discontinuous lava flows that either had erupted from fissures on the flanks of the cinder cone or from the main crater. Current satellite imageries of the volcano, from RISAT-1 and Landsat-8, ISRO (http://www.sac.gov.in/Vyom/index.jsp), show 'hot' zones within the summit crater and around secondary spatter cones that are in tune with the current activity.

The Barren Island volcano is currently in its active phase since 1991, irregularly emitting lava and ash with intermittent quiet periods. The ash eruptions have become a common phenomenon since the 2009–10 lava eruptions; therefore, it should not come as a surprise if sudden eruptions occur during a quiet period. Such eruptions should not be confused with renewed activity of the volcano.

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Higher concentration of heavy metals in surface water and fish near a municipal solid waste dump in Guwahati, Assam, India

Solid waste management is one of the biggest environmental challenges in cities and towns across India. Precipitation infiltrating the solid wastes disposed on land mixes with the liquids trapped in the crevices of the waste and leach compounds from solid waste[1]. Discharge of potentially toxic heavy metals from the leachate into aquatic ecosystems poses serious threat because of their toxicity, persistence, bioaccumulation and biomagnification in the food chain.

Fishes are indicators of metal contamination in aquatic systems[2]. Pollutants enter the fish through four main routes: via food or non-food particles, gills, oral consumption of water and through skin[3]. The present study was planned to assess the possible effect of municipal solid waste (MSW) dumping on the concentration of heavy metals in surface water and accumulation in fish tissue collected from the adjoining wetland.

The study area is the Deepor beel wetland, a Ramsar site (Sl. No. 1207), which is contiguous to the MSW dump site of Guwahati city, Assam, India. Five sampling points (S1–S5) were selected from within 3000 m around the MSW dump (Figure 1). Fortnightly collection of water samples in triplicate was continued for a period of 12 months (March 2011–February 2012). Experimental fish samples (*Anabas testudineus*) in triplicate were collected from within 20 m of the dump site during September–October 2011. The control site for sampling of water and fish was situated at a distance of 4928 m from the dump and was not connected with Deepor beel.

For analysis of heavy metals, standard procedures were followed[4]. Water samples were collected in acid-washed 250 ml

Figure 1. Sampling points (S1–S5) of surface water in the wetland.

Table 1. Concentration of heavy metals in water samples near the dump site (mg/l). (Total number of months studied = 12.)

Parameter	S1 (<20 m)	S2 (<500 m)	S3 (<1000 m)	S4 (<2000 m)	S5 (<3000 m)	Control
Cd						
Range	0.002–0.129	0.006–0.029	0.005–0.494	0.004–0.029	0.001–0.021	BDL
Mean ± SD	0.024 ± 0.016^{a}	0.012 ± 0.010^{ab}	0.010 ± 0.002^{ab}	0.008 ± 0.001^{b}	0.006 ± 0.008^{b}	BDL^{b}
Cr						
Range	0.0004–0.941	0.005–0.721	0.0009–0.090	0.001–0.054	0.0009–0.026	BDL
Mean ± SD	0.363 ± 0.117^{a}	0.230 ± 0.043^{a}	0.032 ± 0.007^{b}	0.028 ± 0.011^{b}	0.005 ± 0.001^{b}	BDL^{b}
Zn						
Range	0.171–0.947	0.271–0.672	0.219–0.515	0.226–0.599	0.199–0.5419	0.101–0.396
Mean ± SD	0.590 ± 0.258^{a}	0.394 ± 0.137^{b}	0.377 ± 0.099^{b}	0.362 ± 0.099^{b}	0.334 ± 0.112^{b}	0.187 ± 0.089^{c}
Cu						
Range	0.008–0.312	0.002–0.099	0.005–0.494	0.007–0.442	0.007–0.110	0.001–0.046
Mean ± SD	0.082 ± 0.050^{b}	0.055 ± 0.007^{b}	0.074 ± 0.004^{b}	0.077 ± 0.013^{b}	0.042 ± 0.011^{b}	0.043 ± 0.012^{b}
Ni						
Range	0.023–0.249	0.001–0.312	0.014–0.191	0.0239–0.249	0.002–0.181	0.0019–0.187
Mean ± SD	0.287 ± 0.009^{a}	0.149 ± 0.003^{b}	0.095 ± 0.036^{b}	0.152 ± 0.040^{b}	0.083 ± 0.024^{b}	0.047 ± 0.009^{c}
Mn						
Range	0.514–6.531	0.211–4.011	0.192–2.530	0.150–2.531	0.132–2.192	0.071–0.254
Mean ± SD	1.985 ± 0.065^{a}	1.168 ± 0.041^{ab}	0.956 ± 0.671^{bc}	0.941 ± 0.101^{bc}	0.817 ± 0.527^{bc}	0.435 ± 0.251^{c}

Mean heavy metal concentration of different sites sharing a common letter (a, b, c) for a particular metal is not significantly different; $P < 0.05$; BDL, Below detectable limit.

plastic bottles and stored at 4°C. Digestion was done with concentrated HNO_3 in a fume hood until 25–30 ml of the sample remained and made up to 100 ml in a volumetric flask. Fish tissues (muscle and skin) were dissected with a scalpel, weighed and dried in a hot-air oven (70°C) until constant weight was obtained. Tissue was homogenized in a porcelain mortar and pestle. One gram of homogenized tissue was digested and processed for heavy metal analysis. Atomic absorption spectrophotometer (Thermofisher iCE 3300 AA system) was used for heavy metal analysis. Sample analyses were performed in triplicate and measured in milligrams per litre or milligrams per kilogram. Calibration standards were run regularly to ascertain the accuracy of the analytical procedure. Milli Q water was used for all purposes. Blanks were run with each batch of samples (25 samples in each batch). Wavelengths for Cu, Ni, Cd, Cr, Mn and Zn were 324.8, 232.0, 228.8, 357.9, 279.5 and 213.9 nm respectively. The precision of the analytical procedure was performed by a strict blank control, standard reference material of commercially available standards (Merck KgaA, 64271 Darmstadt, Germany) and the analysis of replicates. The detection limits for heavy metals were 0.0045 ppm for Cu, 0.0033 ppm for Zn, 0.0016 ppm for Mn, 0.008 ppm for Ni, 0.0054 ppm for Cr and 0.0028 ppm for Cd.

Pearson's correlation analysis was applied to the dataset to quantitatively analyse the correlation that exists between the different heavy metals. One-way ANOVA and Duncan's multiple range test were used to determine whether any variation exists in the heavy metal concentration between the contaminated sites, and also between the control site and contaminated sites. All statistical analyses were performed with SPSS 18.0.

Analysis of surface water and fish tissue samples collected from various points near the MSW dump site revealed that continuous mixing of leachate with beel water had deleterious effect on the water quality and fish in its vicinity. Table 1 presents the concentration of heavy metals in surface water samples. The heavy metals are found to occur in decreasing concentration of Mn > Zn > Cr > Ni > Cu > Cd with increasing distance from the source. This confirms the gradual spread of heavy metals from the MSW dump towards the wetland. The results of one-way ANOVA and Duncan's multiple range test show that there are significant differences in the heavy metal concentration of Cd, Cr, Mn, Ni and Zn between the sampling sites (Table 1). The control site shows significant variations between the group means of Cd, Mn, Ni and Zn. Statistical analysis (SPSS 18.0) revealed highly positive correlation between Cd and Ni, Cd and Zn, Mn and Ni as well as Zn and Cd ($P < 0.01$). Significantly positive correlations were obtained between Zn and Ni, Cr and Ni and between Zn and Cd ($P < 0.05$) (Table 2). This could indicate their similar source of origin.

The Deepor beel supports a number of neighbouring villages where people use the water for their daily activities like drinking, cooking and washing. Certain heavy metals are essential for humans, plants and animals, but they can be potentially toxic above a certain concentration. The concentration of Mn, Cr, Cd and Ni in surface water was found to exceed the MPL (maximum permissible concentration) of WHO[5] (Mn – 0.5, Cr – 0.05, Cd – 0.003, Ni – 0.02 mg/l), IS-10500 (10500 2012; Mn – 0.3, Cr – 0.05, Cd – 0.01, Ni – 0.02 mg/l)[6] and within the MPL of CPCB[7] (Mn – 2, Cr – 2, Cd – 2, Ni – 3 mg/l). The concentration of Mn in excess of 0.2 mg/l makes water distasteful to drink, with no specific toxic effects[8]. Zn is extensively used as a white pigment (zinc oxide) in paint and rubber. High concentrations of Ni, Zn and Cu indicate that paints, batteries and metallic materials are predominant in the waste.

The concentration of heavy metals analysed in *A. testudineus* tissue collected from within 20 m of the dump site was found in the decreasing sequence as follows: Zn > Mn > Cu > Cd > Ni (Table 3). The heavy metal concentration was

Table 2. Pearson's correlation between heavy metals in water samples

	Ni	Cu	Zn	Cd	Cr	Mn
Ni	1					
Cu	0.677	1				
Zn	0.885	0.726	1			
Cd	0.920	0.706	0.991	1		
Cr	0.901	0.456	0.844	0.898	1	
Mn	0.941	0.679	0.984	0.997	0.917	1

Correlation is significant at $P < 0.05$, $P < 0.01$.

Table 3. Concentration of heavy metals in *Anabas testudineus* collected near (within 20 m) the dump site and control site (mg/kg)

Anabus testudineus	Cd	Zn	Cu	Ni	Mn
Muscle (exp)	0.011 ± 0.001	2.441 ± 0.16	0.241 ± 1.04	BDL	1.120 ± 0.06
Muscle (control)	BDL	0.762 ± 0.32	0.019 ± 0.01	BDL	0.221 ± 0.19
Skin (exp)	0.043 ± 0.02	1.410 ± 1.02	0.160 ± 0.09	BDL	0.528 ± 0.22
Skin (control)	BDL	0.814 ± 0.414	0.011 ± 0.06	BDL	0.101 ± 0.07
FAO (2003)	0.05	40	10	10	50

Values represent mean of three replicates.

found to be within the MPL of FAO[9]. The concentrations of Mn (skin tissue), Cu (skin and muscle tissue) and Cd (skin and muscle tissue) was found to be higher than those in fish tissues from the control site. There are reports of accumulation of heavy metals in fishes inhabiting contaminated water[10]. As indicated by the results obtained in the present study, Zn and Mn also showed higher concentration in *A. testudineus* tissue, similar to the trend in surface water. Zinc toxicity is rare, but the concentration in water up to 40 mg/kg may induce toxicity, characterized by symptoms of irritability, muscular stiffness and pain, loss of appetite and nausea[11]. The heavy metal concentration in fish tissues was found to be higher compared to that in the habitat as recorded in other similar studies[12,13]. Heavy metals might accumulate up to toxic concentrations and cause ecological and health hazards. The present study indicates that *A. testudineus* collected near the dump site has accumulated heavy metals from the habitat. Bioaccumulation of heavy metals may lead to biomagnification through the food chain.

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Uranium anomalies in groundwater of Sangrur district of Punjab (India) for cancer risk assessment

THE permissible limit of uranium in drinking water is 30 μg l^{-1} as recommended by the World Health Organization (WHO)[1]. The accumulation of uranium inside the human body targets the kidneys and lungs[2–4] due to chemical and radioactive effects. Drinking water is the major source of uranium to the human body and contributes about 85% of ingested uranium[5], food contributes the remaining 15%. An equivalent of 0.1 mg/kg of body weight of soluble natural uranium exposure results in some short-lived chemical damage to kidneys[6]. Uranium is a radioactive heavy metal; it