Assessment of soil quality parameters and heavy metal load in Mini River Basin, Vadodara
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ABSTRACT

The investigation deals with the characterization of Physico-Chemical properties of soil at four different points at Mini River basin, Vadodara. The emphasis was given to the heavy metal deposition / accumulation in the study area. The results of the study revealed heavy load of pollutants including Zn, Cu, Pb, and Cd metal ions from nearby industries. The samples were collected from four equidistant stations. All the soil quality parameters were analyzed and heavy metals determined on Atomic Absorption Spectrophotometer (AAS). The result showed that the station 3 and 4 which were closer to the industrial area reported highly polluted and under the influence of anthropogenic activities, showing high values of Sulphur and Phosphorus and low values of Nitrogen and also having more accumulation of heavy metals in the soil samples studied in the vicinity of Mini river basin.

Keywords: Mini river, heavy metal, pollutants, AAS, Sulphur, Nitrogen.

1. Introduction

Rapid industrialization, urbanisation activities and intensification of agricultural activities over the last few decades are the biggest contributors to pollute the landscapes by unsafe disposal of industrial wastes into water steams and into the air without giving appropriate treatment. The polluted water stream pollutes the ground beneath their structures and storage areas. A wide range of inorganic and organic compounds cause contamination, these include heavy metals, combustible, hazardous wastes, explosives and petroleum products. Major component of inorganic contaminates are heavy metals (Adriano, 1986 and Alloway, 1990 ) they present a different problem than organic contaminants.. Soil microorganisms can degrade organic contaminants, while metals need immobilisation or physical removal. Although many metals are essential, all metals are toxic at higher concentrations, because they cause oxidative stress by formation of free radicals. Such metals are found naturally in the soil in trace amounts Heavy metals like lead, mercury, cadmium, arsenic, copper, zinc and chromium that are hazardous present in disposal of some industrial wastes. Increased concentrations due to anthropogenic activities in particular areas pose serious threat to all living organisms. Another reason why metals may be toxic is that they can replace essential metals in pigments or enzymes disrupting their function (Henry, 2000). Thus, metals render the land unsuitable for plant growth and destroy the biodiversity.

The metals are classified as “heavy metals” if in their standard state they have a specific gravity of more than 5 g/cm³. There are known sixty heavy metals. Heavy metals get accumulated in time in soils and plants and could have a negative influence on physiological activities of plants (e.g. photosynthesis, gaseous exchange, and nutrient absorption),
determining the reductions in plant growth, dry matter accumulation and yield (Devkota and Schmidt, 2000). In small concentrations, the traces of the heavy metals in plants or animals are not toxic (Vries et al. 2007). Lead, cadmium and mercury are exceptions; they are toxic even in very low concentrations (Galas-Gorchev, 1991).

Heavy metal studies have been conducted in soils with differing levels of anthropogenic influences such as in highly populated and industrialized cities. The heavy metals such as Cu, Cr, Cd, Ni and Pb are potential soil and water pollutants (Karbasi, 2004). So, the regular assessment of heavy metal is necessary.

Though several regulatory steps have been implemented to reduce or restrict the release of pollutants in the soil, they are not sufficient for checking the contamination. Metal contaminated soil can be remediated by chemical, physical and biological techniques.

The heavy metals investigated in this study have been implicated for various human health problems even at trace levels. Lead has been implicated in various disease such as anaemia, brain damage, anorexia, mental deficiency, vomiting and even death in human (Bulut and Baysal, 2006). Cadmium also has been reported to cause agonistic and antagonistic effects on hormones and enzymes leading to lots of malformations like renal damage (Lewis, 1991). These two metals have affinity for SH groups in proteins, haemoglobin, enzymes/ hormones (Manahan, 1992). Likewise, Pb and Cd are classified as carcinogens (USEPA, 1999 and Pekey, 2006). Other metals, investigated in this study were Zn and Cu, each of which has been reported for various health problems being non-biodegradable and with the possibility of accumulation in the food web (Langston, 1990).

2. Study site

Nandesari Industrial Estate (NIE) of Gujarat is located on the banks of the Mini river and its tributary the Mahi river 20 km north of the city of Vadodara situated at 22 ° E and 73 ° N on the globe. The Mini and Mahi Rivers and their easy accessibility served as excellent disposal agents, and attracted other industries to the area. NIE comprised of around 1200 small and large scale dye industries, engineering, and textile, pharmaceutical and petrochemical industries. Sludge and sediments in the Mini River, which floods during the monsoon season, is highly contaminated with legacy heavy metals and other waste (Mishra and Murthy, 1995). Henceforth, this study aimed at the determination of different heavy metal contents in the soils and their seasonal variation at different points in the area.

3. Experimental

3.1 Sample collection

Soil samples were collected from randomly selected locations around the river bank of Mini. First the vegetation was removed with a trowel. Dug the soil upto a depth of 10-20 cm, remove gravels and collected the sample in airtight sealed food grade plastic bags. The collected samples were taken to the laboratory for analysis. In the present study four different sampling stations about 8-10 feet away from each site were selected; Station 1 and 2 were located away from industrial area whereas stations 3 and 4 were near to the polluted area where continuous release of effluent from nearby industries was observed.
3.2 Method of Analysis

All the parameters mentioned in Table 1 followed the analysis method described by Maiti, 2003. For the release of heavy elements from soil and sediments like Pb and Cd given in Table 2, wet oxidation of sample is carried out. Take 0.5-1.0 g sample of air dried soil in digestion tube and add 3 ml Conc. HNO₃, digest on electrically heated block for 1 hr. at 145° C. Add 4 ml of HClO₄ and heat it to 240 ° C for further 1 hr. Cool and filter through Whatman # 42 filter paper and make up to 50 ml volume. Heavy metals were analysed on Atomic Absorption Spectrophotometer (AAS) Model - Aventa, Make- GBH. Set the instrument as given in table 3.

**Table 1:** Summary (Mean) of Soil quality parameters at 4 different stations in the Mini river basin

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Station 1</th>
<th>Station 2</th>
<th>Station 3</th>
<th>Station 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total N (Oc) %`</td>
<td>0.43</td>
<td>0.59</td>
<td>0.22</td>
<td>0.30</td>
</tr>
<tr>
<td>Ava. P (Kg/Ac)</td>
<td>14.00</td>
<td>11.00</td>
<td>28.00</td>
<td>70.00</td>
</tr>
<tr>
<td>Ava. K (Kg/Ac)</td>
<td>73.00</td>
<td>65.00</td>
<td>112.00</td>
<td>85.00</td>
</tr>
<tr>
<td>pH (1:2)</td>
<td>7.97</td>
<td>7.91</td>
<td>8.08</td>
<td>8.16</td>
</tr>
<tr>
<td>Conductivity (mho)</td>
<td>0.48</td>
<td>0.48</td>
<td>1.19</td>
<td>1.83</td>
</tr>
<tr>
<td>Sulphur (ppm)</td>
<td>16.00</td>
<td>17.80</td>
<td>31.80</td>
<td>34.70</td>
</tr>
<tr>
<td>Iron (ppm)</td>
<td>10.28</td>
<td>7.80</td>
<td>14.64</td>
<td>14.28</td>
</tr>
<tr>
<td>Manganese (ppm)</td>
<td>6.34</td>
<td>8.38</td>
<td>3.04</td>
<td>4.00</td>
</tr>
</tbody>
</table>

**Table 2:** Summary (Mean) of heavy metals in soil at 4 different stations in the Mini river basin

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Station 1</th>
<th>Station 2</th>
<th>Station 3</th>
<th>Station 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zinc (ppm)</td>
<td>3.56 ± 0.32</td>
<td>3.40 ± 0.26</td>
<td>4.30 ± 0.01</td>
<td>5.38 ± 0.03</td>
</tr>
<tr>
<td>Copper(ppm)</td>
<td>1.74 ± 0.02</td>
<td>1.56 ± 0.07</td>
<td>1.84 ± 0.06</td>
<td>4.54 ± 0.26</td>
</tr>
<tr>
<td>Cadmium (ppm)</td>
<td>1.925 ± 0.08</td>
<td>1.490 ± 0.21</td>
<td>2.814 ± 0.36</td>
<td>3.096 ± 0.42</td>
</tr>
<tr>
<td>Lead (ppm)</td>
<td>23.589 ± 0.10</td>
<td>19.185 ± 0.05</td>
<td>27.163 ± 0.06</td>
<td>34.199 ± 0.52</td>
</tr>
</tbody>
</table>

**Table 3:** Instrument setting for AAS

<table>
<thead>
<tr>
<th>Element</th>
<th>Wave length (nm)</th>
<th>Silt width (nm)</th>
<th>Working range (µg/ml)</th>
<th>Sensitivity (µg/ml)</th>
<th>Lamp current (mA)</th>
<th>Flame type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cadmium (Cd)</td>
<td>228.8</td>
<td>0.5</td>
<td>0.5-5</td>
<td>0.03</td>
<td>15.0</td>
<td>Air-C₂H₂</td>
</tr>
<tr>
<td>Lead (Pb)</td>
<td>283.3</td>
<td>0.5</td>
<td>4-40</td>
<td>0.2</td>
<td>440.0</td>
<td>Air-C₂H₂</td>
</tr>
</tbody>
</table>
4. Results and discussion

As depicted in Table 1, station 3 was reported to be much deficient in total Nitrogen content than any other sampling station. PO$_4$- P and Sulphur were very high at station 3 and 4 as compared to station 1 and 2. All the results obtained for Available K were within normal range at all the four sampling stations. The pH of the soils at all the stations was found to be moderately alkaline. Low conductivity values were found at station 1 and 2 but were much higher at station 3 and 4. Sampling stations 1 and 2 relatively showed normal Iron content while it was on very much higher side at stations 3 and 4. At these stations the soils were found to be deficient in their Manganese content.

The heavy metal content of the soils at four different sampling stations is shown in Table 2. The soil samples were analysed for Zn, Cu, Cd and Pb. The Cadmium was reported to be tremendously high at station 3 and 4, at stations 1 and 2 they were comparatively lower but within normal range when compared to data given by Alloway 1990.

From the above results it is clear that sampling stations 3 and 4 were found to be highly polluted as compared to the stations 1 and 2 (Figure 1). These stations had soil poor or deficient in Total nitrogen as well as Iron. Both these are nutrients and are required by the plants for their growth. Moreover, total soil nitrogen provides an indication to the soil’s long term nitrogen supplying capacity. In polluted areas the deficiency of these nutrients increases indicating future threat to the plant growth and development (Koetke, 1993).

![Figure 1: Depletion in Total Nitrogen content at four stations in polluted soil](image)

High reported value of PO$_4$- P as shown in Figure 2 in the study area at sampling stations 3 and 4 might be due to the fact that these stations are in direct contact near the pollutant source wherein fertilizer industries discharge their untreated effluent (Figure 2). This might be one of the major causes of enhanced PO$_4$- P level in the area. The increased application of fertilizers, use of detergents and domestic sewage greatly contribute to the heavy loading of Phosphorous in the water.

The increased conductivity at station 3 and 4 might be attributed to high deposition of salts of sulphates and phosphates (Herrero et al., 2003, Paine, 2003, Kaffka et al., 2005 and Seifi et
al., 2010). The high values of sulphur in the area indicated that anthropogenic activities are too high in the river contributing significant rise in the sulphur level (Figure 3).

**Figure 2:** Increase in Phosphorus content in polluted soil at four stations

**Figure 3:** Correlation of Sulphates and Phosphate salts with Conductivity

The moderately alkaline pH of the soil indicates the deteriorate quality of the soil. There found a direct positive correlation between the soil pH and manganese deficiency in the area (Figure 4). Manganese (Mn) is present in the soil as free Mn2+, which is readily available to plants, and as oxides of low solubility. High soil pH greatly reduces the solubility of soil Manganese, and therefore its availability to roots. Thus the present status of Manganese in the soil revealed its poor quality in terms of Manganese (Johnston, 1996).
The metal ion analysis of the soil samples showed presence of all the tested metals in the soil. Of these, cadmium was reported to be much higher side than the other metals. Cadmium in soils is derived from both natural and anthropogenic sources. In the study site the anthropogenic input of cadmium to soils might be the primary reason and might have occurred due to aerial deposition and sewage sludge, manure and phosphate fertilizer application (www.cadmium.org/pg_n.php?id_menu=6) (Figure 5).

**Figure 5:** Correlation of Cadmium content with increase in phosphate content in polluted soil

### 5. Conclusions

This study provides an informative data and helps to understand the contamination of soil in river Mini river basin and the possible factors that imposes various threats in the area. The major source of pollutants in the study area are local anthropogenic activities, agricultural runoff and by industrial effluent. In the present study it was found that physico-chemical characteristics of the soil have crossed the maximum permissible limit, due to heavy mixing of effluent waste and domestic sewage it was noticed that the physico-chemical parameters indicates balance of the river Mini was disturbed. This was regularly observed and monitored during field visits of the study area. The study concluded that the soil quality of the river has been severely deteriorated.

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### 6. References


