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# Seasonal and Spatial Assessment of Surface Sediments Collected from River Jhelum of Kashmir Valley

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**ABSTRACT**
*A fundamental investigation of Jhelum river sediment was conducted to determine its quality characteristics from summer 2014 to spring 2015 in order to assess the effect of anthropogenic activities along either sides of river Jhelum including its catchment area. The results revealed that physico-chemical attributes of Jhelum river sediments get strongly influenced by seasonal and spatial variations due to change in flow rate and the nature of pollutant inputs. Six sampling sites in three discrete regions were selected along its stretch from Verinag (Source) to Baramulla. The sediments were slightly alkaline except at Qamarwari site, where slightly acidic pH was observed. Among the cations Calcium and Magnesium were found dominant as compared to potassium and Sodium, the overall cationic order being Ca > Mg > Na > K. Among the anions Chloride was found to be dominant. Available nitrogen and phosphorus were found to get increased from upstream to downstream with maximum values at Baramulla. Overall the quality parameters of sediments showed a significant trend among sites and seasons, however, most of the parameters showed peak values at Qamarwari site, which receives tremendous sewage inputs from Srinagar city. Furthermore urban sites showed peak values for all parameters as compared to rural area sites.*
***Keywords:*** *Jhelum River, Sediment, Quality parameters, Pollution*

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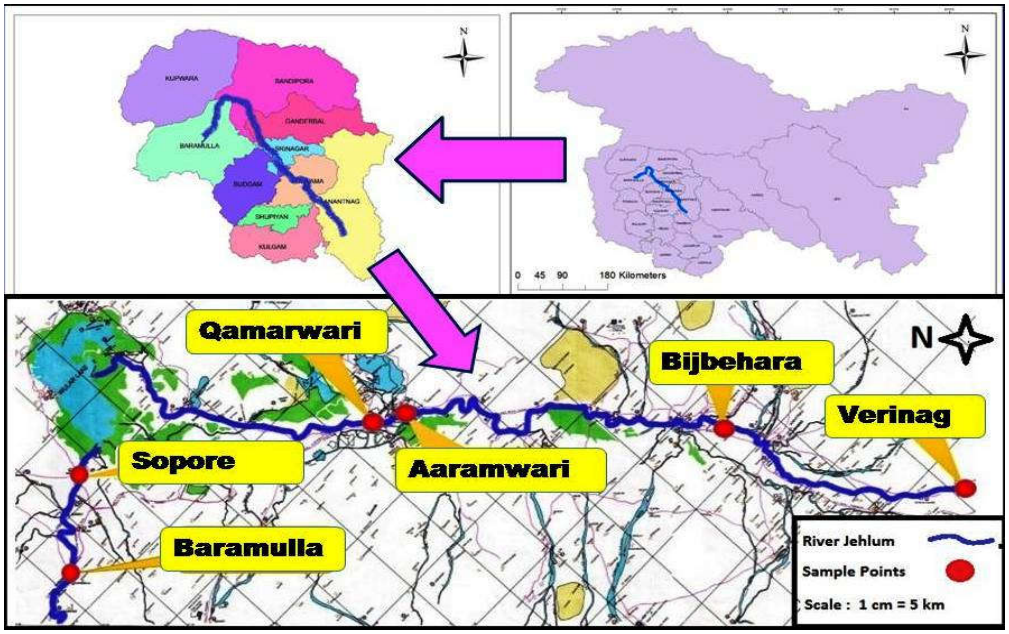
## INTRODUCTION

The physicochemical attributes of any water body are of great ecological importance especially in lotic ecosystems that are prone to seasonal, temporal and spatial fluctuations. Studies on quality characteristics carried out in various rivers have normally focused on the water quality characteristics with little or no consideration given to the bottom surface sediment quality [1,2,3]. River sediments have been identified as ideal habitats of several aquatic organisms and also act as sink for both domestic and industrial wastes originating from anthropogenic activities. Dumping of such wastes could completely alter the ecological balance of these ecosystems. Contaminants once adsorbed from the sediment or water column can move up the food chain and may lead to bioaccumulation and biomagnification [4]. The indiscriminate use agrochemicals, population explosion and alarming urban sprawl have completely changed the river water and quality [5,6]. River Jhelum provides the cultural picture of Kashmir valley due to large dependence of Kashmiri people on its services, surrounded on either sides by dense settlements, small and large scale industries and commercial hubs, as a result large amounts of domestic sewage and industrial effluents are discharged into it without any prior treatment. The worst problem is that the river flows through the heart of Srinagar city and is used as a dumping site for municipal garbage and commercial sewage. These pollutants once settle down reach to sediments and pose a serious threat to the aquatic ecosystem of Jhelum river [7,8,9]. Hence regular assessment studies are required to determine the current status of sediment quality such as pH, electrical conductivity, chlorides, phosphates etc. to provide a vision on the physicochemical characteristics of these habitats.

## MATERIALS AND METHODS

The climate of Jammu and Kashmir varies greatly owing to its topography. In the Jammu, the climate is typically monsoonal, though the region is sufficiently far west to average 40 to 50 mm of rain between

January and March. Because of its closeness to the Arabian sea. Srinagar receives as much as 635 mm of rain from this source, with the wettest months being March to May with around 85 mm per month. River Jhelum, also known as "Vyth" in Kashmiri language, flows a length of 203 Kilometers (km) through the Kashmir, starts from Veirnag spring, 26 km away from Anantnag in south western region of Kashmir and moves northwestward region towards Baramulla. After leaving the Kashmir valley at Khadanyer, it joins the river Chenab in Pakistan. There are various tributaries which join Jhelum on either sides, which include: Lidder, Vishav, Rambiara, Arpal, Romshi, Soanthkol, Dudhganga, Sind Nallah, Sukhang, Ferozpore-Nallah Ningil, Erin, Madhumati, Zaingeer, Pohru, Kishan ganga and Nainsuk river (Fig. 1).




For the study, the entire stretch of Jhelum was divided into six different sampling sites falling in three discrete regions. The sampling sites were selected on the basis of social geography, settlements, agricultural inputs, urban, rural, commercial and population pressure along either banks of the river Jhelum.

The sampling sites have been divided into three regions:

**Upstream region** (Verinag, Bijbehara)

**Middle stream region** (Aaramwari, Qamarwari)

**Downstream region** (Sopore, Baramulla)

Seasons (Spring, Summer, Autumn, Winter)

Sediment samples were collected in replicates from each selected site during four different seasons viz, summer (June to August), autumn (September to November), winter (December to February) and spring (March to May) from June 2014 to March 2015. The sampling has been performed in the mid month of each season on sunny days (10.30 am), when the stream flow was at normal level. 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 [10].

## RESULTS

In summer season, a minimum pH (6.34) was recorded at Qamarwari and maximum (8.10) was recorded at Verinag (Table 1). In autumn, the highest pH was recorded at Aaramwari (8.38) and lowest (7.28) was recorded at Verinag (Table 2). During winter season, the maximum pH (8.08) was recorded at Verinag and Qamarwari (6.8) showed lowest pH (Table 3). In spring season, the highest pH (7.8) was recorded at Baramulla and lowest (6.48) was recorded at Qamarwari (Table 4).

In summer season, a minimum EC (0.24 dS/m) was recorded at Verinag and maximum (1.84 dS/m) was recorded at Baramulla (Table 1). In autumn, the highest EC was recorded at Baramulla (2.18 dS/m) and lowest (0.39 dS/m) was recorded again at Verinag (Table 2). During winter season, the maximum EC (1.77 dS/m) was recorded at Sopore and lowest (0.18 dS/m) was recorded at Verinag (Table 3). In spring

season, the highest (1.39 dS/m) was recorded at Sopore and lowest (0.21 dS/m) was recorded at Verinag (Table 4).

The highest Ca content (149.7 meq/kg) was recorded at Qamarwari and lowest (34.9 meq/kg) at Aaramwari in summer season (Table 1). In autumn season, the highest Ca content was observed at Baramulla (212.0 meq/kg) and lowest (62.9 meq/kg) was recorded at Verinag (Table 2). During winter season, the maximum Ca content (100 meq/kg) was recorded at Baramulla and lowest (21.4 meq/kg) was found at Aaramwari (Table 3). In spring season, the highest ca content (48.8 meq/kg) was recorded at Baramulla and lowest (4.8 meq/kg) was recorded at Verinag (Table 4).

In summer season, the maximum Mg content (90.6 meq/kg) was recorded at Qamarwari and lowest (16.6 meq/kg) was recorded at Verinag (Table 1). In autumn, again the highest Mg content was observed at Qamarwari (124.6 meq/kg) and lowest (46.6 meq/kg) was recorded at Verinag (Table 2). During winter season, the maximum Mg content (68.5 meq/kg) was recorded at Qamarwari and lowest (8.2 meq/kg) at Verinag (Table 3). In spring season, the highest Mg content (37.7 meq/kg) was recorded at Qamarwari and lowest (10.2 meq/kg) was recorded at Verinag (Table 4).

In summer season, the maximum available nitrogen (1.42 mg/kg) was recorded at Sopore and (0.15 mg/kg) at Verinag (Table 1). In autumn, again the highest value of available nitrogen was observed at Sopore (2.73 mg/kg) and lowest (0.16 mg/kg) at Verinag (Table 2). During winter season, the maximum available nitrogen (0.95 mg/kg) was recorded at Baramulla and lowest (0.06 mg/kg) was found at Verinag (Table 3). In spring season, the highest available nitrogen (0.85 mg/kg) was recorded at Baramulla and lowest (0.03 mg/kg) was recorded at Verinag (Table 4).The highest available phosphorus (0.313 mg/kg) was recorded at Baramulla and lowest (0.102 mg/kg) at Verinag in summer season (Table 1). In autumn season, the highest available phosphorus was observed at Baramulla (0.370 mg/kg) and lowest (0.109 mg/kg) at Verinag (Table 2). During winter season, the maximum available phosphorus (0.214 mg/kg) was recorded at Baramulla and lowest (0.102 mg/kg) was found at Verinag (Table 3). In spring season, the highest available phosphorus (0.151 mg/kg) was recorded at Qamarwari and lowest (0.103 mg/kg) was recorded at Verinag (Table 4).

In summer season, the maximum available K content **(**28.66 mg/kg) was recorded at Aaramwari and lowest (9.03 mg/kg) was found at Baramulla (Table 1). In autumn, again the highest available K was recorded at Qamarwari (25.05 mg/kg) and lowest (6.98 mg/kg) was recorded at Verinag (Table 2). During winter season, the maximum available K (22.10 mg/kg) was recorded at Aaramwari and lowest (7.28 mg/kg) was at Baramulla (Table 3). In spring season, the highest available K content (10.08 mg/kg) was recorded at Aaramwari and lowest (3.30 mg/L) was recorded at Baramulla (Table 4).

In summer season, the maximum Na content (21.50 mg/kg) was recorded at Qamarwari and lowest (3.82 mg/kg) was found at Verinag (Table 1). In autumn, again the highest Na Content was recorded at Sopore (40.52 mg/kg) and lowest (6.48 mg/kg) was recorded at Verinag (Table 2). During winter season, the maximum Na content (8.68 mg/kg) was recorded at Qamarwari and lowest (5.09 mg/kg) was found at Verinag (Table 3). In spring season, the highest Na content (4.66 mg/kg) was recorded at Qamarwari and lowest (2.03 mg/kg) was recorded at Verinag (Table 4).

In summer season, the maximum $Cl^-$ content (550.4 mg/kg) was recorded at Sopore and lowest (62.7 mg/kg) at Verinag (Table 1). In autumn, the highest $Cl^-$ content was observed at Baramulla (700.4 mg/kg) and lowest (57.16 mg/kg) was recorded at Verinag (Table 2). During winter season, the maximum $Cl^-$ content (105.0 mg/kg) was recorded at Qamarwari and lowest (60.51 mg/kg) was found at Verinag (Table 3). In spring season, the highest $Cl^-$ content (450.4 mg/kg) was recorded at Qamarwari and lowest (125.13 mg/kg) was recorded at Verinag (Table 4).

**Table – 1 Physico-chemical characteristics of sediments in river Jhelum during summer 2014 - 15**

| Parameters | Verinag | Bijbehara | Aaramwari | Qamarwari | Sopore | Baramulla |
|---|---|---|---|---|---|---|
| **pH** | 8.10 ± 0.12 | 7.38 ± 0.10 | 7.68 ± 0.09 | 6.34 ± 0.09 | 7.72 ± 0.09 | 7.68 ± 0.09 |
| **EC (dS/m)** | 0.24 ± 0.03 | 0.39 ± 0.03 | 0.95 ± 0.04 | 0.78 ± 0.05 | 1.52 ± 0.08 | 1.84 ± 0.06 |
| **Ca (meq/kg)** | 42.9 ± 0.66 | 71.4 ± 0.86 | 34.9 ± 0.65 | 149.7 ± 1.27 | 105.9 ± 0.34 | 112.3 ± 0.60 |
| **Mg (meq/kg)** | 16.6 ± 0.22 | 51.6 ± 0.36 | 52.9 ± 0.52 | 90.6 ± 0.40 | 82.2 ± 0.84 | 44.5 ± 0.51 |
| **Available N (mg/kg)** | 0.15 ± 0.01 | 0.50 ± 0.03 | 0.90 ± 0.03 | 0.92 ± 0.02 | 1.42 ± 0.05 | 1.24 ± 0.05 |
| **Available P (mg/kg)** | 0.103 ± 0.05 | 0.159 ± 0.13 | 0.183 ± 0.46 | 0.216 ± 0.03 | 0.308 ± 0.89 | 0.313 ± 0.06 |
| **Available K (mg/kg)** | 12.39 ± 0.96 | 16.78 ± 1.37 | 28.66 ± 1.30 | 23.38 ± 2.61 | 12.71 ± 1.09 | 9.03 ± 0.47 |
| **Sodium (mg/kg)** | 3.82 ± 0.72 | 9.93 ± 1.21 | 14.95 ± 0.90 | 21.50 ± 1.16 | 14.58 ± 1.49 | 9.28 ± 0.99 |
| **Chloride (mg/kg)** | 62.7 ± 1.21 | 103.8 ± 2.02 | 250.15 ± 0.31 | 450.4 ± 0.51 | 550.4 ± 0.36 | 125.5 ± 0.12 |
| **Sulphur (mg/kg)** | 26.44 ± 2.52 | 57.50 ± 2.47 | 26.78 ± 3.23 | 24.14 ± 1.31 | 59.37 ± 3.56 | 109.94 ± 2.20 |

**Table – 2 Physico-chemical characteristics of sediments in river Jhelum during autumn 2014 – 15**

| Parameters | Verinag | Bijbehara | Aaramwari | Qamarwari | Sopore | Baramulla |
|---|---|---|---|---|---|---|
| **pH** | 7.28 ± 0.09 | 8.02 ± 0.14 | 8.38 ± 0.10 | 8.08 ± 0.17 | 7.36 ± 0.19 | 8.28 ± 0.12 |
| **EC (dS/m)** | 0.39 ± 0.03 | 0.93 ± 0.04 | 1.36 ± 0.07 | 1.85 ± 0.03 | 2.05 ± 0.03 | 2.18 ± 0.06 |
| **Ca (meq/kg)** | 62.9 ± 0.51 | 117.9 ± 0.91 | 134.9 ± 1.11 | 206.7 ± 0.97 | 131.5 ± 1.41 | 212.0 ± 1.17 |
| **Mg (meq/kg)** | 46.6 ± 0.33 | 78.9 ± 0.24 | 81.3 ± 0.44 | 124.6 ± 1.04 | 80.2 ± 0.55 | 88.7 ± 0.49 |
| **Available N (mg/kg)** | 0.16 ± 0.02 | 0.45 ± 0.03 | 1.33 ± 0.07 | 2.14 ± 0.05 | 2.73 ± 0.08 | 2.31 ± 0.09 |
| **Available P (mg/kg)** | 0.109 ± 0.40 | 0.222 ± 0.75 | 0.268 ± 0.60 | 0.304 ± 0.50 | 0.352 ± 0.06 | 0.370 ± 0.63 |
| **Available K (mg/kg)** | 6.98 ± 0.86 | 14.53 ± 1.27 | 20.06 ± 0.76 | 25.05 ± 1.80 | 24.03 ± 1.87 | 14.95 ± 1.40 |
| **Sodium (mg/kg)** | 6.48 ± 0.85 | 12.92 ± 0.87 | 16.98 ± 1.28 | 22.82 ± 1.04 | 40.52 ± 2.57 | 32.82 ± 2.87 |
| **Chloride (mg/kg)** | 57.16 ± 0.15 | 300.2 ± 0.07 | 250.6 ± 0.00 | 665.5 ± 0.15 | 600.6 ± 0.11 | 700.4 ± 0.08 |
| **Sulphur(mg/kg)** | 21.90 ± 2.77 | 59.93 ± 1.30 | 83.41 ± 2.91 | 107.07 ± 1.81 | 211.32 ± 4.63 | 212.59 ± 6.62 |

**Table – 3 Physico-chemical characteristics of sediments in river Jhelum during winter 2014 – 15**

| Parameters | Verinag | Bijbehara | Aaramwari | Qamarwari | Sopore | Baramulla |
|---|---|---|---|---|---|---|
| **pH** | 8.08 ± 0.10 | 7.00 ± 0.07 | 7.34 ± 0.08 | 6.84 ± 0.05 | 7.48 ± 0.04 | 7.28 ± 0.06 |
| **EC(dS/m)** | 0.18 ± 0.02 | 0.57 ± 0.04 | 0.78 ± 0.03 | 0.67 ± 0.04 | 1.77 ± 0.04 | 1.52 ± 0.08 |
| **Ca (meq/kg)** | 25.9 ± 0.43 | 7.11 ± 0.88 | 21.4 ± 0.37 | 55.2 ± 0.84 | 83.9 ± 0.32 | 100.0 ± 1.01 |
| **Mg (meq/kg)** | 8.2 ± 0.35 | 27.0 ± 0.28 | 46.7 ± 0.39 | 68.5 ± 0.22 | 43.0 ± 0.39 | 28.0 ± 0.48 |
| **Available N (mg/kg)** | 0.06 ± 0.01 | 0.35 ± 0.04 | 0.58 ± 0.03 | 0.94 ± 0.02 | 0.85 ± 0.03 | 0.95 ± 0.03 |
| **Available P (mg/kg)** | 0.102 ± 0.36 | 0.113 ± 1.89 | 0.164 ± 3.47 | 0.208 ± 4.19 | 0.213 ± 3.64 | 0.214 ± 2.08 |
| **Available K (mg/kg)** | 9.59 ± 0.48 | 13.34 ± 1.01 | 22.10 ± 1.01 | 13.76 ± 1.06 | 10.56 ± 0.65 | 7.28 ± 1.14 |
| **Sodium (mg/kg)** | 5.09 ± 0.53 | 6.54 ± 0.66 | 7.36 ± 0.85 | 8.68 ± 0.76 | 7.37 ± 0.76 | 4.73 ± 0.74 |
| **Chloride (mg/kg)** | 60.51 ± 0.25 | 150.45 ± 0.13 | 165.3 ± 0.29 | 1050.3 ± 0.21 | 300.12 ± 0.08 | 600.14 ± 0.01 |
| **Sulphur (mg/kg)** | 20.70 ± 2.11 | 28.22 ± 1.89 | 26.53 ± 1.97 | 45.12 ± 2.98 | 74.93 ± 2.92 | 97.57 ± 3.00 |

**Table – 4 Physico-chemical characteristics of sediments in river Jhelum during spring 2014 – 15**

| Parameters | Verinag | Bijbehara | Aaramwari | Qamarwari | Sopore | Baramulla |
|---|---|---|---|---|---|---|
| **pH** | 7.54 ± 0.09 | 6.82 ± 0.09 | 6.66 ± 0.15 | 6.48 ± 0.16 | 7.78 ± 0.09 | 7.86 ± 0.09 |
| **EC (dS/m)** | 0.21 ± 0.03 | 0.27 ± 0.04 | 0.49 ± 0.03 | 0.55 ± 0.05 | 1.39 ± 0.08 | 1.01 ± 0.05 |
| **Ca (meq/kg)** | 4.80 ± 0.30 | 26.1 ± 0.51 | 9.60 ± 0.42 | 27.8 ± 0.50 | 35.7 ± 0.17 | 48.8 ± 0.69 |
| **Mg (meq/kg)** | 10.2 ± 0.01 | 10.4 ± 0.01 | 31.7 ± 0.40 | 37.7 ± 0.11 | 24.3 ± 0.37 | 28.4 ± 0.46 |
| **Available N (mg/kg)** | 0.03 ± 0.00 | 0.13 ± 0.01 | 0.28 ± 0.02 | 0.40 ± 0.01 | 0.57 ± 0.03 | 0.85 ± 0.03 |
| **Available P (mg/kg)** | 0.103 ± 0.03 | 0.109 ± 0.04 | 0.127 ± 0.05 | 0.151 ± 0.06 | 0.149 ± 0.06 | 0.125 ± 0.01 |
| **Available K (mg/kg)** | 3.69 ± 0.73 | 9.70 ± 0.59 | 10.08 ± 0.61 | 6.53 ± 1.06 | 6.09 ± 0.90 | 3.30 ± 0.69 |
| **Sodium (mg/kg)** | 2.03 ± 0.00 | 3.06 ± 0.61 | 4.42 ± 0.48 | 4.66 ± 0.75 | 4.37 ± 0.81 | 2.51 ± 0.95 |
| **Chloride (mg/kg)** | 125.13 ± 0.04 | 136.4 ± 0.03 | 143.2 ± 0.08 | 450.4 ± 0.01 | 300.6 ± 0.04 | 153.8 ± 0.00 |
| **Sulphur (mg/kg)** | 11.29 ± 0.77 | 15.00 ± 1.56 | 17.09 ± 1.13 | 22.69 ± 1.82 | 41.02 ± 3.37 | 78.61 ± 5.67 |

In summer season the maximum S (109.94 mg/kg) was recorded at Baramulla and lowest (24.14 mg/kg) was found at Qamarwari (Table 1). In autumn, again the highest S was observed at Baramulla (212.59 mg/kg) and lowest was (21.90 mg/kg) recorded at Verinag (Table 2). During winter season, the maximum S (97.57 mg/kg) was recorded at Baramulla and lowest (20.70) mg/kg was found at Verinag (Table 3). In spring season, the highest S (78.61 mg/kg) was recorded at Baramulla and lowest (11.29 mg/kg) was recorded at Verinag (Table 4).

## Discussion

During the study, various physico-chemical parameters show a fluctuating behaviour over time. The pH of the sediments at six sites was found neutral to slightly alkaline, but pH at Qamarwari was slightly acidic. The low pH at the Qamarwari may be due to discharge of effluents (sewage, commercial wastes and other solid wastes) from Srinagar city. Marathe *et al.* (2011) [11] have shown a relation between low pH and city discharges. Further, high concentration of $CO_2$ and organic acids released by decomposed organic matter were found to decrease the pH [12]. The hydrolysis of salts present in waste displaces $Al^{+3}$ ions and release $H^+$ in sediments [13]. Decrease in pH noticed from spring to summer at all sites, together with rise in temperature may result in increase of $CO_2$ concentration and organic matter decomposition in the sediments [14]. Increase of pH from summer to winter was due to decrease in temperature, which decreases the microbial activity in the sediments and results least decomposition of organic matter, which in turn decrease the pH of sediments [15]. The maximum EC was observed at the Baramulla (the end point of Jhelum) and the minimum was recorded at Verinag (the starting point of the river) in all the seasons. The decrease in EC from summer to spring could be attributed to decrease in the temperature, which influences the mobility of elements. Nitrogen and phosphorus are important nutrients found in sediments and play essential role in the process of transformation in aquatic systems [16]. Available

phosphorus and nitrogen decreases from summer to spring at all the sites. The comparatively higher phosphorus and nitrogen concentration recorded at the Baramulla may be due to the cumulative waste water inputs from agricultural runoff, commercial and settlements in catchment area of river Jhelum, which have the potential to increase the phosphorus content in sediments. Similar finding and correlation have been reported elsewhere [16,17]. The $Cl^-$ content showed an increasing trend from summer to autumn and decreased towards winter and spring. The significant $Cl^-$ content at Qamarwari and Baramulla can be attributed to direct discharge of sewage and other solid wastes into the river at these sites. Cole (1975) [18] has found large $Cl^-$ content in sewage. Among the cations, Na and K were found dominant as compared to Mg and Ca in the present study. The overall cationic distribution in the sediments was observed as K > Na > Ca > Mg. The K mainly comes into sediments as a weathering product of minerals and sewage [14]. The high Na content observed at the Sopore could be related to high input of sewage and other wastes along the river. The high K content was observed at Aaramwari followed by Qamarwari, which could be related to the nature of sewage and effluents received by the river Jhelum. In stream sediments, sulphur (S) exists predominantly as the free $SO_4^{2-}$ anion. S comes in aquatic sediments from mining and smelting operations, kraft pulp and paper mills, textile mills and tanneries. Other potential anthropogenic sources include fertilisers, pesticides, coal combustion, petrol refining and vulcanisation of rubber [19]. S in sediments followed a typical trend from upstream to downstream. Maximum value of S has been recorded at Baramulla followed by Sopore in all the seasons. Increasing trend of S towards downstream can be attributed to the cumulative effect of run-off from agricultural, urban, rural and commercial areas along riverside of Jhelum that is in consonance with the study of Singh *et al.* [19].

## CONCLUSION

During the present investigation, it was found that river Jhelum sediments are slightly alkaline. The results also confirmed that there is strong seasonal and spatial impact on quality parameters of river Jhelum sediments. Slightly acidic pH was recorded at Qamarwari site which may be attributed with domestic waste based organic acids and industrial effluents from Srinagar city. Calcium and Magnesium dominated among cations and Potassium and Sodium also contributed significantly. Overall quality characteristics dominated at Qamarwari site of the study area and least value of all parameters were recorded at Verinag site. Available nitrogen and phosphors were found to increase from upstream to downstream as the anthropogenic activities also increase with distance from upstream.

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