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Total and dissolved metals in the industrial wastewater: A case study from Dhaka Metropolitan, Bangladesh

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ABSTRACT

The present study was conducted to assess the contamination of heavy metals in the industrial waste waters collected from Dhaka city, Bangladesh. Seven different types of industries have been considered as the major sources of untreated effluents. Total and dissolved metals were analyzed using inductively coupled plasma mass spectrometer (ICP-MS) and compared with different international standard values. In samples, the ranges of Cr, Ni, Cu, As, Cd and Pb were 1.1–7910, 0.11–11, 0.69–13, 0.88–16, 0.01–9.3 and 0.19–11 mg/L and 0.76–1994, 0.04–5.2, 0.47–6.4, 0.26–5.7, 0.01–3.7 and 0.06–4.5 mg/L, respectively for total and dissolved concentration. The study revealed that the untreated activities of tanneries, dye-chemical, metal processing and battery manufacturing industries are contributing to the metal contamination in the surrounding environment. The concentration of heavy metals exceeded the acceptable environmental quality standards due to continuous discharge of untreated wastewaters that pose severe threat to the aquatic environment and human health in the urban area of Dhaka City. Results showed that rice husk can be fruitfully used for the removal of heavy metals from industrial wastewater. All possible sources of agro-based inexpensive adsorbents should be explored and their feasibility for the removal of heavy metals should be studied in detail.

1. Introduction

Globally, the contamination of heavy metal in water bodies ranks among the major environmental problems with many issues accompanying rapid economic development in both developed and developing countries like Bangladesh (Wu et al., 2011; Islam et al., 2015a). As a direct consequence, untreated wastewater from different industries is being discharged into the channels around city. Without advanced technology land disposal of industrial sludge can be carried out. However, application of wastewater from various industries may result in heavy metal accumulation in water, soils and other environmental media that deserve more attention (Fuentes et al., 2004).

Rapid urbanization is enlarging the size of Dhaka City in terms of geographical area and population with about 12 million people in an area of 815.8 km^2 (Mohiuddin et al., 2011; Islam et al., 2015b). Population growth and economic development in the urban area can accelerate the consumption of commodities and increase the waste generation in developing countries like Bangladesh (Islam et al., 2015c). Wastewater that is disposed from different industries contains heavy metals, organic compounds, macronutrients, micronutrients, organic micro pollutants, microorganisms and eggs of parasitic organisms (Yuan et al., 2011). So, the accumulation of heavy metals in the industrial wastewater poses a growing environment problem and the disposal of these wastewaters with toxic metals may result in secondary environmental pollution. Thus, contamination of aquatic environment by toxic metals from untreated wastewater of various industries is a worldwide environmental problem. Mining, electroplating, metal processing, textile, battery manufacturing, tanneries, petroleum refining, paint

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manufacture, pesticides, pigment manufacture, printing and photographic industries are the main sources of heavy metals in the environment (Ahmaruzzaman, 2011). Metals such as chromium, nickel, copper, arsenic, cadmium and lead have been documented as hazardous elements (Ahmaruzzaman, 2011; Islam et al., 2015b). Unlike organic wastes, heavy metals are non-biodegradable and they can be accumulated in living tissues, causing various diseases and disorders; therefore, they must be removed before discharge to the environment.

The wide spread industrial development in urban areas has radically reduced land area for waste disposal. The untreated industrial and domestic wastes disposal into environment affects quality of soil and ground water and considered as undesirable soil use (Quazilbash et al., 2006). Xu and Lancaster (2008) reported that the residues and byproducts of thermo-chemical reaction of industrial wastewater should be analyzed, while utilization of the residues of wastewater should be investigated. Literature on heavy metals in the industrial wastewater in Bangladesh is scarce. Thus this study monitors and interprets the contamination level of toxic metals in the wastewater of various industries. The objectives of the present study is to evaluate the concentrations level of trace metals in the wastewater samples collected from different industries and to assess the contamination levels as compared to international standards.

2. Materials and methods

2.1. Sampling and pre-treatment

Sampling stations were selected by site survey during August and September, 2013. Fifty seven wastewater samples were collected from the disposal channels of seven different types of industries such as tanneries, dye chemicals, textiles, metal processing, battery manufacturing, paper mills and jute mills in Dhaka City, Bangladesh (Fig. 1). Wastewater samples were filtered immediately after collection using ADVANTEC® 0.45 μm size sterile syringe filter for estimation of dissolved metals and were transferred immediately into acid cleaned 100 mL polypropylene bottles. After filtration samples were preserved in the refrigerator until other chemical analysis was carried out.

The physicochemical parameters such as pH, electrical conductivity (EC), suspended solid (SS), dissolved solid (DS), total solid (TS) and ash were estimated within the same day of sampling (Al Yaqout, 2003; Biswas et al., 2015).

Analytical grade reagents and Milli-Q (Elix UV5 and MilliQ, Millipore, USA) water was used for solution preparation. For metal analysis, 20 mL of wastewater sample was treated with 1.5 mL 69% HNO_3 (Kanto Chemical Co, Japan) and 4.5 mL concentrated HCl (Kanto Chemical Co., Japan) in a closed Teflon vessel and was digested in a Microwave Digestion System (Berghof-MWS2, Berghof Speedwave® Germany). The digested sediment and waste water samples were then transferred into a Teflon beaker and total volume was made up to 50 mL with Milli-Q water. The digested solution was then filtered by using syringe filter (DISMIC® - 25HP PTTF, pore size = 0.45 μm) Toyo Roshi Kaisha, Ltd., Japan and stored in 50 mL polypropylene tubes (Nalgene, New York). Finally, blank digestion with 5 mL HNO_3 following the said digestion procedures were carried out to clean up the digestion vessels (Berghof's product user manual, 2008).

2.2. Batch experiment

Adsorption batch experiments were carried out by shaking a series of bottles containing various amounts of rice husk and heavy metal ions at normal pH condition. The pH of the slurry was adjusted to a desired value 6.5 and was agitated (agitation rate 200 rpm) in a shaking bath at (28 ± 3 °C) for 20 min until the pH was stabilized. Then, the Cr, Ni, Cu, A, Cd and Pb ions in the form of chromium chloride, nickel chloride, copper chloride, arsenic chloride, cadmium chloride and lead chloride were added to the bottles to make initial concentrations of 5–30 mg/L and the bottles were further agitated for 2 h until equilibrium was obtained (Hegazi, 2013; Shaheen et al., 2013). The residual concentration of heavy metals was determined by Inductively Coupled Plasma mass spectrometer (ICP-MS).

2.3. Instrumental analysis and quality assurance

For metals, samples were analyzed by using Inductively Coupled Plasma mass spectrometer (ICP-MS, Agilent 7700 series). Multi-element Standard XSTC-13 (Spex CertiPrep® USA) solutions was used to prepare calibration curve. The calibration curves with $R^2 > 0.999$ were accepted for concentration calculation. Internal calibration standard solutions containing 1.0 mg/L of indium, yttrium, beryllium, tellurium, cobalt and thallium were purchased from Spex CertiPrep® USA. Working standards were prepared daily in 5% (v/v) HNO_3 at 69% ultrapure grade and were used. Multielement solution (Agilent Technologies, USA) 1.0 μg/L was used as tuning solution covering a wide range of masses of elements. A blank also carried out in the sequential extraction experiment. A run included blank and samples were analyzed in duplicate to eliminate any batch-specific error. Before starting the analysis sequence, relative standard deviation (RSD, <5%) was checked by using tuning solution purchased from the Agilent Technologies.

3. Results and discussion

3.1. Physicochemical properties and heavy metals in wastewater samples

The physicochemical properties of wastewater samples are presented in Table 1. Data showed that the physico-chemical properties of wastewater from selective industries in Dhaka City, Bangladesh varied widely. Among the industries, the highest mean value of suspended solid was observed for jute mill (mean: 1.1 g/L and range: 0.045–2.2 g/L) and the lowest value was observed for dye-chemical industry (mean: 0.08 g/L and range: 0.04–0.16 g/L). The mean value of the suspended solid content for samples was 0.08–1.1 g/L (Table 1) which was higher than the standard concentration (0.06 g/L) (DEG, 1994) indicated that the suspended solid content in samples of the industries might (perturb/disturb) the aquatic life (Muttamara and Leong, 1997). Among the industries, the highest mean value of ash was observed for tannery industry (mean: 4.9 g/L and range: 0.91–10 g/L) and the lowest value was observed for dye-chemical industry (mean: 0.28 g/L and range: 0.011–0.45 g/L). Among the industries the pH ranged from 2.6 to 9.4. The average values of pH of wastewater samples of the studied industries were slightly alkaline except jute mill (mean pH: 6.5 and range: 6.3–6.9) and battery manufacturing industries (mean pH: 4.9 and range: 2.4–7.3), indicating that it was slightly acidic (Table 1). Due to the lower pH, the wastewater of jute mill and battery manufacturing industries might cause detrimental effects and react synergistically with other materials such as heavy metals causing toxicity (Muttamara and Leong, 1997).

3.2. Total and dissolved concentration of heavy metals in samples

The total and dissolved concentrations of heavy metals viz. Cr, Ni, Cu, As, Cd and Pb in wastewater samples are presented in Table 2 showed a wide variation in the concentration of heavy metals. This difference in concentration of heavy metals among industries may