Accumulations of Heavy metals in marshy and sandy habitats from Kachchh to Diu (Saurashtra Coast) Gujarat-India.

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ABSTRACT

Heavy metals are extremely toxic and they are present in our immediate environment. They occur in soil, surface water and plants. Moreover, they are mobilized by the human activities through. Foregoing facts generated the base of the present investigation included the objective of heavy metals viz., Fe, Mn, Ni, Zn, Pb and Cu in habitats located from 8 different sites viz., 5 marshy locations such as Navinal, Wandi, Jungi, Navlakhi and Bedi Bandar from Gulf of Kachchh and 3 sandy sites Madhavpur, Muldwarka and Gangeshwar from open sea coast of Arabian sea. Heavy metals concentration in 24 soil samples supporting halophytes in Saurashtra eco-region from Gujarat coast could possibly be arranged in order as: Fe>Mn>Ni>Zn>Pb>Cu. Thus the present study clearly revealed that metals content in sediments collected from 3 different quadrats laid down 2.5m; 22.5m and 47.5m away from the belt started at point. Heavy metals in same habitats would be almost equal. Then the heavy metals in 8 different habitats along about 800 km-long sea coast of Gujarat were significantly very different.

Keywords: Saurashtra coast, Heavy metals, Habitats.

INTRODUCTION

The accumulation of metals in sediments from both natural and anthropogenic sources occurs in the same way, thus making it difficult to identified and determine the origin of heavy metals present in the sediments (Idris et al., 2007; Okoro et al., 2012). In coastal ecosystem, sediments are the main sink and source of heavy metals,
playing as a significant role in the toxicity, hazardous and storage potentially for ecological effects (C. Zhang C. et al., 2014). Heavy metals might be degraded either by microbial or by chemical process and tend to accumulate in soils or to be transported by streaming water and contaminate surface water and ground water (USEPA, 2000). Although the toxic metals are naturally occurring through geochemical weathering effects of rocks, they may also be added by anthropogenic inputs (Sheikh et al., 2014; Skordas et al., 2014). Toxic metals contamination of soil and sediment water causes major environmental and human health problems, especially in arid zones with saline soils. The most commonly used methods for dealing with heavy metal pollution are still extremely costly (Memon et al., 2001; Singh et al., 2006). Salt marshes are the most productive ecosystems and provide a buffer zone between terrestrial and aquatic ecosystems (Rajendran et al., 1993; Ashrafual et al. 2009). Physical, chemical, and biological interactions between freshwater and saltwater systems can have significant influences on the transportation of trace and heavy metals in the estuarine environment (Ip et al., 2006).

MATERIALS AND METHODS

Study Sites: The state of Gujarat is situated on the north-western parts of India. It lies (20° 2´ - 24° 41´ N latitude and 68° 8´ - 74° 23´ E longitude) occupies an area of 1,96,024 sq.km and has 1663-km-long coastline, which spreads along 13 maritime districts and one Union Territory of Diu between Kachchh to Valsad. Gujarat coast is characterized by typical salt marshes, salt plains, sand dunes and rocky shore found along 1663-km-long sea coast of Gujarat out of 5700-km-long Indian coast. Accumulations of heavy metals in habitats from 5 marshy and 3 sandy along about 800 km long sea coast from Kachchh to Diu (Saurashtra coast). Eighat habitats comprising of two different groups were selected i.e. 5 marshy sites (H1) Navinal; (H2) Wandi; (H3) Jungi (H4) Navlakh and (H5) Bedi Bandar whereas, 3 sandy locations such as (H6) Madhavpur; (H7) Mul Dwarka and (H8) Gangeswar. 24 soil samples from these 8 habitats were collected and analyzed for estimation of heavy metals viz., Fe, Mn, Ni, Zn, Pb and Cu by Atomic Absorption Spectrophotometry-200.

Preparation of Samples:
Soil samples were taken from (0-15 cm) deep collected from 1st, 5th and 10th quadrats from 2.5m, 22.5m and 47.5m respectively from the started point of the belt (Fig. 1). Soil samples were analyzed for estimation of heavy metals viz., Fe, Mn, Ni, Zn, Cu and Pb by atomic absorption spectrophotometry-200.
About 1.00 ± 0.05 g dried soil sample was taken into silica crucible, incinerated and was ignited in a muffle furnace at a temperature of 400 °C before transferring to a 100 ml Teflon beaker. 10 ml of 1:1 diluted hydrochloric acid was added to the sample and was kept on water bath (60-80 °C for 1 hour). The supernatant was decanted, while, 10 ml of Hydrofluoric acid and 10 ml of Hydrochloric acid were added to the residue, which was evaporated to dryness on water bath. The last step was repeated once, later on 5 ml of both these acids was added and sample was evaporated to dryness. The residue was dissolved in 10-12 ml of Hydrochloric acid and was combined with the supernatant separated earlier and final volume was made upto 250 ml with distilled water. This extract was further used for estimation of Fe, Mn, Ni, Zn, Cu, and Pb by atomic absorption spectrophotometry (Perkin Elmer Analyst 200).

RESULTS AND DISCUSSION

Heavy Metals – Habitats:
Sediment quality is vital for survival and well being of the living resources, both flora and fauna, in the coastal areas. Elevated concentrations of heavy metals found in halophyte sediments often reflect the long-term pollution caused by human activities. Heavy metals are amongst the most serious pollutants within the natural environment.

HEAVY METALS - HABITATS
environment due to their toxicity, persistence and bioaccumulation problems. Furthermore, as heavy metals cannot be degraded biologically, they are transferred and concentrated into halophyte plant tissues from soils and pose long-term damaging effects on halophytes.

This section examines distribution pattern of heavy metals \textit{viz.}, Fe, Mn, Ni, Zn, Cu and Pb in five marshy and three sandy habitats supporting morphologically different halophytes. 24 soil samples were collected from 3 different quadrats \textit{i.e.}, Q1, Q5, Q10, which were 2.5 m, 22.5 m, 47.5 m away from the belt.

\textbf{Fig. 2.} Selected locations between Kachchh to Junagadh districts and Union Territory Diu along Gujarat coast.
Habitat 1 Navinal

Heavy metals composition in sediments at this site indicated that Fe values fluctuated between 13,095 to 13,369 mg.kg\(^{-1}\) (Table 1). As compared to Fe, the Mn content was less (Q1 = 667 mg.kg\(^{-1}\), Q5 = 741 mg.kg\(^{-1}\) and Q10 = 761 mg.kg\(^{-1}\)) and it was further observed that the habitat contained yet lesser Ni and Zn, respectively between 90 to 117 mg.kg\(^{-1}\) and 88 to 102 mg.kg\(^{-1}\). Cu in soils varied in a close range of 31.25 to 33.75 mg.kg\(^{-1}\) and Pb fluctuated between 61 to 79 mg.kg\(^{-1}\) in three quadrats. Heavy metal accumulation followed a declined pattern Fe > Mn > Ni > Zn > Pb > Cu in this marshy habitat situated on the northern boundary of the Gulf of Kachchh.

Table 1. Concentrations of heavy metals (mg.kg\(^{-1}\)) in halophyte habitats from 5 marshy sites (Kachchh district).

<table>
<thead>
<tr>
<th>Location</th>
<th>Fe</th>
<th>Mn</th>
<th>Ni</th>
<th>Zn</th>
<th>Pb</th>
<th>Cu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Navinal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(H1) Q1</td>
<td>13237</td>
<td>667</td>
<td>90</td>
<td>93</td>
<td>61</td>
<td>32.25</td>
</tr>
<tr>
<td>(H1) Q5</td>
<td>13095</td>
<td>741</td>
<td>111</td>
<td>102</td>
<td>66</td>
<td>31.25</td>
</tr>
<tr>
<td>(H1) Q10</td>
<td>13369</td>
<td>761</td>
<td>117</td>
<td>88</td>
<td>79</td>
<td>33.75</td>
</tr>
<tr>
<td>Wandi</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(H2) Q1</td>
<td>11633</td>
<td>917</td>
<td>132</td>
<td>90</td>
<td>54</td>
<td>37.25</td>
</tr>
<tr>
<td>(H2) Q5</td>
<td>11688</td>
<td>841</td>
<td>109</td>
<td>79</td>
<td>73</td>
<td>27.75</td>
</tr>
<tr>
<td>(H2) Q10</td>
<td>11504</td>
<td>878</td>
<td>114</td>
<td>93</td>
<td>68</td>
<td>32.75</td>
</tr>
<tr>
<td>Jungi</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(H3) Q1</td>
<td>11360</td>
<td>916</td>
<td>124</td>
<td>98</td>
<td>107</td>
<td>36.5</td>
</tr>
<tr>
<td>(H3) Q5</td>
<td>11451</td>
<td>903</td>
<td>125</td>
<td>101</td>
<td>122</td>
<td>33.75</td>
</tr>
<tr>
<td>(H3) Q10</td>
<td>11468</td>
<td>892</td>
<td>102</td>
<td>89</td>
<td>147</td>
<td>40.75</td>
</tr>
<tr>
<td>Navlakhi</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(H4) Q1</td>
<td>12972</td>
<td>818</td>
<td>113</td>
<td>87</td>
<td>122.2</td>
<td>27</td>
</tr>
<tr>
<td>(H4) Q5</td>
<td>13197</td>
<td>878</td>
<td>129</td>
<td>101</td>
<td>176.5</td>
<td>30.75</td>
</tr>
<tr>
<td>(H4) Q10</td>
<td>12999</td>
<td>844</td>
<td>102</td>
<td>112</td>
<td>149</td>
<td>27.75</td>
</tr>
<tr>
<td>Bedi bandar</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(H5) Q1</td>
<td>12906</td>
<td>843</td>
<td>112</td>
<td>97</td>
<td>113</td>
<td>17.25</td>
</tr>
<tr>
<td>(H5) Q5</td>
<td>12638</td>
<td>765</td>
<td>145</td>
<td>79</td>
<td>103</td>
<td>32</td>
</tr>
<tr>
<td>(H5) Q10</td>
<td>12946</td>
<td>812</td>
<td>108</td>
<td>74</td>
<td>80</td>
<td>28.5</td>
</tr>
</tbody>
</table>

Q = Quadrat

Habitat 2 Wandi

The Fe concentration at marshy site Wandi was higher than that of all other elements. Its values for Q1 (11,633 mg.kg\(^{-1}\)), Q5 (11,688 mg. kg\(^{-1}\)) and Q10 (11,504 mg.kg\(^{-1}\)) were almost identical (Table 1). Mn was the second major element varying from 841 to 917 mg.kg\(^{-1}\). Ni values fluctuating from 109 to 132 mg.kg\(^{-1}\) were marginally greater than that of Zn (79 to 93 mg.kg\(^{-1}\)), whereas similar and low amounts of Cu (27.75 to 37.25 mg.kg\(^{-1}\))
were recorded in three quadrats. The Pb content in Q5 (73 mg.kg\textsuperscript{-1}) was slightly greater than that in Q1 (54 mg.kg\textsuperscript{-1}) or Q10 (68 mg.kg\textsuperscript{-1}). Thus, the relative order of the metals at this location was alike the previous habitat.

**Habitat 3 Jungi**
Heavy metals composition in sediments at this marshy site, too, (Table 1) showed quite high amount of Fe (11,360 to 11,468 mg.kg\textsuperscript{-1}) and of Mn (892 to 916 mg.kg\textsuperscript{-1}) indicating their dominance. However, Ni, Zn and Cu in three quadrats fluctuated between 102 to 125 mg.kg\textsuperscript{-1}; 89 to 101 mg.kg\textsuperscript{-1} and 33.75 to 40.75 mg.kg\textsuperscript{-1}, respectively. Pb accumulation ranged from 107 to 147 mg.kg\textsuperscript{-1}. These findings were indicative of a little greater concentration of three metals viz., Fe, Cu and Pb in quadrant 10, which was away from the creek and relative accumulation of heavy metals in the habitat followed declining order as Fe > Mn > Ni ≥ Pb > Zn > Cu.

**Habitat 4 Navlakhi**
 Presents data of heavy metals recorded for Navlakhi habitat (Table 1). The Fe content ranging between 12,972 to 13,197 mg.kg\textsuperscript{-1} indicated its greater values than that of any other heavy metals. Mn varied from 818 to 878 mg.kg\textsuperscript{-1} followed by Ni (102 to 129 mg.kg\textsuperscript{-1}), Zn (87 to 112 mg.kg\textsuperscript{-1}) and Cu (27 to 30.75 mg.kg\textsuperscript{-1}). However, concentration of Pb (122.25 to 176.5 mg.kg\textsuperscript{-1}) in sampled quadrats was quite high as compared to that of the last three metals. The order of abundance of different metals at this site was as follows: Fe > Mn > Pb > Ni > Zn > Cu.

**Habitat 5 Bedi bandar**
Results presented in Table 1 showed that marshy sediments at Bedi bandar had extremely high Fe content (12,638 to 12,946 mg.kg\textsuperscript{-1}), as compared to other elements e.g., Mn (765 to 843 mg.kg\textsuperscript{-1}), Ni (108 to 145 mg.kg\textsuperscript{-1}), Zn (74 to 97 mg.kg\textsuperscript{-1}), Cu (17.25 to 32 mg.kg\textsuperscript{-1}), Pb (80 to 113 mg.kg\textsuperscript{-1}). These data were suggestive of minor differences in heavy metals concentration, which in turn, reflected declining order as Fe > Mn > Ni > Pb > Zn > Cu.

**Habitat 6 Madhavpur**
The Fe content in this sandy site was noticeably less than that recorded for all other marshy locations and it was different in Q1 (4892 mg.kg\textsuperscript{-1}), Q5 (5593 mg.kg\textsuperscript{-1}) and Q10 (6089 mg.kg\textsuperscript{-1}, Table 2), respectively. Although Mn concentration in three quadrats (242 to 262 mg.kg\textsuperscript{-1})
Table 2. Concentrations of heavy metals (mg.kg\(^{-1}\)) in halophyte habitats from 3 Sandy sites.

<table>
<thead>
<tr>
<th>Location</th>
<th>Fe</th>
<th>Mn</th>
<th>Ni</th>
<th>Zn</th>
<th>Pb</th>
<th>Cu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Madhavpur</td>
<td>4892</td>
<td>262</td>
<td>43</td>
<td>9.25</td>
<td>88</td>
<td>3.5</td>
</tr>
<tr>
<td>(Q5)</td>
<td>5593</td>
<td>258</td>
<td>58</td>
<td>4.25</td>
<td>86</td>
<td>12.25</td>
</tr>
<tr>
<td>(Q10)</td>
<td>6089</td>
<td>242</td>
<td>65</td>
<td>2.5</td>
<td>73</td>
<td>6.25</td>
</tr>
<tr>
<td>Mul Dwarka</td>
<td>6277</td>
<td>304</td>
<td>57</td>
<td>3.5</td>
<td>112</td>
<td>4.75</td>
</tr>
<tr>
<td>(H7)</td>
<td>6428</td>
<td>337</td>
<td>73</td>
<td>3</td>
<td>148</td>
<td>9</td>
</tr>
<tr>
<td>(Q10)</td>
<td>6460</td>
<td>299</td>
<td>76</td>
<td>7.5</td>
<td>126</td>
<td>10.75</td>
</tr>
<tr>
<td>Gangeshwar</td>
<td>10718</td>
<td>543</td>
<td>91</td>
<td>59</td>
<td>47</td>
<td>26.75</td>
</tr>
<tr>
<td>(H8)</td>
<td>10080</td>
<td>523</td>
<td>81</td>
<td>80</td>
<td>32</td>
<td>28</td>
</tr>
<tr>
<td>(Q10)</td>
<td>10840</td>
<td>544</td>
<td>102</td>
<td>38</td>
<td>29</td>
<td>27</td>
</tr>
</tbody>
</table>

Q = Quadrat

was identical, like Fe, it was obviously less than other habitats. Additionally, Ni, too, varied in a low and close range (Q1 = 43 mg.kg\(^{-1}\); Q5 = 58 mg.kg\(^{-1}\); and Q10 = 65 mg.kg\(^{-1}\)) and Zn (Q1 = 9.25 mg.kg\(^{-1}\), Q5 = 4.25 mg.kg\(^{-1}\) and Q10 = 2.5 mg.kg\(^{-1}\) was noticed in a decreasing order in sampled quadrats. Likewise, low values were recorded for Cu in Q1 (3.5 mg.kg\(^{-1}\)), Q5 (12.25 mg.kg\(^{-1}\)) and Q10 (6.25 mg.kg\(^{-1}\)). The Pb content fluctuated between 73 to 88 mg.kg\(^{-1}\). Thus, the relative order of metals in this sandy habitat was noted as under: Fe > Mn > Pb > Ni > Cu > Zn.

Habitat 7 Mul Dwarka

Compared to marshy habitats, sandy location Mul Dwarka, too, had less Fe (6277 to 6460 mg.kg\(^{-1}\)) in three quadrats, but its amounts were greater than that in preceding sandy site Madhavpur (H6, Table 2). The Mn content fluctuated between (299 to 337 mg.kg\(^{-1}\)); Ni was present in almost similar amounts in Q1 (57 mg.kg\(^{-1}\)), Q5 (75 mg.kg\(^{-1}\)) and Q10 (73 mg.kg\(^{-1}\)); and Zn showed yet lower and closer differences (Q1 = 3.5 mg.kg\(^{-1}\), Q5 = 3 mg.kg\(^{-1}\) and Q10 = 7.5 mg.kg\(^{-1}\)). Likewise, low values of Cu for Q1 (4.75 mg.kg\(^{-1}\)), Q5 (9 mg.kg\(^{-1}\)) and Q10 (10.75 mg.kg\(^{-1}\)) were also recorded. Pb, which was noted between 112 to 148 mg.kg\(^{-1}\), was high here as compared to four marshy and two sandy habitats. Thus, this sandy site contained less amounts of five metals viz., Fe, Mn, Ni, Zn and Cu in sediments than those in all marshy and one sandy sites Gangeshwar (H8). Nevertheless, it had greater concentrations of metals than that in previous sandy location Madhavpur (H6). Furthermore, the Pb content was maximum here as compared with all remaining habitats, except Navlakhi (H4) and relative order of accumulation was slightly different Fe > Mn > Pb > Ni > Cu > Zn.
**Habitat 8 Gangeshwar**

Concentration of Fe was quite high and its amount in three sampled quadrats was as follows: Q1 = 10,718 mg.kg\(^{-1}\); Q5 = 10,080 mg.kg\(^{-1}\); and Q10 = 10,840 mg.kg\(^{-1}\) (Table 2). Mn was observed in a very close range (Q1 = 543 mg.kg\(^{-1}\); Q5 = 523 mg.kg\(^{-1}\); and Q10 = 544 mg. kg\(^{-1}\)). Ni, Zn and Cu fluctuated between 81 to 102 mg.kg\(^{-1}\); 38 to 80 mg.kg\(^{-1}\) and 26.75 to 28 mg.kg\(^{-1}\), respectively. Low accumulation of Pb (29 to 47 mg.kg\(^{-1}\)) was noted. These data showed marginally higher values of heavy metals (Fe, Mn and Ni) in a quadrat 10, that was away from the creek. In addition, concentration of all metals except Pb, were greater here than that of two forgoing sandy habitats.

The data of heavy metals in 24 sediment collections from Kachchh to Diu along upper half of Gujarat coast indicated that the Fe varying between 4,892 mg.kg\(^{-1}\) to 13,369 mg.kg\(^{-1}\), was a main element. It was followed by Mn, with its amounts between 242 mg. kg\(^{-1}\) to 917 mg.kg\(^{-1}\). Ni fluctuating from 43 mg.kg\(^{-1}\) to 145 mg.kg\(^{-1}\), Zn between 2.5 mg.kg\(^{-1}\) to 112 mg.kg\(^{-1}\), and Pb accumulation ranging from 29 mg.kg\(^{-1}\) to 176.5 mg.kg\(^{-1}\) constituted the second major group of heavy metals in halophyte habitats. Cu content varying from 3.5 to 40.75 mg.kg\(^{-1}\) was comparatively low. Moreover, concentrations of major heavy metals were less in two sandy sites viz., Madhavpur and Mul Dwarka.

**DISCUSSION**

**Heavy Metals - Habitats**

Heavy metals level in soils often result from anthropogenic activities such as mining, smelting, electroplating, agriculture practices, and industrial and municipal waste disposal on land (Errasquin and Vazquez, 2003; Ait Ali et al., 2004; Yang et al., 2004).

Results of heavy metals in 24 soil samples presently collected from 8 locations in upper half of Gujarat coast showed that Fe and Mn were major elements and their concentrations varied between 4892 to 13,369 mg.kg\(^{-1}\) and 242 to 917 mg.kg\(^{-1}\) in 5 marshy and 3 sandy habitats. While 5 marshy locations showed concentration between 11,360 to 13,369 mg.kg\(^{-1}\) and 667 to 917 mg.kg\(^{-1}\) for Fe and Mn, respectively. For sandy site Fe value fluctuated between 4892 to 10,840 mg.kg\(^{-1}\) and that of Mn 242 to 544 mg.kg\(^{-1}\). Ramanathan et al. (1999) reported very high amount of Fe (2910 mg.kg\(^{-1}\)) as compared to Mn (385 mg.kg\(^{-1}\)) in salt marsh habitat at Pichavaram on east coast of India. Similarly, Carrasco et al. (2006) noticed yet greater concentrations of Fe ranging from (2490 to 17,660 mg.kg\(^{-1}\)) and that of Mn between (153 to 448 mg.kg\(^{-1}\)) for 4 different contaminated salt marsh sites in Spain.

Milic et al., (2012) found concentration of Fe between 3000.53 to 4100.8 mg. kg\(^{-1}\) and of Mn varied from 479.73 to 748.91 mg.kg\(^{-1}\) was on Maritime Saline and Inland Saline areas of mediterranean coast in motenegro and in the pannonian plain in Serbia. (Talekar et al., 2014) reported concentration of similar Fe from 12,430 to
12, 629 mg.kg\(^{-1}\) and of Mn between 903 to 1,179 mg.kg\(^{-1}\) on the Bhal eco-region from Bhavnagar west coast of India at Gujarat. Our results were in conformity with few investigations reported earlier by some authors.

In this study, concentrations of Ni, Zn and Cu at 5 marshy sites fluctuated between 90 to 145 mg.kg\(^{-1}\), 74 to 112 mg.kg\(^{-1}\) and 17.25 to 40.75 mg.kg\(^{-1}\), respectively, while in case of sandy habitats, amounts of Ni were noted in a range of 43 to 102 mg.kg\(^{-1}\); than that of Zn between 2.5 to 80 mg.kg\(^{-1}\); and Cu between 3.5 to 28 mg.kg\(^{-1}\).

Yoon et al. (2006) found less Cu content (2 to 3 mg.kg\(^{-1}\)) during their studies on 10 sites in Florida. Nevertheless, the Florida sites also noticeably less concentration of Zn (195 to 220 mg.kg\(^{-1}\)) than that observed during present investigation. On the other hand, Carrasco et al. (2006) reported 4 to 16 mg.kg\(^{-1}\) of Cu and 12.5 to 145.1 mg.g\(^{-1}\) of Zn for four locations in Spain.

Ramnathan et al., (1999) observed low content of Cu (0.024 mg.kg\(^{-1}\)) as well as of Zn (0.05 mg.kg\(^{-1}\)) in natural habitat of mangroves and salt tolerant plants. According to Luoma (1990) and De Lacerda et al. (1993), Zn often occurs in high concentrations in polluted estuarine sediments, typically up to 0.8 mg.kg\(^{-1}\).

Studies on coastal habitats in India indicate that marshy locations in Orissa contained 0.063 mg.kg\(^{-1}\) of Cu and 0.015 mg.kg\(^{-1}\) of Zn (Sarangi et al., 2002); while that found on Kerala coast showed 0.303 mg.kg\(^{-1}\) of Cu and 0.764 mg.kg\(^{-1}\) of Zn (Thomas and Fernandez, 1997). Earlier, Nirmal Kumar et al. (2006) recorded most abundant of Zn (55.4 mg.kg\(^{-1}\)) and low concentration of Cu up to (3.3 mg.kg\(^{-1}\)) in sediments collected from Nal Sarovar in Gujarat.

Zahir et al. (2004), while working on Karachi coast in Pakistan, noted 0.012 to 0.056 mg.g\(^{-1}\) of Cu and 0.035 to 0.067 mg.g\(^{-1}\) of Zn in salt marshes. Zheng and Lin (1996) observed 3.6 mg.kg\(^{-1}\) of Cu and 9.9 mg.kg\(^{-1}\) of Zn from salt marsh sites in China. Talekar (2009) noted low concentrations of Ni (115 to 144 mg.kg\(^{-1}\)); Zn (9.6 to 12.4 mg.kg\(^{-1}\)); and of Cu (7.6 to 11 mg. kg\(^{-1}\)) in marshy areas of ‘Bhal’ eco-region. Milic et al., (2012) indicated concentrations of Ni (44 to 223.86 mg.kg\(^{-1}\)), Zn (77 to 97.2 mg.kg\(^{-1}\)) and of Cu (28.33 to 45.94 mg.kg\(^{-1}\)) in maritime saline and inland saline area at Serbia.

Pb fluctuated between 54 to 176.5 mg.kg\(^{-1}\) for 5 marshy habitats; and 29 to 148 mg.kg\(^{-1}\) for 3 sandy locations. Reboreda and Cacador (2007) observed lower availability of Pb (5.75 to 9.70 mg.kg\(^{-1}\)) in the sediment of salt marsh site. However, the Pb content (0.8 mg.g\(^{-1}\)) reported for a nearby at Nal Sarovar Bird Sanctuary (Nirmal Kumar et al., 2006) is in conformity with present results.

**CONCLUSION**

It can be concluded from above discussion that marshy locations of other countries contain greater amounts of all metals, except that of Pb, when compared to Indian coastal sites, perhaps because of their contaminated nature. As for Indian habitats, no consistency in the metallic composition appears to exist, as the value varies for different locations.
In sum, it can be said that although upper half of Gujarat coast from Kachchh to Diu (Saurashtra coast) has showed high concentrations of the heavy metals, and concentration be arranged in a decreasing order as follows: Fe > Mn > Ni > Zn > Pb > Cu.

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REFERENCES


