Impact of September 2014 Floods on Sediment Quality of Himalayan Jhelum River Kashmir

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***Abstract* - September 2014 unprecedented floods in Jammu & Kashmir tell the story of human gloom not witnessed by this state in over 100 years. The damage caused by the flood was enormous. Kashmir suffered losses in excess of one trillion INR. River Jhelum overflows played a major role in the devastation of Kashmir in general and Srinagar city in particular. The relation between the magnitude of a flood and the resulting environmental impacts remains unclear. This investigation examines the impact of the flood on heavy metal deposition in the Jhelum river sediments and relative change in physico-chemical and heavy metal content in pre and post flood seasons. There was a significant variability in physico-chemical parameters and heavy metal content with different sites, but overall concentration of heavy metals were found to get enriched and increased in post flood season. River Jhelum sediments were assessed for physico-chemical characteristics (pH, EC, Ca, Mg, N, P, K, Na, Cl and S) and heavy metal content (Cd, Cr, Cu, Mn, Fe, Ni, Pb and Zn) in pre and post flood seasons at six sites along its whole stretch from Verinag to Baramulla. Two sampling sites each were selected in three different zones of the river viz, upstream, middle stream and downstream. In post flood season, physico-chemical parameters and trace element content was found to get increased drastically except for pH, which showed a slight decline in post flood season.**

Keywords: Flood, Heavy metals, Jhelum river, Kashmir

INTRODUCTION

Catastrophic events of large magnitude are very rare and their occurrence provides a special opportunity to better understand a system in an extreme state. The environmental impact of floods, especially large floods, with respect to contaminants such as herbicides, pesticides, nutrients and heavy metals are poorly understood [1]. Heavy metals are among the most comprehensively studied contaminants in fluvial environments [2,3,4]. The primary source of contamination by heavy metals following a flood is the contamination of sediments on the floodplain. The spatial and seasonal distribution of heavy metals in floodplain sediments is often noted to increase in the downstream direction [5,6]. Flooding often decreases the concentration of heavy metals in rivers because of the large volume of water and dilution from the addition of non-contaminated sediment [7]. The event provided a unique opportunity to evaluate the environmental impact of an extreme and rare event. Given the magnitude of the flood and the nature of the many industrial, agricultural and residential sites that were flooded, it is reasonable to question if sediments deposited by the flood were contaminated with heavy metals, and if so, was there enough contamination to constitute an environmental concern. These questions are addressed by evaluating the concentration of environmentally sensitive heavy metals, As, Cr, Cu, Ni, Pb, Zn in sediment deposited by the flood.

It was observed that intense rains in the state from 1 to 7th September 2014 that caused the floods. The causes of too much rainfall were the combined effect of the western disturbances (WD) and its interaction with monsoon rains over Jammu & Kashmir. In the aquatic environment 90 per cent of the trace element content is linked with the suspension of river sediments [8]. The flood events affect the processes taking place in the river sediments [9]. The change in physicochemical conditions that occurs in the sediments at that time affects the release of trace elements and their introduction to the environment [10,11,12]. These phenomena are governed by the following processes: desorption/sorption, dissolution/ precipitation, coagulation and complexing reactions [13]. It has been stated that the mobility of trace elements in sediments is conditioned to the largest extent by physicochemical parameters and organic matter content [14,15]. The availability of trace elements accumulated in the sediments depends on their binding affinity with sediment [16]. The total contents of trace elements do not have the same content as the actually available ones that intimidate the environment [17, 18]. These forms may be released to water as a result of a rapid change in physicochemical characteristics of the sediments that is mainly pH [19].

As a result of inundating the sediments during flood, the aerobic environment may change into anaerobic and consequently, a slow and stable decrease in pH may occur [14]. pH strongly influence the decrease of trace element dissolution properties in sediment inundation. In the aerobic environment, Mn, Fe, and S occur in oxidized forms, which are indirectly linked to low pH values [19]. In the immobilization of trace elements, the hydrated oxides play a vital role. They are found to be sparingly soluble [20] and they affect the immobilization of trace elements

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by their sorption [21]. The aim of this paper was to determine the changes in the physicochemical chemical parameters available from contents of Cd, Cr, Cu, Ni, Pb, Co, Mn, Mo, Fe B As and Zn in sediments of Jhelum river following September floods 2014.

STUDY AREA

The principal river of the Kashmir valley is the Jhelum, locally called as *Veth*. Starting from its origin at the Verinag spring, the Jhelum continues its 241 Km long journey through the valley and enters Pakistan. There are several tributaries and nallahs such as, Sandran, Brang, Arapat kol, Lidder, Arapal, Harwan, Sindh, Erin, Mudhumati, Pohru and Vijidakil, Vishav, Rambria, Romshi, Doodhganga, Ferozpura and Ningal that contribute to river Jhelum. The sampling sites have been selected on the basis of geography, settlements, agricultural land, urban, rural and commercial areas along either banks of river Jhelum (Fig.1). The sampling sites have been divided into three regions:

Upstream: [Site 1 (Chinigund Verinag), Site 2 (Zirpara Bridge Bijbehara)]

Middle Stream: [Site 3 (Zero Bridge Srinagar), Site 4 (Qamarwari Bridge Srinagar)]

Down Stream: [Site 5 (Ningli Sopore), Site 6 (Cement Bridge Baramulla)]

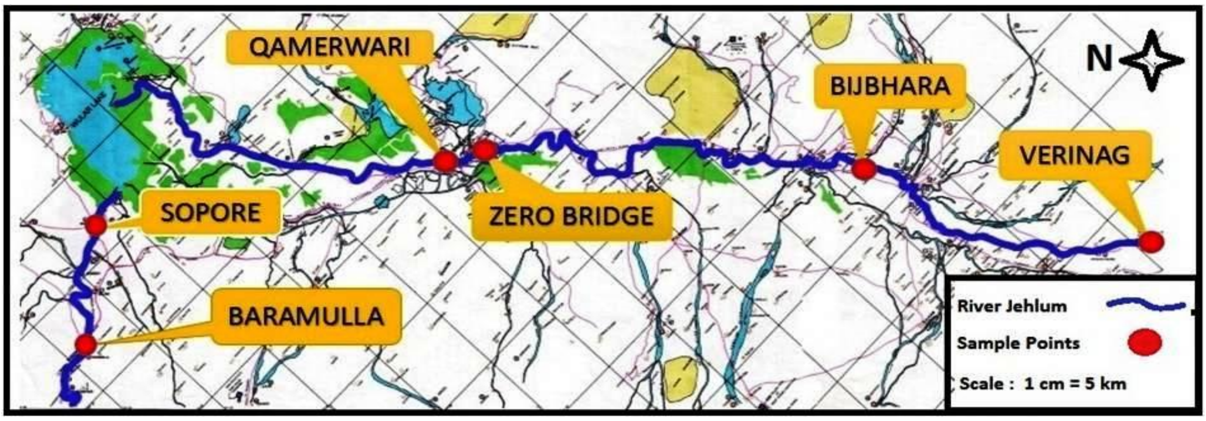

Fig. 1. Study area map showing sampling sites

MATERIALS AND METHODS

Sediment samples were collected in replicates from each selected site with the help of Rickley Ekman grab (Model, 43) on seasonal basis. The collected sediment samples were dried in shade. During drying process, lumps were broken by wooden mallet. The rocky lumps were discarded. The sediment sample then passed through 2 mm sieve and packed into labeled polythene bags. The contamination of sediment sample with any foreign material was totally avoided with great care. Two types of sediment water extracts were prepared for analyzing various parameters, 1:4 sediment water extract was prepared for estimation of Mg, Ca and Cl and 1:2 sediment water extract was made for pH and electrical conductivity. Similarly 1 N ammonium acetate extract was made for analysis of Na and K. Standard APHA methodology was adopted to estimate the physico-chemical parameters of sediments [22]. For heavy metal estimation, 10 g of each dried and sieved sediment samples was digested with repeated addition of nitric acid and hydrogen peroxide. The resultant digestate was reduced in volume and then diluted to a final volume of 50 ml with distilled water. Again the samples were evaporated to 5 ml for final estimation. The elements (Fe, Mn, Zn, Cu, Cd, Cr, Mo, Pb, As, Ni, B and Co) were determined by Varian Vista MPX- ICP-OES at Research Centre for residue and Quality Analysis (RCRQA), SKUAST-K. The reagents used in the analyses were analytically ultra pure (Millipore, France). Standard solutions were prepared using Merck commercial standards for ICP-OES (Merck, Darmstadt, Germany). The accuracy of trace elements measurement was determined on the basis of certified reference material with a recovery rate of (%): 98.4 for Cd, 98.1 for Cr, 97.8% for Cu, 97.3% for Ni, 98.4 for Pb, 97.2 for B, 99.2 for As, 96.8 for Mo, 97,5 for Mn, 99.1 for Co,98.7 for Fe and 98.1% for Zn. The statistical analysis of the observations was performed in MS-Excel and Statistica v. 8.0 programmes. The obtained results were tested at 5% level of significance.

RESULTS AND DISCUSSION

During the present study, the various physico-chemical characteristics appeared to follow a definite trend, but some of them showed a fluctuating behaviour over time. During the current study the pH of the sediments at six sites was neutral to slightly alkaline. But pH at Qamarwari site was slightly acidic (6.05). The maximum pH of 8.1 was recorded in pre flood period in the month of summer at Verinag sampling site and minimum pH of 6.05 was found in post flood period in spring season at Qamarwari sampling site. The low pH at Qamarwari site to discharge of effluents (sewage, commercial wastes and other solid wastes) from surrounding areas as sewage and other effluents lower the pH of the sediments [23] (Fig. A). Most reductive reactions inside aquatic ecosystem release H^+, which results in pH decrease in river sediments [14]. High

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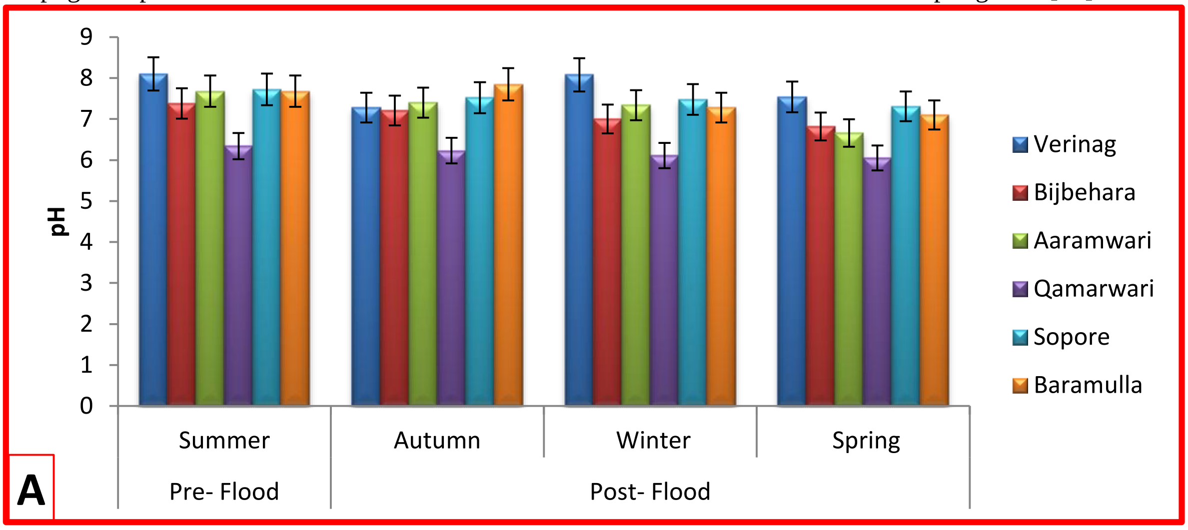
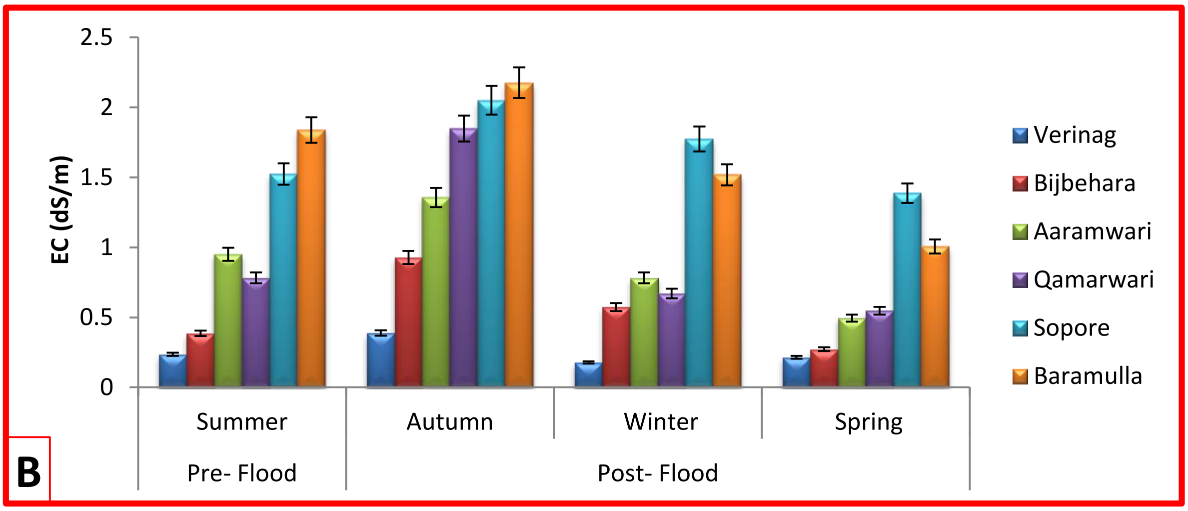
concentration of CO_2 and other organic acids released from organic matter and comparatively low precipitation of $CaCO_3$ in sediments also decrease the pH, due to presence of salts, which upon hydrolysis replaces Al ions and release H^+ in sediments [14,24].

The maximum electrical conductivity of 2.17 ds/m was observed at Baramulla sampling site in post flood season and the minimum of 0.17 ds/m was recorded at Verinag sampling site in post flood period (Fig. B). The lower conductivity at Verinag in all the seasons may be due to more exchange of ions between sediments and overlying water at the site. Furthermore this site is completely free from anthropogenic pollution as this site is the source spring of river Jhelum. The increase in conductivity in post flood season may be attributed to increase in pollution level in the river due to floods as flood water entered in commercial, rural and urban settlements and washed wastes from punctual and non punctual sources [25].

Available nitrogen content was found to get increased in the post flood season with a maximum value of 2.72 mg/kg at Sopore site (Fig. E). The abrupt increase in nitrogen content in downstream region may be mainly attributed to run off from agricultural lands from the catchment during floods. The lower nitrogen at Verinag site was due to low impact of floods as this site is located at relatively higher altitude than rest of the sampling sites [23].





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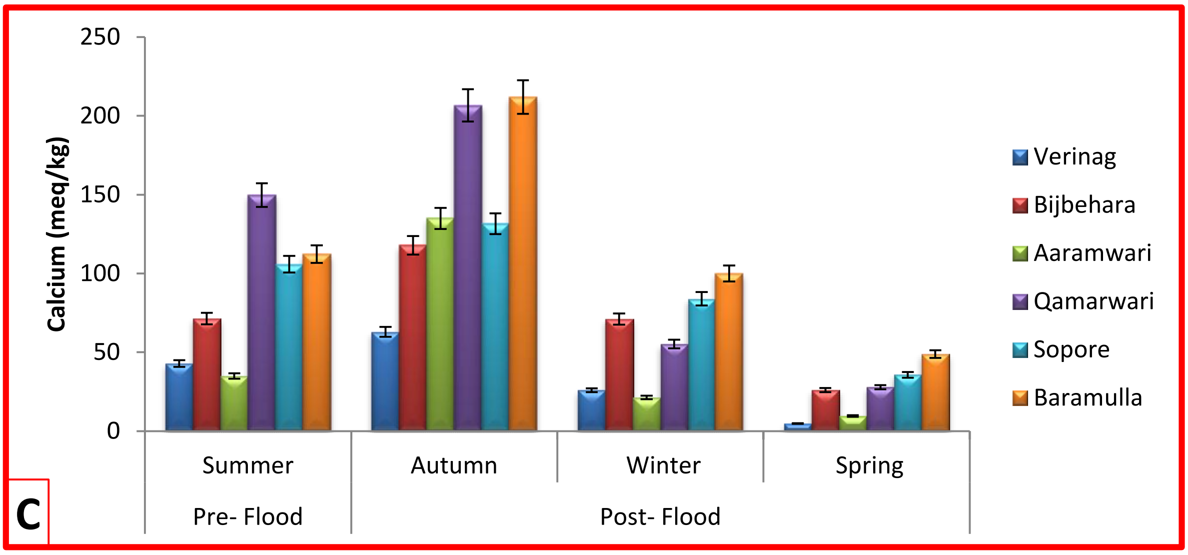
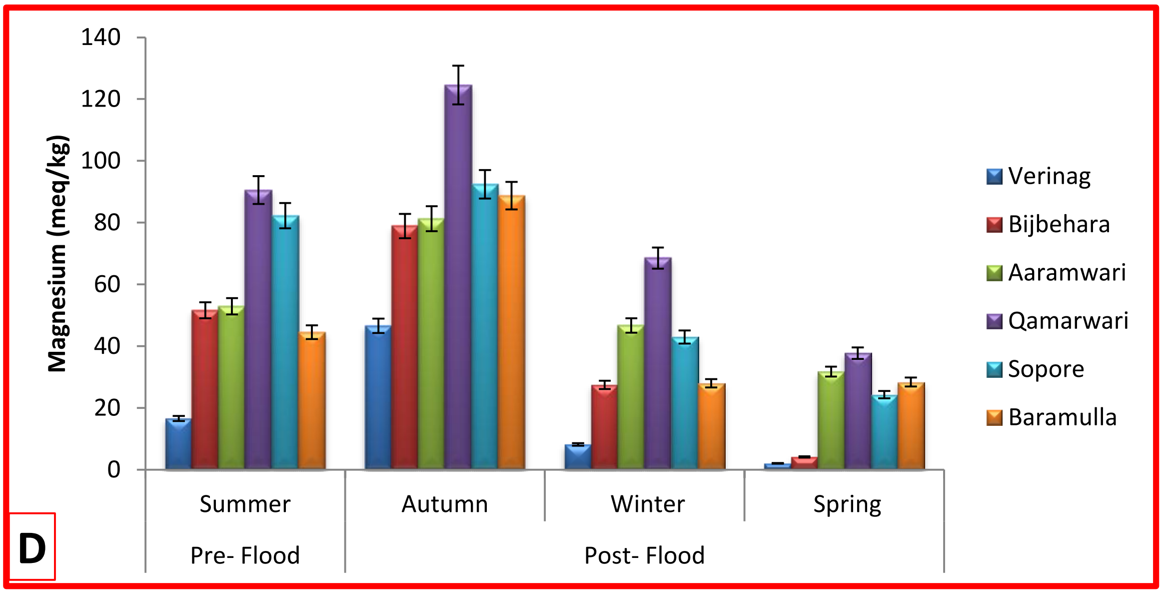
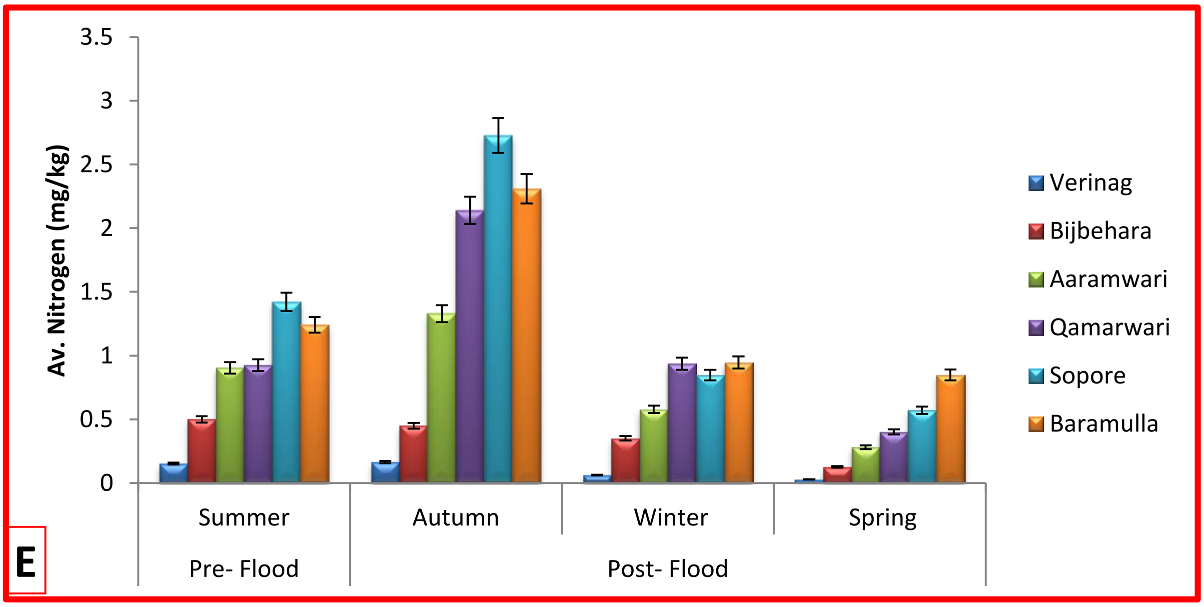
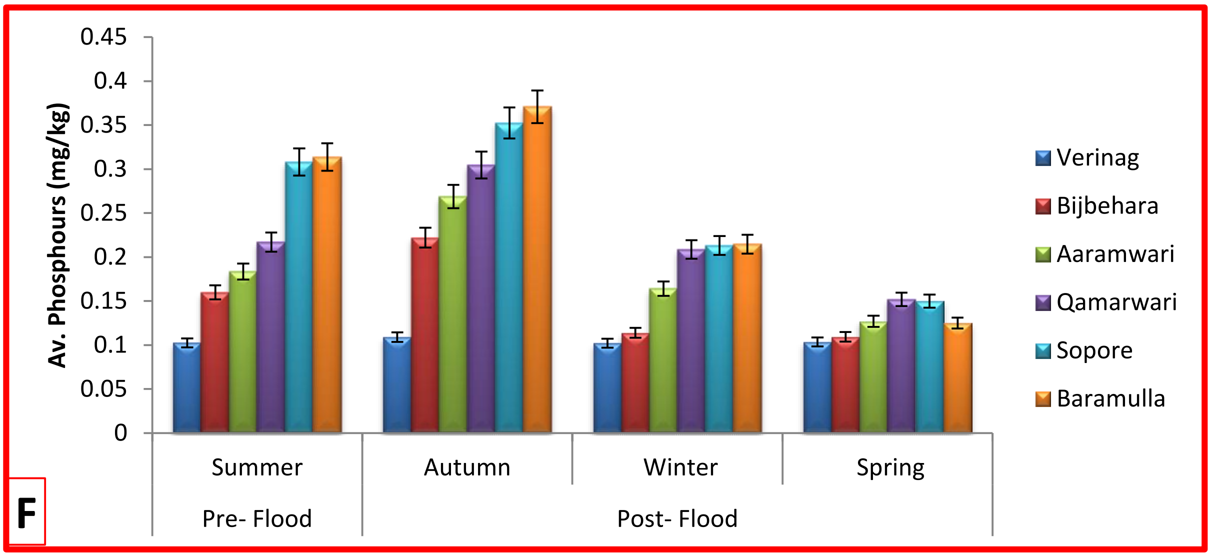
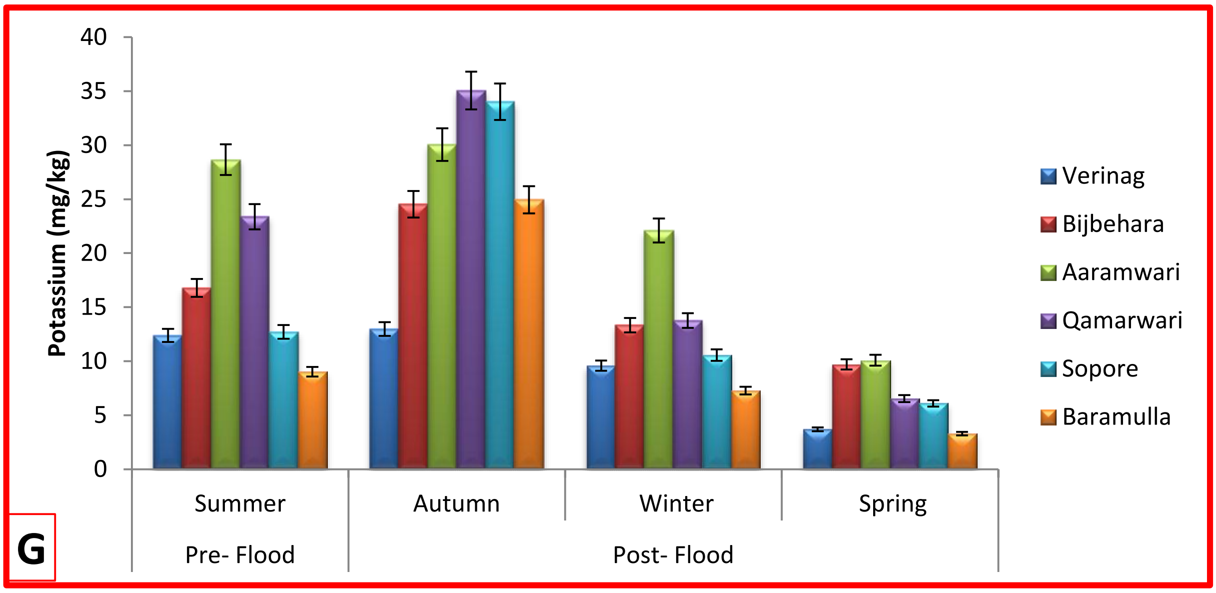
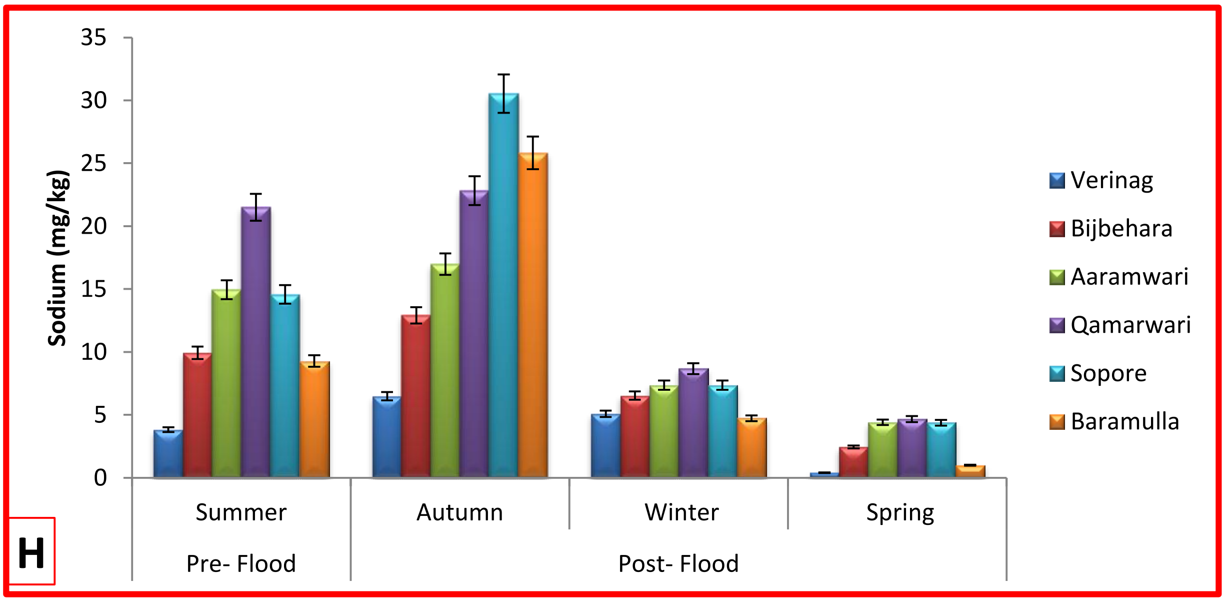


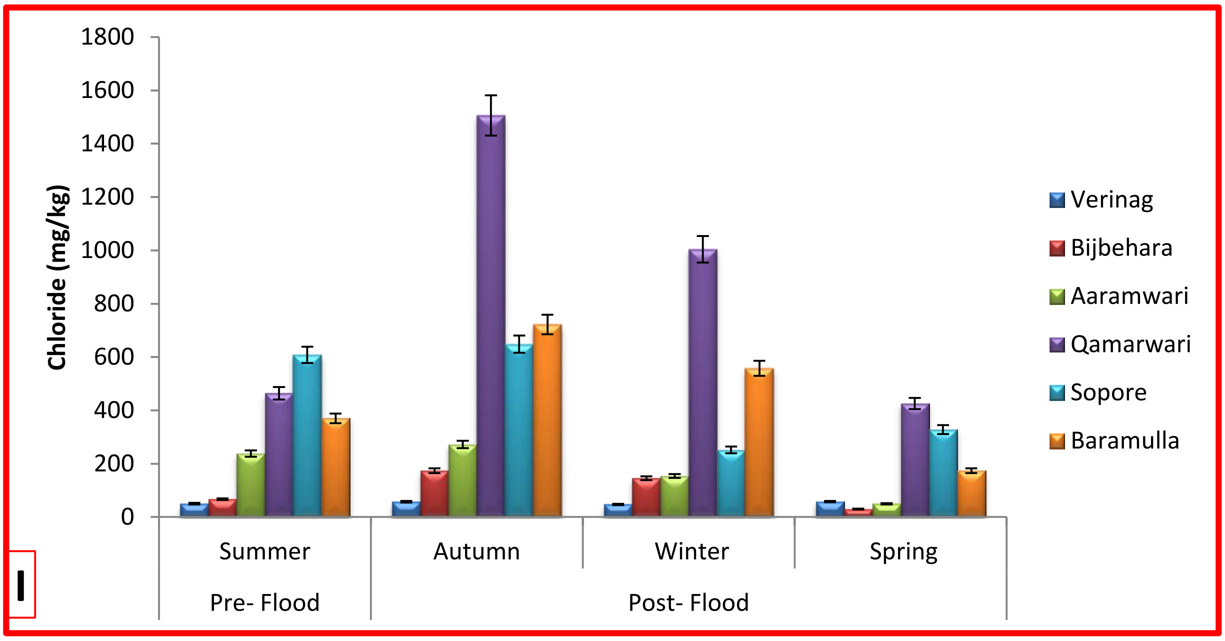


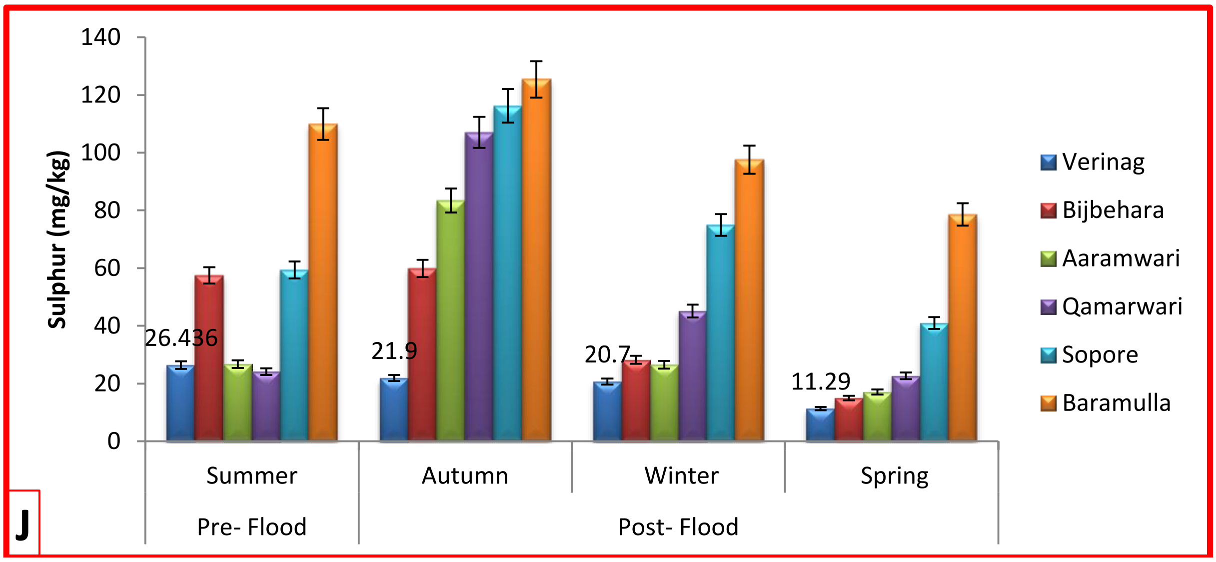



0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Av. Phosphours (mg/kg)
Summer
Autumn
Winter
Spring
Pre- Flood
Post- Flood
Verinag
Bijbehara
Aaramwari
Qamarwari
Sopore
Baramulla
F


40
35
30
25
20
15
10
5
0
Potassium (mg/kg)
Summer
Autumn
Winter
Spring
Pre- Flood
Post- Flood
Verinag
Bijbehara
Aaramwari
Qamarwari
Sopore
Baramulla
G


35
30
25
20
15
10
5
0
Sodium (mg/kg)
Summer
Autumn
Winter
Spring
Pre- Flood
Post- Flood
Verinag
Bijbehara
Aaramwari
Qamarwari
Sopore
Baramulla
H





Like nitrogen, phosphorus is also important nutrient found in the sediments and plays an essential role in the processes of its transformation and accumulation in aquatic ecosystems [26]. Available phosphorus was recorded maximum at Baramulla site with a value of 0.37 mg/kg (Fig. F) and lower values were again recorded at Verinag site of the study area. The comparatively higher phosphorus concentration at downstream sampling sites may be from non punctual pollution sources and agricultural runoff from the nearby catchments as organic compounds and its decomposition are the major mechanisms affecting he distribution pattern of phosphorus in sediments [27]. The domestic wastes discharged into the river also have the potential to increase the phosphorus concentration in sediments [26,28,29,30].

Chloride during the present study was found from a minimum value of 50.23 mg/kg at Verinag sampling site to a maximum value of 1506 mg/kg at Qamarwari site in post flood season (Fig. I). The chloride content showed an abrupt increase in autumn season of the post flood period and started decreasing towards winter and spring seasons. The higher Cl content in post flood period may be due to contribution from punctual and non punctual sources containing solid wastes and sewage [31].

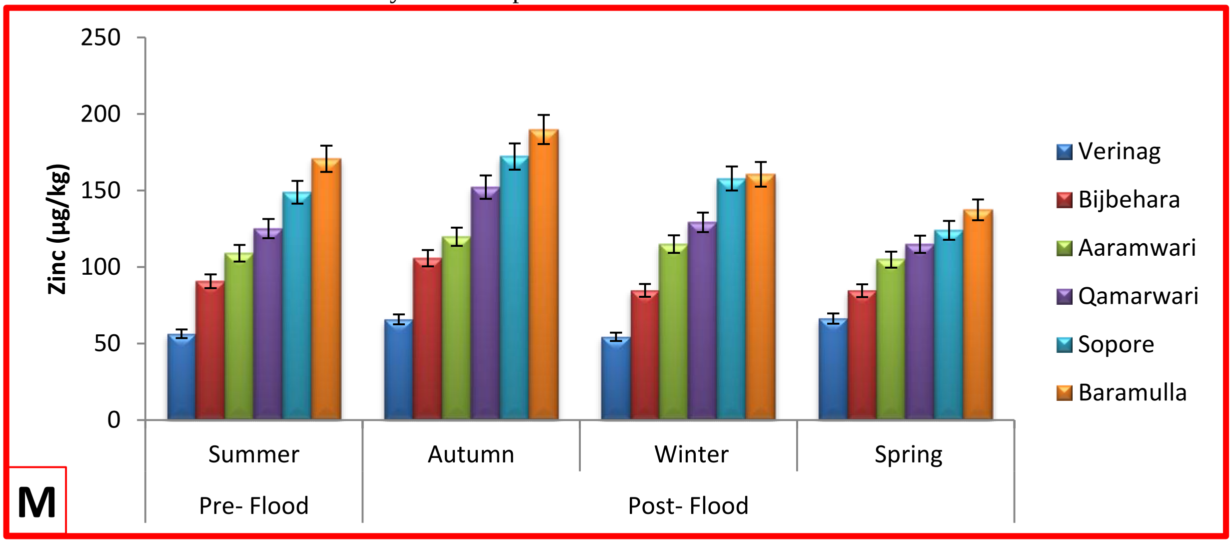
Among the cations calcium and magnesium were found dominant as compared to potassium and sodium the overall cationic order being Ca > Mg > K > Na. Soluble Ca content was recorded maximum at Baramulla site in downstream in post flood season period with a value of 211.96 meq/kg and maximum magnesium content was recorded in post flood season at Qamarwari site with a value of 124.56 meq/kg (Fig. C, D, G, H). The higher concentration at these sites may be due to floods and biogenic precipitation [32].

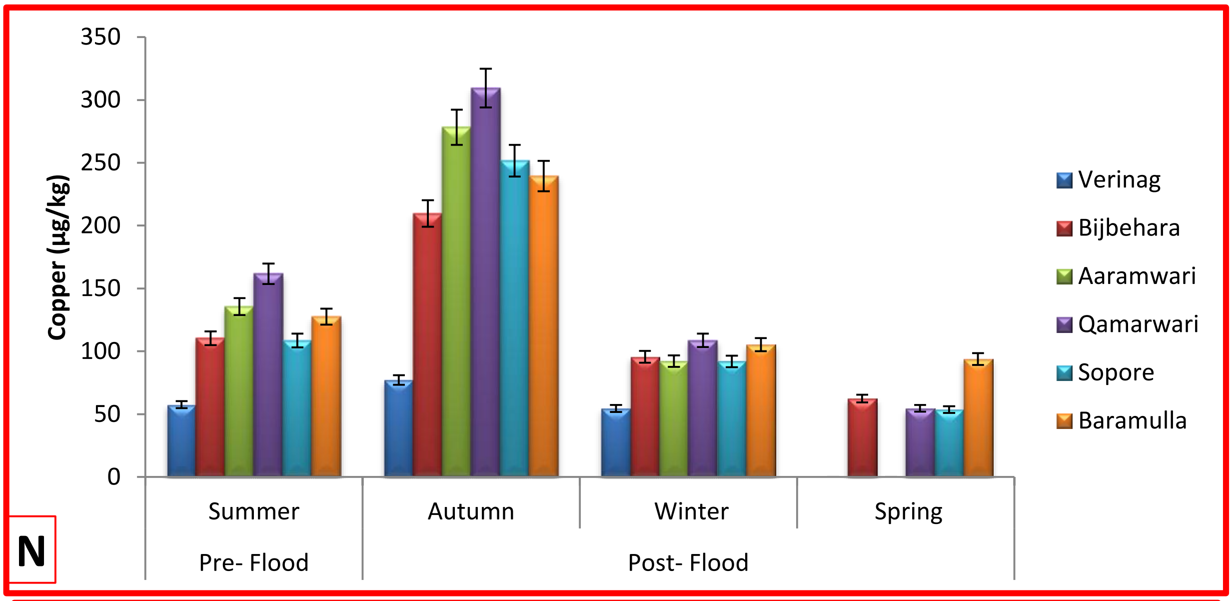
The potassium and sodium mainly comes into sediments as a weathering product of minerals and sewage [33]. Sodium content was recorded maximum at Sopore site in downstream in post flood season period with a value of 30.5 mg/kg and maximum potassium content was recorded in post flood season at Qamarwari site with a value of 35.05 mg/kg. The relatively less concentration of Na and K can be attributed with their solubility. Increase in content of

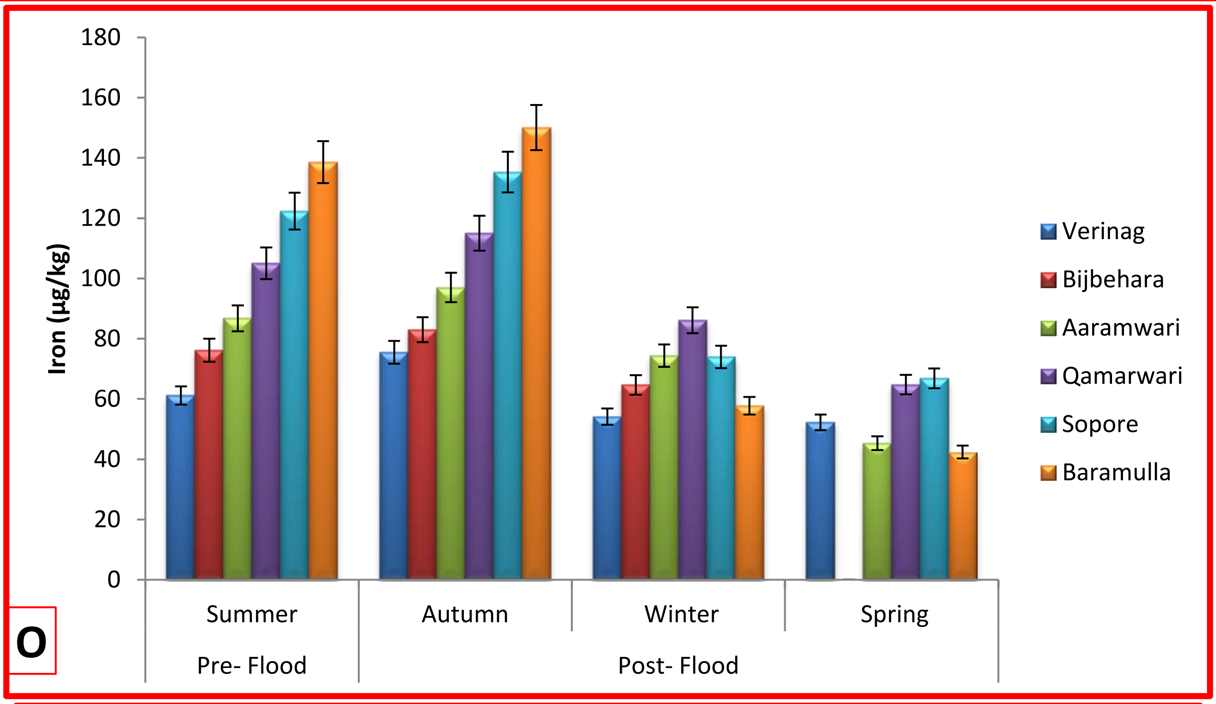
Ca and Mg can also be attributed to biological activity, erosion and allocthonous inputs.
Sulphur during the present study was found from a minimum value of 11.29 mg/kg at Verinag sampling site to a maximum value of 125.4 mg/kg at Baramulla site in post flood season (Fig. J). The sulphur content showed an abrupt increase in autumn season of the post flood period and started decreasing towards winter and spring seasons. The higher Cl content in post flood period may be due to contribution from punctual and non punctual sources containing solid wastes and sewage [31].

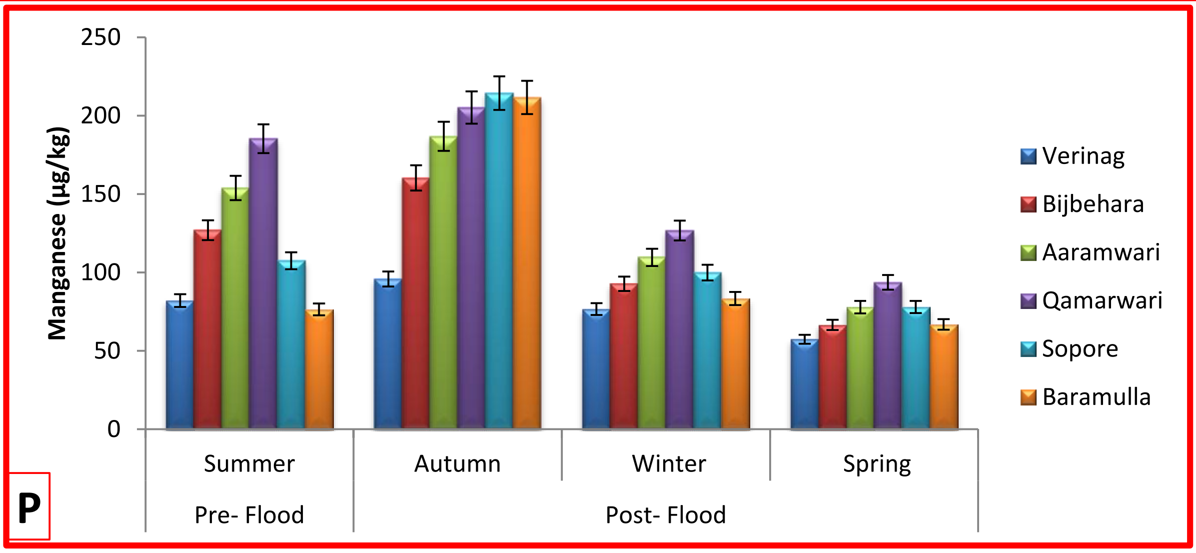
HEAVY METALS

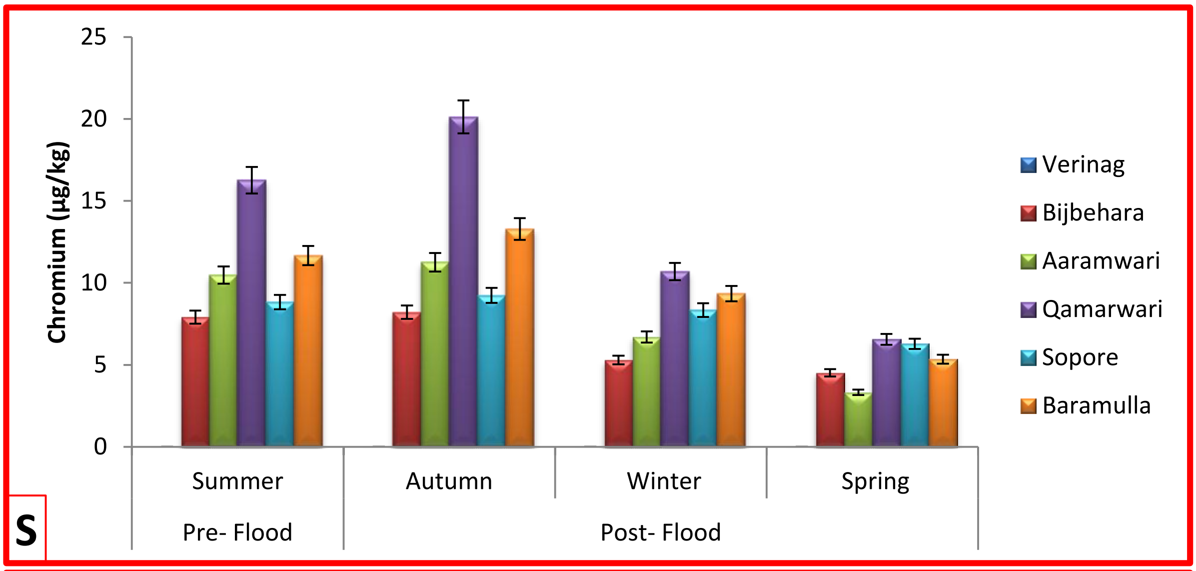
Heavy metal content in river Jhelum sediments varied significantly. There was no correlation between heavy metal concentration and sampling sites, presumably because heavy metals in this case were diffused from non-point and non punctual sources. Samples collected from Qamarwari showed significantly higher levels of most of the heavy metals. It was assumed that this sampling site was contaminated from urban and industrial wastes. In the samples of fluvial sediments collected in 2009, the highest maximum contents were determined for B (194 µg/kg), As (0.22 µg/kg), Zn (189 µg/kg), Cu (309.45 µg/kg), Fe (150.10 µg/kg), Mn (240.14 µg/kg), Ni (35.82 µg/kg), Cr (20.13 µg/kg), Mo (291.56), Cd (10.04 µg/kg), Co (12.14 µg/kg), Pb (346.01 µg/kg) (Fig. M, N, O, P, S , U, W).
The increase in the contents of the studied metals in sediments after flood may be indirectly caused by the decreased pH values and, consequently, the decreased solubility of Fe and Mn. The hydrated oxides of Fe and Mn may affect the mobilization of metals by their sorption [35]. It should be underlined that the pH relation and metal availability are also influenced by other factors, such as buffer capacity of sediments, microbiological activity and diagenetic processes [36,37]. This finding is partly inconsistent with the results of studies conducted in the Middle Odra river [38]. These studies revealed that the flood sediments of Jhelum river investigated in pre and post flood period were characterized by high, statistically significant, concentrations of all heavy metals. It is also indicated that during massive floods, pollutants originating from punctual and non-punctual sources get absorbed and adsorbed in river sediments and intern lead to increase in heavy metal content in sediments [39]. As a result, the changes in the concentrations may be minor and difficult to determine.
Heavy metal concentrations of the Jhelum river sediments yielded mixed results which are dependent on the reference to which they are compared. The magnitude of the flood was a likely factor in the overall low heavy metal concentrations through dilution of point source and non-point source contaminants. Some concentrating of metals did occur as seen by comparison with background levels. Both the inclusion of anthropogenic sources and the selective concentration of fine-grained sediment in the flood deposits are likely causes of the enrichment over background levels. The amount of sediment deposited on the floodplain resulting from an extreme flood is more sensitive to event sequencing, flood duration, and sediment availability than the magnitude of the flood. Heavy runoff from catchment area initially activated sediment stored on hillslopes and channels throughout the basin.

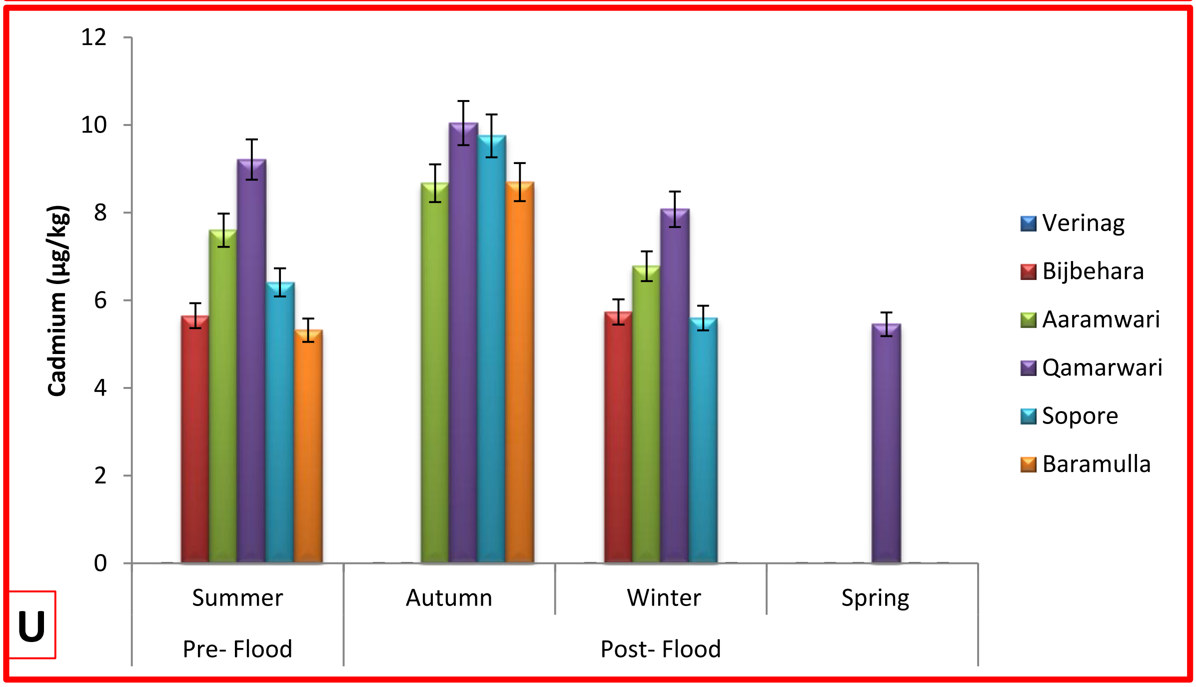


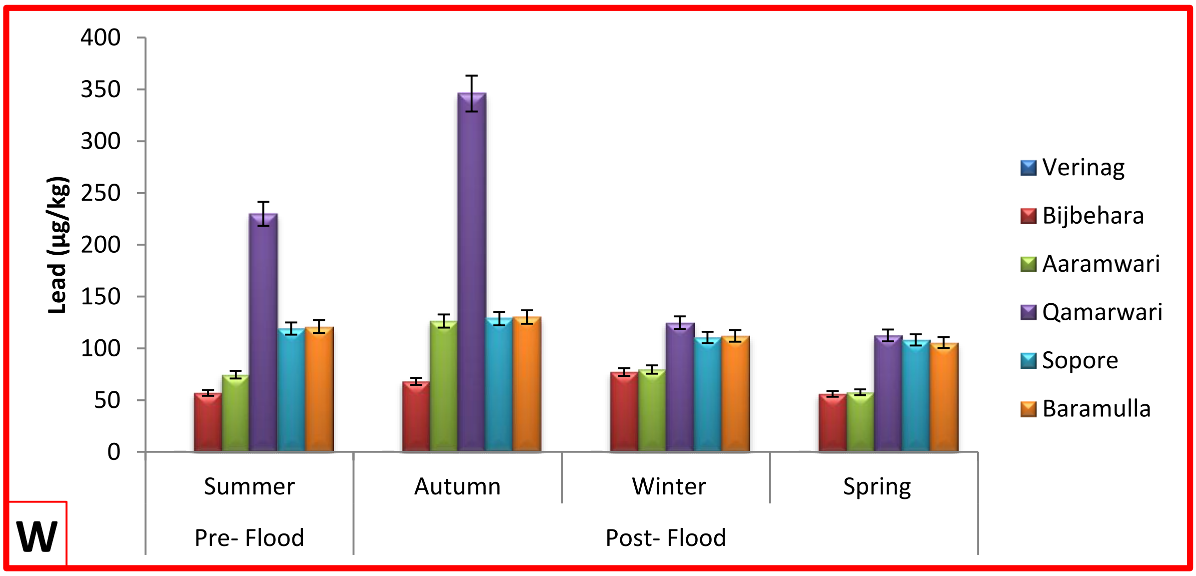

Copper (µg/kg)
350
300
250
200
150
100
50
0
Summer
Autumn
Winter
Spring
Pre- Flood
Post- Flood
Verinag
Bijbehara
Aaramwari
Qamarwari
Sopore
Baramulla
N


Iron (µg/kg)
180
160
140
120
100
80
60
40
20
0
Summer
Autumn
Winter
Spring
Pre- Flood
Post- Flood
Verinag
Bijbehara
Aaramwari
Qamarwari
Sopore
Baramulla
O


Manganese (µg/kg)
250
200
150
100
50
0
Summer
Autumn
Winter
Spring
Pre- Flood
Post- Flood
Verinag
Bijbehara
Aaramwari
Qamarwari
Sopore
Baramulla
P


Chromium (µg/kg)
25
20
15
10
5
0
Summer
Autumn
Winter
Spring
Pre- Flood
Post- Flood
Verinag
Bijbehara
Aaramwari
Qamarwari
Sopore
Baramulla
S


Cadmium (µg/kg)
12
10
8
6
4
2
0
Summer
Autumn
Winter
Spring
Pre- Flood
Post- Flood
Verinag
Bijbehara
Aaramwari
Qamarwari
Sopore
Baramulla
U


Lead (µg/kg)
400
350
300
250
200
150
100
50
0
Summer
Autumn
Winter
Spring
Pre- Flood
Post- Flood
Verinag
Bijbehara
Aaramwari
Qamarwari
Sopore
Baramulla
W

CONCLUSIONS

The obtained findings reveal the role of flood as a potential agent carrying significant amounts of heavy metals, as well as influence of change of physico-chemical characteristics on their availability. In the samples of sediments collected after the September flood of 2014, the statistically significant increase in the total contents of heavy metals at all selected sites. Moreover, the current concentrations of the studied trace metals are not strongly correlated with their total contents.

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