA for which soil data were available for both pre- and post-Hurricane Katrina time periods. They compared the soil Pb levels and assessed the difference of it in samples between the 2000 and the 2007–2008 surveys. In the 2000 survey, soil Pb ranged from 25 to 1,789 ppm; in the 2007–2008 survey the range was 10–24,000 ppm. This indicates that the Pb level may increase after flooding. In our study we also expect similar effect.In another study Suparna Gupta et al. [12] explained their results on the presence of heavy metals like Hg, Pb and Cd around ***Bruguiera sexangula (Sundarban region).*** They claimed that the heavy metals like Hg, Pb and Cd ***are*** commonly found in the estuarine ecosystem, on Bruguiera sexangula by observing some important anatomical characters and heavy metal accumulation potentiality during their growth and development at ex situ. The present study has covered an area which basically falls under the mangrove ecosystem areas. So the element Hg might have been present even before the occurrence of flood. It is likely that the effect of flood might have enhanced the concentration. Pollution by heavy metals and many organic contaminants is practically irreversible. Excess heavy metal accumulation in soils is toxic to humans and other animals. Exposure to heavy metals is normally chronic (exposure over a longer period of time), due to food chain transfer. Chronic problems associated with long-term heavy metal exposures are known [13-16]. Lead [17-26] is well known to be toxic and its effects have been more extensively reviewed than the effects of other trace metals. Lead can cause serious injury to the brain, nervous system, red blood cells, and kidneys. Exposure to Pb can result in a wide range of biological effects depending on the level and duration of exposure. Various effects occur over a broad range of doses, with the developing young and infants being more sensitive than adults. Lead poisoning severe enough to cause evident illness is now very rare. Lead can be harmful after uptake from food, air, water or contaminated dust. This element is a particularly dangerous chemical, as it can accumulate in individual organisms, as well as entire food chains. But it is also observed that the mobility of toxic heavy metals is less and within the order of Cd>Pb> Hg into the plant body [20-21]. Mercury is associated with kidney damage [24][25]. Exposure to methylmercury, the most harmful form of mercury to human health, affects brain development, resulting in a lower IQ, and consequently a lower earning potential. The long-term cost to society can be calculated as lifetime earning loss per person, although this estimate does not take into account other aspects of brain toxicity or risks of cardiovascular disease in adults. Once methylmercury is formed, it cycles though the environment for thousands of years, exposing humans and other species to potentially toxic levels for generations [26]. No previous data exist as a reference level of soil pollution. This study tried to assess the level of soil contamination with heavy metals like Pb, Hg, Mn, Ni, Cr, Zn, and Cu. In order to assess the health risk of any chemical pollutant, it is essential to estimate the level of exposure by quantifying the routes of exposure of a pollutant to the target organisms. There are various possible exposure pathways of pollutants to humans but the food chain is one of the most important pathways. Food crops were likely to contaminate with heavy metals and the consumption of such foodstuffs can cause human health risks. The values for Zn in soils showed significant relationships with plant Zn [23]. The most common problem caused by cationic metals (metallic elements whose forms in soil are positively charged cations e.g., Pb^{2+}) are Hg, Cd, Pb, Ni, Cu, Zn, Cr and Mn [23]. Human being may be exposed to Ni by eating contaminated food containing the element. Foods naturally high in nickel include soya-beans, nuts and oat meals. Miller and Miller [27] noted that Zn and Cu are toxic to plants before they accumulate in sufficient concentrations to affect animals or human. Consequently, high concentrations of Zn and Cu kill or stunt plants growth. A table presenting here for comparison of heavy and trace metals concentrations (mg/kg) in soil of the present study with other studies around the world. The data of present study shows significantly high compare with some of the previous studies worldwide and some of the cases it is comparable with the previous studies around the world [28][29]-43). Inundated Ayla water deposition for longtime into the local soil may be the cause for this high concentration of metal.

Table 3: Comparison of heavy and trace metals concentrations (mg/kg) in soil of the present study with other studies around the world

Country	Cr	Ni	Pb	Zn	Ref.
Jubail, Saudi Arabia	6.9-130	ND-17	ND-24	8-69	Almasoud et al., 2014
Jalamid, Saudi Arabia	103.62	_	_	73.33	El-Taher et al., 2016
Riyadh, Saudi Arabia	14.88	15.97	6.5	20.38	Hasayen et al., 2017
Qassim, Saudi Arabia	17.4	2.61	26.9	21.1	Al-Wabel et al., 2017
Algria	_	35.78	130.97	61.08	Benhaddya and Hadjel, 2014
Azerbaijan	19.9	_	29.2	47.9	Khalilova and Mammadov, 2016
Australia	19	13	194	187	Birch et al., 2011
China	68.28	29.36	28.40	65.81	Lv et al., 2015
Greece	193.2	58.2	359.4	137.8	Christoforidis and Stamatis, 2009
India	8.29	18.78	12.52	_	Tiwari et al., 2011
Iraq	71.2	52.5	9.0	_	Al-Dabbas et al., 2015
Turkey	51.21	209.22	17.68	56.62	Guler et al., 2010
Nepal	38.83	17.31	21.2	66.86	Tripathee et al., 2016
Poland	3.0	1.1	11	4.9	Jarzyńska and Falandysz, 2012
Italy	90.54	34.67	63.67	166.73	Guagliardi et al., 2012
Serbia	46.3	320	41.5	21.8	Dragovic 2008
Nigeria	186.2	ND	469.2	168.1	Clement et al. 2014
Nigeria	30	ND	760.37	3420	Adamu et al, 2011
Bangladesh	573	149	781	207	Present work (Agriculture soil)
Bangladesh	867	87	679	159	Present work (Deep soil)

These are some of the wider ranged effects we may foresee due to the increase of heavy metals in the soil of the areas studied. To get an idea of the true public health risk, other sources that people are exposed to alongside soils must also be taken into account.

4. CONCLUSION

In this study we were analyzed soil sample to determine elemental contamination by PIXE. The elemental concentration in the investigated soil samples of Ni, Cu, Zn, Hg and Pb are higher than the value obtained from reference soil samples provided from IAEA. Results also shows that the high Z elemental concentration of surface soil is higher compare with the deep soil. So it is also a fact of this research that the prompt investigation is necessary after any natural devastation by cyclone of the locality.

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