Assessing the health of Dachigam stream: A water quality Analysis

Comment [m1]: The title of the article is clear

Abstract:

Comment [m2]: The abstract is not complete, only explaining the introduction. The abstract should contain an introduction, methods and results. Abstracts need to be equipped with research methods and results

The research explored the water quality status, spatial distribution, and temporal variations along the Dachigam stream, utilizing a variety of statistical methodologies. Significant spatiotemporal variability was apparent with parameters sampled.Human impacts, such as pollutants from municipal, industrial, and agricultural changes, have a significant impact on water quality. Deforestation, transformation of natural catchments, and industrial origin atmospheric deposition of nitrogen and sulfur are serious threats to water quality.The chemical composition of water plays a critical role in defining the aquatic environment and maintaining its ecological balance. Various natural and anthropogenic factors can significantly influence stream water chemistry. The increasing pollution levels observed from upstream to downstream sites suggest heightened anthropogenic influences in downstream regions. These findings are expected to inform the development of a comprehensive watershed management strategy aimed at improving the water quality of this significant stream.

Keywords: water quality, fisheries resources, irrigation, Deforestation

Introduction:

Comment [m3]: The introduction still needs to be added by strengthening the urgency of research using the latest references (last five years). The introduction would be better if it added scientific state of the art.

Water is a critical resource for humans as populations continue to grow and climate change affects global and local water cycles.Streams, characterized by their unidirectional flow, represent prime systems for investigating ecological phenomena across spatial and temporal scales (Downes *et al.* 1993). Streams cover only 0.8% of the Earth's surface, but deliver several fundamental ecosystem services to mankind (Vörösmarty *et al.* 2010) such as they act as sources of drinking water, fisheries resources, irrigation supplies, and waste removal systems which are threatened by the multiple environmental pressures impacting these ecosystems (Malmqvist and Rundle 2002; Dudgeon *et al.* 2005). Human impacts, such as pollutants from municipal, industrial, and agricultural changes, have a significant impact on water quality. Deforestation, transformation of natural catchments, and industrial origin atmospheric deposition of nitrogen and sulfur are serious threats to water quality. Proper water quality maintenance of these freshwater ecosystems is important for preserving biodiversity. The increasing scarcity of freshwater resources (Varol *et al.*, 2012) has amplified the urgency of water quality assessment. Maintaining good water quality is fundamental for ensuring individual and public health, environmental protection, and sustainable development (Rajini *et al.*, 2010). The suitability and utility of any water resource are directly linked to its physical, chemical, and biological characteristics (Sunitha *et al.*, 2012). The chemical composition of water plays a critical role in defining the aquatic environment and maintaining its ecological balance. Various natural and anthropogenic factors can significantly influence stream water chemistry (Ahearn *et al.*, 2005), potentially leading to adverse consequences to the ecosystem. Monitoring water chemistry serves an important tool for assessing freshwater stream health (Ahearn *et al.*, 2005). This approach offers valuable insights due to its sensitivity to various environmental changes, both natural and human-induced (Malmqvist & Rundle, 2002). Analyzing water chemistry provides critical information about pollutants, acting as an early warning system for potential issues (Vörösmarty et al., 2000). This information forms the basis for effective management and coming up with restoration strategies, safeguarding the health and sustainability of freshwater streams. Thus, to proficiently manage the water sources, there is a vital need to assess the spatiotemporal changes of water quality, to indicate the sources of pollution, and to control stream pollution (Hajigholizadeh& Melesse, 2017; Nong *et al.*, 2020; Tian *et al.*, 2019).

Materials and method

Comment [m4]: The method still explains more about the research location. The method does not yet explain the variables that will be discussed and it is necessary to explain how to measure them

Study area:

Jammu and Kashmir lies in the northwestern region of India, with geographical coordinates ranging from 32° 17' to 36° 30' north latitude and 73° 26' to 80° 30' east longitude (Zutshi & Khan, 1978). The region is characterized by a lacustrine basin, formed during the Pleistocene epoch through tectonic activity (Zutshi & Khan, 1978). Embedded within the western Himalayas, the Kashmir Valley is recognized for its exceptional biodiversity, captivating natural beauty, and unique species composition. The valley is distinguished by a network of freshwater bodies, ranging in elevation from 1505 meters to 4000 meters above sea level. Dachigam National Park lies within the Srinagar district, Jammu and Kashmir, India (34°00′N - 34°11′N & 74°54′E - 75°09′E) (Naqash& Sharma, 2011). It falls under the 2.38.12 (Himalayan Highlands) biogeographical province and the 2A Bio-geographic zone. **It is** Situated 21 km northeast of Srinagar, the park resides within the Zabarwan mountain range of the Himalayas (Naqash& Sharma, 2011).The park is traversed by the Dachigam stream, originating from the high-altitude Marsar lake (4000 m) and fed by surrounding snowmelt. Tributaries of perennial and non-perennial nature join the stream throughout its course (Naqash& Sharma, 2011). A portion of the stream feeds agricultural fields and floating gardens before flowing into the Harwan Reservoir (Sarband), supplying drinking water to parts of Srinagar. The remaining stream flows through the park's diverse vegetation and enters Dal Lake near Hazratbal. A major tributary, the Dara stream, joins the Dachigam stream at Wangund. The Telbal-Dachigam catchment, encompassing an area of 234.17 sq km (69% of the total area) and ranging from 1600 to 4250 meters above sea level, is the largest feeding ground for Dal Lake (Badar *et al.*, 2013). Land cover is classified into 16 categories, with deciduous forest being the most dominant. Dachigam stream contributes approximately 80% of the total water inflow to Dal Lake (292 x 106 m3) (Badar *et al.*, 2013).

To assess the current water quality of the Dagwan/Dachigam stream in Kashmir, data on various water quality parameters was collected over a year at six different sampling locations.The water samples were collected from six different study sites along the Dagwan stream designated as S1, S2, S3, S4,S5 and S6.

- **Site 1:** This site was located inside the Dachigam National Park at geographical coordinates of 34.1492346 latitude; 74.9199326 longitude. This site was present on the upper side of Laribal Trout Farm.
- **Site 2:** This site was also located inside the National park just outside the Laribal trout farm. It was situated at geographical coordinates of 34.1508167 latitude; 74.9186964 longitude.
- **Site 3:** This site was located at Harwan new bridge in Harwan area at a geographical coordination of 34.162 latitude; 74.891 longitude.This site was exposed to anthropogenic activities like bathing during high stream flow.

- **Site 4:** This site was located at Dara nallah confluence.This site was located within geographical coordinates of 34.1651827 latitude and 74.8733832 longitudes. This is the site where the other stream from Dara joins the Dagwan stream and together it flows as one.
- **Site 5:** This site was located in Telbal village. The geographical coordinates of this site is 34.1657875 latitude and 74.8674404 longitudes. This site is surrounded by village.
- **Site 6:**Telbal nallah: This site is located near market place surrounded by human habitation near Telbal nallah besides embankment. This site has been subjected to intense human pressure and has produced stretches of stagnant water in which locals litter. This site has also been used intensely for washing the clothes.

Monthly sampling was done from September 2021 to August 2022 to monitor the changes caused by seasonal hydrological cycle. Sample preservation, transportation, and analysis were done within 24h as per standard methods (American Public Health Association (APHA) 2012).The parameters such as air and water temperature, depth, and transparency were determined on the spot while other parameters were determined in the laboratory. The other water quality parameters include pH, dissolved oxygen (DO), electrical conductivity (EC), ammoniacal-nitrogen (NH_4–N), nitrate-nitrogen (NO_3–N), total phosphorus (total-P), were also analyzed. Results obtained were verified by careful calibration and blank measurements (American Public Health Association (APHA) 2012).

Data handling and statistical analysis of physicochemical parameters of water samples were obtainable as mean values and study using expressive analysis.

Figure 1: Map representing sampling sites

Results and Discussion:

1. **Air temperature:**

During the present investigation, air temperature recorded the lowest value of 4.5℃ at site 1 in the month of February while the highest of 29.6°C was recorded in the month of August at site 6 with an overall mean ± S.E of

Comment [m5]: The results and discussion have been widely described, but the results presented have not been explained completely. more explanation in other articles.

16.7 ± 2.04.The variation in the air temperature (°C) on monthly basis at different sites of Dachigam Stream is graphically represented in Fig. 1. This constantdecrement of temperature as winter season is approached and then steady increment of temperature as moving towards summercan be related to fluctuation in solar radiation and photoperiod over the course of sampling period. The lowest air temperature in winter season was due to short photoperiod, cold atmosphere and the highest during summer was due to clear atmosphere and higher solar radiation. These results are in confirmation with Vyas *et al.* 2013 in Barna Stream; Arafat *et al.*, 2022 in Vishav stream.

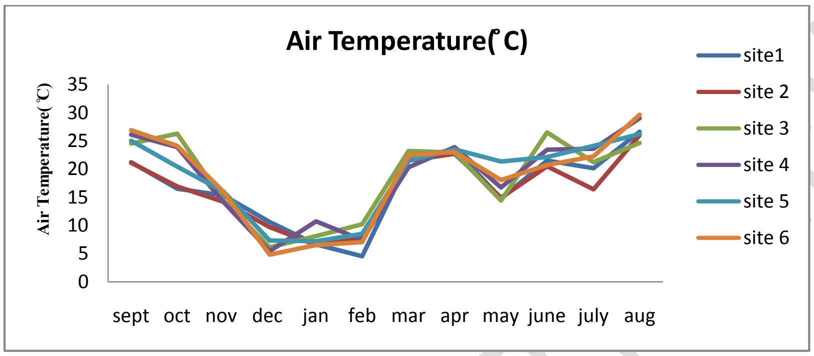

Figure 2: Monthly Variation in Air Temperature (°C) at different sites in Dachigam Stream

2. **Water Temperature:**

Water temperature is of enormous significance as it regulates various abiotic characteristics and biotic activities of an aquatic ecosystem (Hutchinson, 1975). During the present study, water temperature recorded lowest value of 4.8° C at site 4 in the month of December while the highest of 19.2°C was recorded in the month of August at site 6 with a overall mean ± S.E of 12.1 ± 0.96.There was significant difference (p<0.05) in water temperature found between the different seasons which can be related to the fact that water temperature is significantly influenced by the air temperature, which in turn is influenced by increased solar radiation, clear atmosphere and low temperature in winter is influenced by low intensity of solar radiation, shorter duration of sun.There was a significant difference (p<0.05) in water temperature was also seen among sampling sites which may be due to the local influence of the sites such as latitude, elevation, and riparian shading. These observations are in confirmation with the studies of Sharma and Chowdhary, 2011 in river Tawi, Sharma *et al* 2016 in stream Baldi, Garhwal Himalayas, Khandey*et al.* 2021 in river Jhelum, Arafat *et al.*, 2022 in Vishav stream, Arismendi *et al.* 2014 in different streams in United states, Johnson, 2004 while studying Oregon stream and Bellinger *et al.* 2006 in 10 streams in Tanzania.

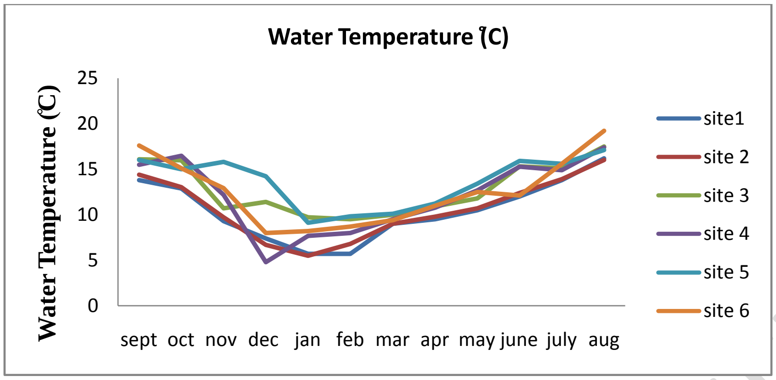

Figure 3: Monthly Variation in Water Temperature (°C) at different sites in Dachigam Stream

3. **Depth:**

Depth has an important impact on the physicochemical variables of water in aquatic ecosystem. It's a significant determinant for growth and development of diverse vegetative life forms, as well as for absorbing ions in water masses and productivity of the ecosystem (Kaul *et al.* 1980, Scheffer and Van Nes, 2007).

During the present study, depth recorded lowest value of 0.05m at site 3 in the month of February while the highest value of 0.82 m was recorded in the month of August at site 5 with an overall mean ± S.E of 0.33±0.04. Depth varied significantly ($p<0.05$) between seasons. The depth of water in the stream was low in winter and high in summer. During winter, freezing of water at higher altitudes resulted in low water volume and hence low flow, while during spring – summer melting of snow led to increased flow in the stream in addition to received precipitation in the form of rainfall. This was also reported by Zutshi *et al.* 1980 while studying the lakes of J&K who related depth variation to inflow discharge rate and precipitation amount in the form of rain. Abubakr *et al.*2018 who also observed the dependence of depth over the volume of water column, discharge rate of inflow, precipitation forms and other anthropogenic activities in different water bodies of the Jammu and Kashmir. On the other hand, the decrease in water depth during winter season can be related to reduction in water flow from the source of water due to cold climatic conditions. And also it might be attributed to low rainfall and diversion of water for other purposes. Bhat *et.al.*, 2014 also reported low volume of water in Lidder stream during winter.

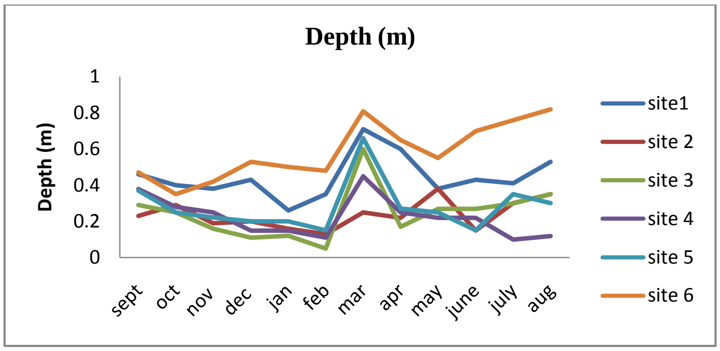

Figure 4: Monthly Variation in Depth (m) at different sites in Dachigam Stream

4. Water Transparency

Transparency is one of the physical parameter of water and is a characteristic which is indicative of the degree to which sunlight can penetrate through water (Abubakr *et al.* 2018). Water transparency recorded lowest value of 0.05 m at site 3 in the month of February while the highest value of 0.71 m was recorded in the month of March at site 1 with an overall mean ± S.E of 0.25±0.04. During the present investigation, the water transparency varied significantly ($p<0.05$) both between seasons and sites with highest mean being recorded in spring season. The water transparency results were similar to the depth of the sites as the stream depth was shallow and the substrate was clearly visible. However, low transparency values at middle and lower stretches can be related to suspended materials brought by stream flow from their catchment. Zutshi *et al.*, 1980 and Hassan *et al.* 2014 in river Jhelum also recorded that the reason for significant reduction in water transparency can be associated with large amounts of suspended matter. Abubakr *et al.*, 2018 who also relate it with suspended particles, settlement of sand silt from catchment area.

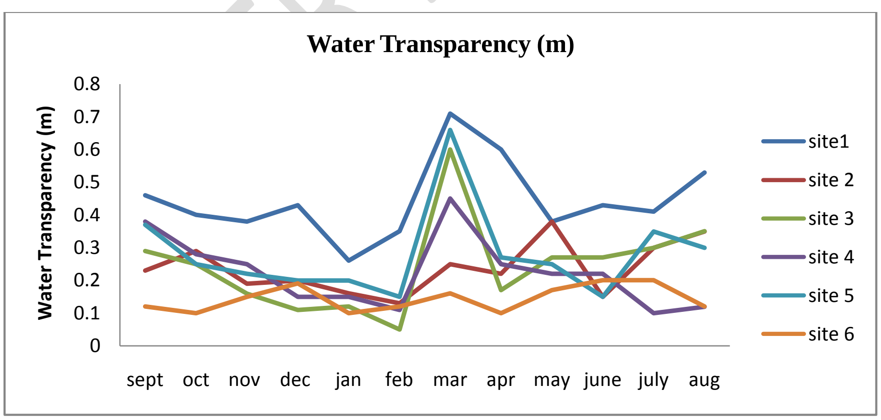

Figure 5: Monthly Variation in Water Transparency (m) at different sites in Dachigam Stream

5. **pH**

It is a measure of whether the liquid is acidic or alkaline. It serves as an index for sustainability of environment and an important factor affecting productivity (Welch, 1952). Overall during the present study, pH recorded lowest value of 6.7 at site 5 in the month of December, February and April while the highest value of 8.8 was recorded in the month of October at site 4 with an overall mean ± S.E of 7.4 ± 0.17. During the study period, a significant difference ($p<0.05$) was recorded between the sampling sites and this difference was also observed on seasonal basis. The decrease in pH values observed during spring can be attributed to increased rainfall and snowmelt elevating water levels. Other factors influencing pH variation include the combined effects of low temperatures and carbon dioxide concentrations in the water, resulting from the conversion of bicarbonate into carbonate. Allan and Castillo (2007), stated that pH in natural waters, is influenced by the presence of $H+$ ions from the dissociation of H_2CO_3 and OH^- ions from the hydrolysis of bicarbonate. Likens and Bormann, 1974 and Johnson *et al.* 1972 noted that stream pH is influenced by the acidity of precipitation and the extent to which this acidity is neutralized by cations supplied through rock weathering.

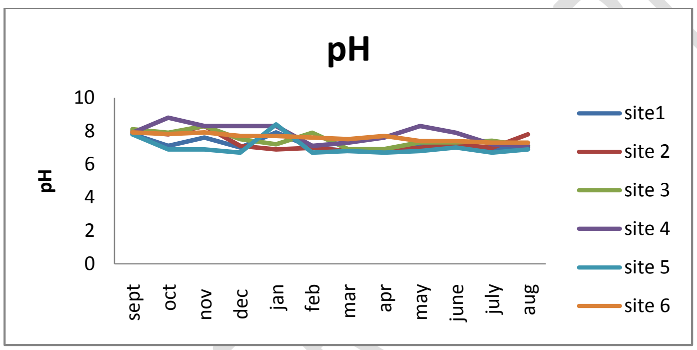

Figure 6: Monthly Variation in pH at different sites in Dachigam Stream

6. **Electrical conductivity**

The ability of water to conduct an electrical current is measured by its conductivity. During the present study, electrical conductivity recorded lowest value of 73.2µS/cm at site 2 in the month of May while the highest value of 495.3µS/cm was recorded in the month of October at site 6 with an overall mean ± S.E of 204.9±23.0with a significant difference ($p<0.05$) between the seasons. . Higher values might be owed to lesser volume of water in lean months; it may also be due to the leaching of soluble materials from fallen leaves, and interaction of catchment rocks with the water, less water flow rate, low rainfall and divergence of water for irrigation. Slack and Felta, 1968 also recorded a rise in conductivity as a result of increased leachate from fallen leaves in a South American stream. Koul, 1988 in mountainous stream of Telbal-Dachigam catchment reported that the higher value in the stream during winter can also be related to simple concentration effect. On contrary to our study, studies of Sabha *et al.* 2019; Khandey*et al.* 2021; Arafat *et al.* 2022 recorded higher values of EC during summers and attributed it to increase in temperature leading to increasing the mobility of ions.

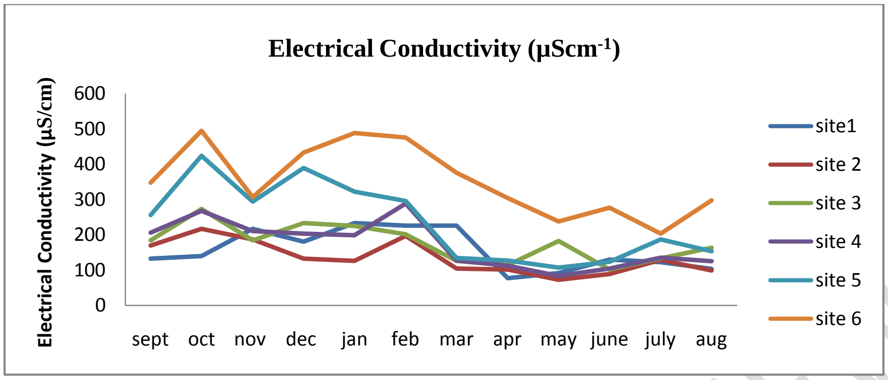

Figure 7: Monthly Variation in Electrical conductivity (µS/cm) at different sites in Dachigam Stream

Table 1:Values of different physicochemical parameters of surface water samples of Dachigam stream for a period of 1 year.

S.no.	Variable		Max.	Min.	Mean +S.E.
1.	Air temperature	℃	$29.6_{(aug)}$	$4.5_{(feb)}$	16.7 ± 2.04
2.	Water temperature	℃	$19.2_{(aug)}$	$4.8_{(dec)}$	12.1 ± 0.96
3.	Depth	m	$0.82_{(aug)}$	$0.05_{(feb)}$	0.33 ± 0.03
4.	Water transparency	m	$0.71_{(mar)}$	$0.1_{(oct,apr,july)}$	0.26 ± 0.02
5.	pH		$8.8_{(oct)}$	$6.7_{(dec,feb,apr)}$	7.4±0.17
6.	Electrical conductivity	μScm^{-1}	$495.3_{(oct)}$	$73.2_{(may)}$	204.9 ± 20.7
7.	Dissolved oxygen	mg/L	$13.6_{(jan)}$	$4.4_{(may)}$	8.35 ± 0.32
8.	Free Carbon dioxide	mg/L	$28_{(dec)}$	$0_{(oct, nov,dec, jan, may)}$	10.4 ± 6.02
9.	Chloride	mg/L	$24.7_{(nov)}$	$4.5_{jun)}$	13.1 ±1.2.
10.	Nitrate- nitrogen	(µg/L)	$577.8_{(oct)}$	$106.5_{(may)}$	307.6 ± 25.4

11.	Ammonia- nitrogen	(µg/L)	421.6 (aug)	33.1 (apr)	188.6 ± 26.0
12.	Total Phosphorus	(µg/L)	881.3(nov)	62.7(mar)	293.0 ± 20.9

7. Dissolved oxygen (DO):

Oxygen is present in dissolved form in an aquatic ecosystem. It is among one of the important variable for evaluating the quality of water, which is essential to maintain biotic forms in water. Dissolved oxygen (DO), a pivotal parameter in stream ecology (Hynes 1960; Dauer *et al*. 2000; Chang 2002), is intricately linked to the biological oxygen demand within the stream. The measurement of dissolved oxygen widely used and is the most essential of all chemical methods available for studying the aquatic environment (Wetzel and Likens, 2000). Overall, DO recorded lowest value of 4.4mg/L at site 6 in the month of August while the highest value of 13.6 mg/L was recorded in the month of January at site 2 with an overall mean ± S.E of 8.35±0.58. During the present study, the DO values were significantly different ($p<0.05$) between sites was found. DO shows decrement downstream. Increased dissolved oxygen levels upstream may be correlated with lower air temperatures due to higher altitudes and the presence of dense riparian vegetation cover which cause low temperature, pristine condition of water, and stronger water currents with substrate composition of boulders, pebbles or cobbles which increases turbulence. While lower values at downstream can be attributed to increased water temperature, organic pollution, nutrient runoff from the local farming terraces, human intervention. Similar results were observed by Bernot *et at* 2010 in various streams in Puerto Rico who reported DO varied from land use to forested streams and from upstream to low stream in response to the organic pollution and water temperature; Vyas *et al.*, 2013 in Barna stream; Hassan *et al.* 2014 in Jhelum river; Sharma *et al.* 2016 in Baldi stream; Bakure*et al.* 2020 stream draining in Gilgel Gibe catchment who observed forest streams have high DO and low water temperature because of the riparian vegetation cover. Welch (1952) noted that in unaltered aquatic ecosystems, running waters frequently exhibit comparatively elevated concentrations of dissolved oxygen, with tendencies toward reaching saturation levels.

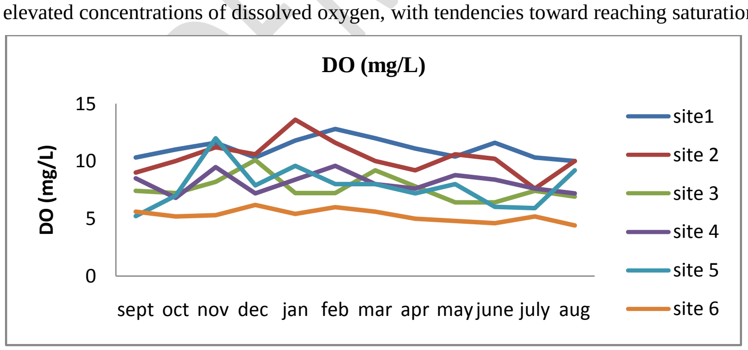

Figure 8: Monthly Variation in Dissolved oxygen (mg/L) at different sites in Dachigam Stream

8. Free Carbon dioxide (mg/L):

Carbon dioxide is highly soluble in water and atmospheric carbon dioxide is absorbed at the air-water interface (Naik, 2005). In addition, CO_2 is produced within water bodies by the respiration of aquatic biota, during aerobic and anaerobic decomposition of suspended and sediment organic matter (Chapman, 1992). Overall during the present study, free CO_2 recorded lowest value was below detectable level at site 2,3,4 and 5 in the month of October, November, December, January and May while the highest value of 28 mg/L was recorded in the month of December at site 6 with an overall mean ± S.E of 10.4 ±6.02. During the present study, the free CO_2 values have significant difference ($p< 0.05$) between sites. The lower values of free CO_2 are related to shallow depth, clean water, less organic matter and low decomposition activity and high pH due to which dissociation of carbonic acid occurs, bicarbonates and carbonates are present, and CO_2 and H_2CO_3 are no longer detectable. The increase in the concentration of free CO_2 at downstream can be due to decomposition of organic wastes and possible groundwater inflow, which are considerably enriched by CO_2 due to soil respiration throughout the catchment. (Mulholland 2003).These results are on line with Araoye, 2009 who also attributed high CO_2 with increased decomposition activity in Asa Lake Llorin, Ahanger*et al.* 2012, Abubakr *et al.* 2018 in Anchar Lake.

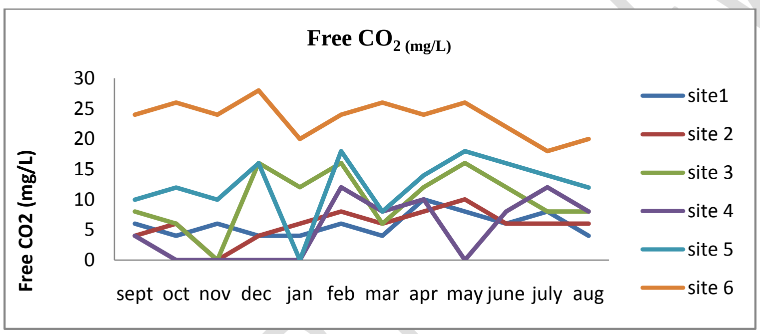

Figure 9: Monthly Variation in Free CO_2 (mg/L) at different sites in Dachigam Stream

9. Chloride:

Chloride exists in all natural waters. In freshwaters, the sources include soil and rock formation, sea spray and waste discharges from man and other animals that excrete very high quantities of chloride. Overall during the present study, chloride concentration recorded lowest value of 4.5 mg/L at site 1 in the month of June while the highest value of 28.0 mg/L was recorded in the month of February at site 6 with an overall mean ± S.E of 13.1 ± 1.2. During the present investigation, chloride values have a significant difference ($p<0.05$) between the sites and seasons, minima being at upstream and maxima at downstream. The chloride values showed increasing trend while moving downstream which can be attributed to increase in organic pollution because anthropogenic activities increases downstream. During summer, low concentration of chloride can be owed to dilution effect of running water and high stream flow while during winter; high value can be due to shallow depth and low stream flow. The similar results were shown by Chakrabarty *et al.* 1959 in river Jumna, Ray *et al.* 1966 in rive Ganga and Jumna, Imevbere 1970 in river Niger and Vitousek 1977 in mountain streams in northeastern US and observed the maximum chloride concentration corresponding with lower water levels and the minimum of concentration appearing as a result of precipitation. Capblancq and Tourenq 1978 considered the flow of the river influencing the fluctuations and variations of the mineral content in the river Lot. These results are in line with Perera *et al.* 2013 in Highland Creek watershed of Toronto, Vyas *et al.*, 2013 in Barna stream, Hassan *et al.* 2014, Yu *et al.* 2016 in Wei river basin, Sabha *et al.* 2019 in Dachigam stream, Corsi *et al.* 2015 observed high chloride levels with low water level and low stream flow. Arafat *et al.*2022 also reported water get saturated with chloride salts due to continuous influx from the domestic sewage from the anthropogenic sources along the riparian zones of the Vishav stream.

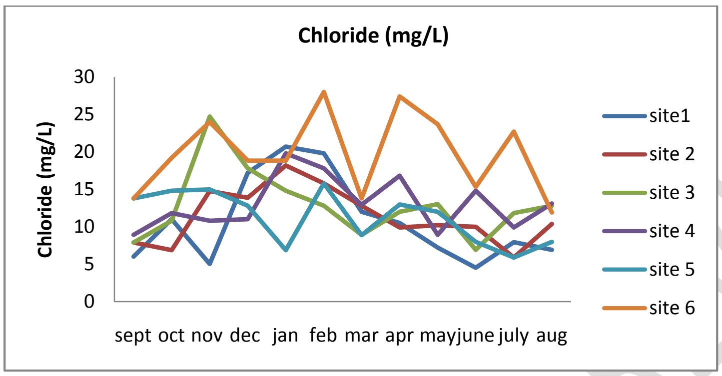

Figure 10: Monthly Variation in Chloride (mg/L) at different sites in Dachigam Stream

10. Ammonical-nitrogen:

Ammonia is an important component of the nitrogen cycle in streams, where it can be dissolved or coupled with sediments. There is chemical equilibrium in aqueous solutions between un-ionized ammonia (NH_3), ionised ammonia (NH_4^+), and hydroxide ions (OH^-).Un-ionised ammonia (NH_3) is extremely toxic to aquatic life, especially fish, whereas ionised ammonia (NH_4^+) is significantly less hazardous. Furthermore, unionised ammonia can be hazardous to *Nitrosomonas* and *Nitrobacter* bacteria, slowing the nitrification process (Anthonisen*et al.*1976, Russo, 1985, Adams and Bealing, 1994, Richardson, 1997, Environment Canada, 2001, Constable *et al.* 2003). Overall, ammonical-nitrogenconcentration recorded lowest value of 33.1µg/L at site 1 in the month of April while the highest value of 421.6µg/L was recorded in the month of August at site 6 with an overall mean ± S.E of 188.6± 26.0. During the present study, there was a significant difference (p<0.05) between the mean values of ammonical-nitrogen between sites. There was an increase in mean concentration of ammonia downstream which could be a direct result of human interference downstream and addition of organic and inorganic waste in waterbodies, leaching from the agricultural farms in the catchment. Several authors such as Mulholland 1992 in temperate forest stream in Tennessee, Bohlke and Denver 1995, Bu *et al.* 2014 in Taizi River, Ding *et al.* 2016 in Dongjiang River basin, China, and Bakure*et al* 2020 in three different streams in Gilgel Gibe catchment, Southwest Ethiopia also observed increased human activity causes an increase in the quantity of ammonium nitrogen in freshwater, suggesting that water quality varies depending on land-use type. Mouri *et al.*2011 observed that land use is more influential upstream in larger stream while local land use and other factors may be more important in smaller streams. Meyer and likens, 1979 observed net transformation of nutrients delivered downstream from inorganic to dissolved organic or particulate forms can also occur as a result of in stream activities. Yu *et al.* 2016 showed that the influence of land use was greater in flatter portions of the stream than in steeper areas, which is consistent with present study.

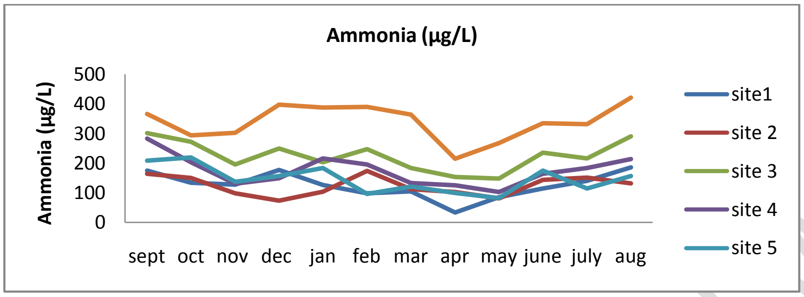

Figure 11: Monthly Variation in Ammonical-nitrogen(µg/L) at different sites in Dachigam Stream

11. Nitrate-nitrogen:

The most prevalent form of nitrogen is nitrate, and different transformational events including nitrification, denitrification, and biological absorption affect how readily available nitrate is (Kendall *et al.*, 2007). During the present study, the nitrate-nitrogenconcentration recorded lowest value of 114µg/L at site 2 in the month of May while the highest value of 577.8µg/L was recorded in the month of October at site 6 with an overall mean ± S.E of 286.2 ± 24.3. During the present study there was a significant difference (p<0.05) between the mean values of nitrate- nitrogen between sites and there is an increase in the concentrations as we move downstream. The lower concentration of nitrate at upstream can be attributed to no human intervention, no household runoff, dilution factor of water while as high concentration at downstream might be influenced by rapid nitrification process , domestic wastes, agricultural activities from upstream, surface runoff and leaching of nitro-phosphate fertilizers from nearby farms. Bellinger *et al* 2006 also reported slightly high nitrate concentration in stream areas having deforested watersheds containing small villages. Kannel *et al* 2007 also related high nitrate levels with high anthropogenic activities and agricultural runoff. Heathwaite*et al* 1996, Gächter*et al* 2004 linked nitrogen containing fertilizers when applied to crops at high levels leading to leaching into surface and groundwater which causes significant increase in river nitrate concentration. Bakure*et al.* 2020 reported that high amount of nitrate in the water downstream on a urban site of stream because of high rate of denitrification and the rate of nutrient discharge is greater than the rate of denitrification in the stream which was also in line with works of Yogendra and Puttaia 2008; Chang 2008 in Han River, Waziri and Ogugbuaja 2010 in River Yobe-Nigeria, Bohlke and Denver 1995, Mulholland 1992, Mouri *et al*. 2011,Bernot *et al.* 2010.

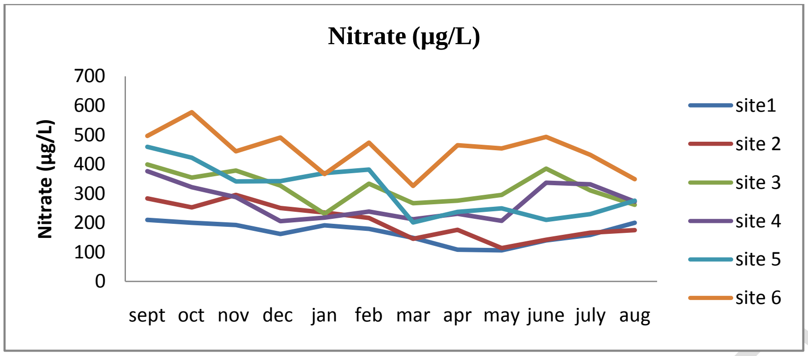

Figure 12: Monthly Variation in Nitrate-nitrogen (µg/L) at different sites in Dachigam Stream

12. Total Phosphorus:

Phosphorus occurs in natural water primarily as dissolved ortho-, pyro-, and polyphosphates (Hem 1992). The main source of phosphorus is found in rocks and sediments, as opposed to another limiting component, N, which is fairly abundant in the atmosphere. It is slowly released by weathering, and in unpolluted waters, it is frequently insufficient compared to metabolic demand. Phosphorus concentrations are often higher where sedimentary rock deposits drain and lower where crystalline bedrock is present (Allan and Castillo, 2007). During the present study, the total phosphorusconcentration recorded lowest value of 62.7µg/L at site 1 in the month of September while the highest value of 881.3µg/L was recorded in the month of November at site 6 with an overall mean ± S.E of 293.0 ± 35.0. During the present investigation, the significant difference ($p<0.05$) was found spatially for total phosphorus concentration. The fluctuating values of total phosphorus as it moves downstream for the Dachigam stream can be attributed to the nature of the geology of the drainage basin and leaching from agricultural lands using phosphorus based fertilizers in the catchment. Tailing and Tailing, 1965 observed the weathering of rocks results in high concentrations of phosphates. Phosphorus produced by plant breakdown and stored in the organic layer of the soil enters streams via surface runoff and subsurface pathways (McDowell *et al.* 2001). Areas with steep slopes and little vegetation cover, sediment eroded during storms carries phosphorus with it. Sharpley *et al.* 1995, Weld *et al.* 2001, and Sharpley *et al.* 1999 found that the concentrations of phosphorus in surface runoff vary with the amount of phosphorus in surface soils and the proximity of P- rich soils to the stream channel.

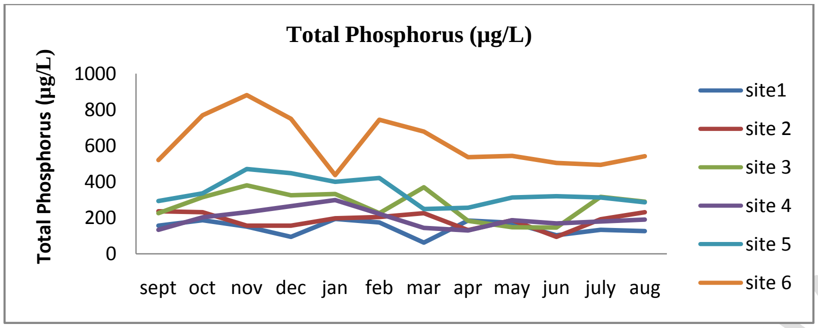

Figure 13: Monthly Variation in Total Phosphorus (µg/L) at different sites in Dachigam Stream

Conclusion:

Comment [m6]: Conclusions have been drawn based on the research results

The research explored the water quality status, spatial distribution, and temporal variations along the Dachigam stream, utilizing a variety of statistical methodologies. Significant spatiotemporal variability was apparent with parameters sampled. Disparities in element concentrations were observed among different sites, with an overall trend indicating an increase from upstream to downstream sites. Analysis of physicochemical parameters suggests a noticeable decline in water quality downstream, although it remains within acceptable limits for various purposes such as drinking, irrigation, washing, agriculture, and fisheries. The increasing pollution levels observed from upstream to downstream sites suggest heightened anthropogenic influences in downstream regions. These findings are expected to inform the development of a comprehensive watershed management strategy aimed at improving the water quality of this significant stream.

References

Comment [m7]: The number of references is large, but most of them are still old references. There needs to be improvements to the latest references

1. Abubakr, A., Gojar, A. A., Balkhi, M. H. and Malik, R. 2018. Macro-Invertebrates (Annelida; Oligochaeta) As Bio-Indicator of Water Quality under Temperate Climatic Conditions. *Int. J. Pure App. Biosci*, ***6***(1): 726-737.
2. Adams, N. and Bealing, D. 1997. Organic pollution: biochemical oxygen demand and ammonia. *Handbook of Ecotoxicology*, 728-749.
3. Ahangar, I. A., Saksena, D. N. and Mir, M. F. 2012. Seasonal Variation in Zooplankton Community Structure of Anchar lake, Kashmir. *Universal Journal of Environmental Research & Technology*, ***2***(4).
4. Ahearn, D. S., Sheibley, R. W., Dahlgren, R. A., Anderson, M., Johnson, J. and Tate, K. W. 2005. Land use and land cover influence on water quality in the last free-flowing river draining the western Sierra Nevada, California. *Journal of hydrology*, *313*(3-4), 234-247.
5. Allan, J.D. and Castillo, M.M. 2007. Stream ecology: structure and function of running waters, 2nd edn. Chapman and Hall, New York
6. American Public Health Association (APHA). 2012. Standard methods for examination of water and wastewater. 22st Edn. Washington DC, USA.
7. Anthonisen, A. C., Loehr, R. C., Prakasam, T. B. S. and Srinath, E. G. 1976. Inhibition of nitrification by ammonia and nitrous acid. *Journal (Water Pollution Control Federation)*, 835-852.

8. Arafat, M. Y., Bakhtiyar, Y., Mir, Z. A. and Islam, S. T. 2022. Assessment of physicochemical parameters of Vishav stream: an important tributary of river Jhelum, Kashmir Himalaya, India. *Environmental Monitoring and Assessment*, *194*(3), 158.
9. Araoye, P.A. 2009. The seasonal Variation of pH and dissolved oxygen (DO_2) concentration in Asa lake Ilorin, Nigeria. *International Journal of Physical Sciences,* **4** (5):271-274.
10. Arismendi, I., Safeeq, M., Dunham, J. B. and Johnson, S. L. 2014. Can air temperature be used to project influences of climate change on stream temperature? *Environmental Research Letters*, *9*(8): 084015.
11. Badar, B., Romshoo, S, A. and Khan, M,A. 2013. Geospatial modelling for impact assessment of changing land system on erosion and sediment yield in a micro-watershed of Dal lake, Kashmir Himalaya. *J. Earth Syst. Sci.,* 122(2):433–449.
12. Bakure, B. Z., Fikadu, S. and Malu, A. 2020. Analysis of physicochemical water quality parameters for streams under agricultural, urban and forest land-use types: in the case of GilgelGibe catchment, Southwest Ethiopia. *Applied Water Science*, **10**: 1-8.
13. Bellinger, B. J., Cocquyt, C. and O'Reilly, C. M. 2006. Benthic diatoms as indicators of eutrophication in tropical streams. *Hydrobiologia*, *573*, 75-87.
14. Bernot, M. J., Sobota, D. J., Hall Jr, R. O., Mulholland, P. J., Dodds, W. K., Webster, J. R., ... and Wilson, K. Y. M. 2010. Inter-regional comparison of land-use effects on stream metabolism. *Freshwater Biology*, **55**(9):1874-1890.
15. Bhat, F. A., Yousuf, A. R., Balkhi, M. H. and Najar, A. M. 2014. Occurrence of macro-zoobenthos against the varied altitudinal gradient and ecology in a trout stream (Lidder) of Kashmir Himalaya, India. *Proceedings of the National Academy of Sciences, India Section B: Biological Sciences*, *84,* 287-297.
16. Böhlke, J. K. and Denver, J. M. 1995. Combined use of groundwater dating, chemical, and isotopic analyses to resolve the history and fate of nitrate contamination in two agricultural watersheds, Atlantic coastal plain, Maryland. *Water Resources Research,* **31**(9): 2319-2339.
17. Bu, H., Meng, W., Zhang, Y. and Jun, W.2014. Relationships between land use patterns and water quality in the Taizi River basin,China. *Ecolo. Indicat.,***41**(2014):187–197
18. Capblanoq, J. Par and Tourenq, J.N. 1978. Water chemistry of the river Lot. *Annls. Limnol.,***14**(1):25-37.
19. Chakrabarty, R. D., Roy, P. and Singh, S. B. 1959. A quantitative study of the plankton and physico-chemical conditions of the River Jumna at Allahabad in 1954-55. *Ind .J. Fish.,***6**(1):186-203.
20. Chang, H. 2002. Spatial and temporal variations of water quality in the river and its tributaries, Seoul, Korea, 1993–2002. *Water Air Soil Pollution,161*:267–284
21. Chang, H. 2008. Spatial analysis of water quality trends in the Han River basin, South Korea. *Water research*, **42**(13):3285-3304.
22. Chapman, D. 1992. Water Quality Assessments - A Guide to Use of Biota, Sediments and Water in Environmental Monitoring -Second Edition. Published by E&FN Spon, *an imprint of Chapman & Hall Printed inGreat Britain at the University Press, Cambridge.*

23. Constable, M., Charlton, M., Jensen, F., McDonald, K., Craig, G., & Taylor, K. W. (2003). An ecological risk assessment of ammonia in the aquatic environment. *Human and Ecological Risk Assessment*, *9*(2), 527-548.
24. Corsi, S. R., De Cicco, L. A., Lutz, M. A. and Hirsch, R. M. 2015. River chloride trends in snow-affected urban watersheds: increasing concentrations outpace urban growth rate and are common among all seasons. *Science of the Total Environment*, *508*, 488-497.
25. Dauer, D.M., Ranasinghe, J.A. and Weisberg, S.B. 2000. Relationships between benthic community condition, water quality, sediment quality, nutrient loads, and land use patterns in Chesapeake Bay. *Estuaries*, ***23***(1):80–96
26. Ding, J., Jiang, Y., Liu, Q., Hou, Z., Liao, J., Lan, Fu. and Peng, Q .2016. Influences of the land use pattern on water quality in low-order streams of the Dongjiang River basin, China: a multi-scale analysis. *Sci. Total Environ.*, 551–552:205–216
27. Downes, B.J, Lake, P.S. and Schreiber, E.S.G. 1993. Spatial variation in the distribution of stream invertebrates—implications of patchiness for models of community organization. *Freshw Biol.*, 30:119–132
28. Dudgeon, D., Arthington, A.H., Gessner, M.O., Kawabata, Z.-I., Knowler, D.J., Lévêque, C., Naiman, R.J., Prieur-Richard, A.-H., Soto, D., Stiassny, M.L.J. and Sullivan, C.A. 2005. Freshwater biodiversity: importance, threats, status and conservation challenges. *Biological Reviews of the Cambridge Philosophical Societ*y, 81:163.
29. Environment Canada. 2001. Priority substances assessment report: ammonia in theaquatic environment. *Minister of Public Works and Government Services*Canada, Ottawa, ON, Canada.
30. Gächter, R., Steingruber, S. M., Reinhardt, M. and Wehrli, B. 2004. Nutrient transfer from soil to surface waters: Differences between nitrate and phosphate. *Aquatic sciences*, **66**:117-122.
31. Hajigholizadeh, M. and Melesse, A. M. 2017. Assortment and spatiotemporal analysis of surface water quality using cluster and discriminant analyses. *CATENA, 151*, 247–258.
32. Hassan, K., Yousuf, A. R., Zargar, U., Jamila, I. and Rehman, M. 2014. Distributional Pattern of Macro Invertebrates across River Jhelum in Kashmir Valley. *International Journal of Fisheries and Aquatic Studies*, ***1***(6), 113-120.
33. Heathwaite, A. L., Johnes, P. J. and Peters, N. E. 1996. Trends in nutrients. *Hydrological processes*, **10**(2):263-293.
34. Hem, D. 1992. Study and interpretation of the chemical characteristics of natural water, 3rd edition, *U.S. Geological Survey Water-Supply Paper 2254, U.S. Washington DC: Geological Survey.*
35. Hutchinson, G.E. 1975. A treatise on limnology chemistry of lakes.John Wiley & Sons Inc., New York., I-II.
36. Hynes, H. B. N. 1960. *The biology of polluted waters*. Liverpool: Liverpool University Press.
37. Imevbere, A.M.A.1970. The chemistry of the river Niger in the Kainj reservoir area. *Arch. Hydrobiol.*,**67**(3):412-431.
38. Johnson, N. M., Reynolds, R. C. and Likens, G. E. 1972. Atmospheric sulfur: its effect on the chemical weathering of New England. *Science*, **177**(4048): 514-516.

39. Kannel, P. R., Lee, S., Lee, Y. S., Kanel, S. R. and Pelletier, G. J. 2007. Application of automated QUAL2Kw for water quality modeling and management in the Bagmati River, Nepal. *Ecological modelling*, 202(3-4):503-517.
40. Kaul, V., Pandit, A. K.andFoteder, D. N. 1980. Management of wetland ecosystem and as wildlife habitats in Kashmir. In *Proc. Int. Seminar Management of Environment. Bhabha Atomic Research Center, Bombay, India*.
41. Kendall, C., Elliott, E.M. and Wankel, S.D. 2007. Tracing anthropogenic inputs of nitrogen to ecosystems. *Stable isotopes in ecology and environmental science*, **2**(1):375-449.
42. Khanday, S. A., Bhat, S. U., Islam, S. T. and Sabha, I. 2021. Identifying lithogenic and anthropogenic factors responsible for spatio-seasonal patterns and quality evaluation of snow melt waters of the River Jhelum Basin in Kashmir Himalaya. *Catena*, *196*, 104853.
43. Koul, K. 1988. Ecology of some mountain streams in TelbalDachigam catchment. Ph.D thesis. *Deptt. of Botany,Kashmir University*.
44. Likens, G. E. and Bormann, F. H. 1974. Linkages between terrestrial and aquatic ecosystems. *BioScience*, **24**(8):447-456.
45. Malmqvist, B. and Rundle, S. 2002. Threats to the running water ecosystems of the world. *Environmental Conservation, 29*:134–153.
46. McDowell, R., Sharpley, A. and Folmar, G. 2001. Phosphorus export from an agricultural watershed: linking source and transport mechanisms. *Journal of Environmental Quality*, **30**(5):1587-1595.
47. Meyer, J. L. and Likens, G. E. 1979. Transport and transformation of phosphorus in a forest stream ecosystem. *Ecology*, **60**(6), 1255-1269.
48. Mouri, G., Takizawa, S. and Oki, T. 2011. Spatial and temporal variation in nutrient parameters in stream water in a rural-urban catchment, Shikoku, Japan: Effects of land cover and human impact. *Journal of Environmental Management*, **92**(7): 1837-1848.
49. Mulholland, P. J. 1992. Regulation of nutrient concentrations in a temperate forest stream: roles of upland, riparian, and in stream processes. *Limnology and oceanography*, **37**(7), 1512-1526.
50. Mulholland, P.J. 2003. Large scale patterns in DOC concentration, flux, and sources. *In: Findlay S, Sinsabaugh R (eds) Aquatic ecosystems: interactivity of dissolved organic matter*. Elsevier Science,Amsterdam, 139–159.
51. Naik, S. 2005. *Studies on pollution status of Bondamunda area of Rourkela industrial complex* (Doctoral dissertation). *Submitted to the national institute of Technology, Rourkela.*
52. Naqash, R. Y. and Sharma, L. K. 2011. Management Plan 2011-2016 Dachigam National Park.
53. Nong, X., Shao, D., Zhong, H., & Liang, J. (2020). Evaluation of water quality in the South-to-North water diversion project of China using the water quality index (WQI) method. *Water Research, 178*, 115781.
54. Perera, N., Gharabaghi, B. and Howard, K. 2013. Groundwater chloride response in the Highland Creek watershed due to road salt application: A re-assessment after 20 years. *Journal of Hydrology*, *479*, 159-168.

55. Rajini, K., Roland, P., John, C. and Vincent, R. 2010. Microbiological and physicochemical analysis of drinking water in George Town. *Nat Sci* 8(8):261–265.

56. Richardson, J. 1997. Acute ammonia toxicity for eight New Zealand indigenous freshwater species.*NZ J Mar Freshw Res.*, **31***:* 185-190.

57. Russo, R.C. 1985. Ammonia, nitrite and nitrate*. In: Rand GM, Petrocelli SR, editors. Fundamentals of aquatic toxicology*. Washington DC: Hemisphere Publishing Corporation; p. 455–71.

58. Sabha, I., Bhat, S. U., Hamid, A. and Rather, J. A. 2019. Monitoring stream water quality of Dagwan stream, an important tributary of Dal Lake, Kashmir Himalaya. *Arabian Journal of Geosciences*, 12:1-17.

59. Scheffer, M. and Van Nes, E. H. 2007. Shallow lakes theory revisited: various alternative regimes driven by climate, nutrients, depth and lake size. *Hydrobiologia*, **584**(1):455-466.

60. Sharma, K. K. and Chowdhary, S. 2011. Macroinvertebrate assemblages as biological indicators of pollution in a Central Himalayan River, Tawi (JK). *International Journal of Biodiversity and Conservation*, *3*(5):167-174.

61. Sharma, R. C., Singh, N. and Chauhan, A. 2016. The influence of physico-chemical parameters on phytoplankton distribution in a head water stream of Garhwal Himalayas: a case study. *The Egyptian Journal of Aquatic Research*, *42*(1): 11-21.

62. Sharpley, A. N. 1995. Dependence of runoff phosphorus on extractable soil phosphorus.*American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America*. 24(5): 920-926.

63. Sharpley, A. N., Gburek, W. J., Folmar, G. J.and Pionke, H. B. 1999. Sources of phosphorus exported from an agricultural watershed in Pennsylvania. *Agricultural water management*, **41**(2):77-89.

64. Slack, K. V. and Feltz, H. R. 1968. Tree leaf control on low flow water quality in a small Virginia stream. *Environmental Science & Technology*, *2*(2), 126-131.

65. Sunitha, V., Muralidhara, R.B. and Ramakrishna, R.M. 2012. Variation of fluoride and correlation with alkalinity in groundwater of shallow and deep aquifers—a case study in and around Anantapur district, Andhra Pradesh. *International Journal of Applied Sciences and Engineering Research* 1(4):569–575

66. Tian, Y., Jiang, Y., Liu, Q., Dong, M., Xu, D., Liu, Y., & Xu, X. (2019). Using a water quality index to assess the water quality of the upper and middle streams of the Luanhe River, northern China. *Science of the Total Environment*, *667*, 142–151.

67. Varol, M., Gökot, B., Bekleyen, A. and Sen, B. 2012. Water quality assessment and apportionment of pollution sources of Tigris River (Turkey) using, multivariate statistical techniques: a case study. *River Res Appl* 28(9):1428–1438.

68. Vitousek, P.M.1977. The regulation of element concentration in mountain streams in northeastern United States. Ecological Monogr., **47**:65-87.

69. Vorosmarty, C. J., Green, P., Salisbury, J. and Lammers, R. B. 2000. Global water resources: vulnerability from climate change and population growth. *science*, *289*(5477), 284-288.

70. Vörösmarty, C.J., McIntyre, P.B., Gessner, M.O., Dudgeon, D., Prusevich, A., Green, P., Glidden, S., Bunn, S.E., Sullivan, C.A., Liermann, C.R. and Davies, P.M. 2010. Global threats to human water security and river biodiversity *Nature*, 467: 555–561.

71. Vyas, V., Bhawsar, A. and Bhat, M.A. 2013. Assessment of Macrozoobenthic Structure in relation to physicochemical components in Barna Stream network of Narmada River Basin. *Asian Academic Research Journal of multidisciplinary*,*1*(14):20-38.
72. Waziri, M. and Ogugbuaja, V. O. 2010. Interrelationships between physicochemical water pollution indicators: A case study of River Yobe-Nigeria. *American Journal of Scientific and Industrial Research*, **1**(1):76-80.
73. Welch, P.S. 1952. Limnology, 2nd edn. McGraw Hill book Company, New York
74. Weld, J. L., Sharpley, A. N., Beegle, D. B. and Gburek, W. J. 2001. Identifying critical sources of phosphorus export from agricultural watersheds. *Nutrient Cycling in Agroecosystems*, **59**: 29-38.
75. Wetzel, R.G. and Likens, G.E. 2000. Dissolved Oxygen. In *Limnological Analyses.* Springer, New York, NY.pp:73-83.
76. Yogendra, K. and Puttaiah, E. T. 2008. Determination of water quality index and suitability of an urban waterbody in Shimoga Town, Karnataka. In *Proceedings of Taal2007: The 12th world lake conference* **342**: 346.
77. Yu, S., Xu, Z., Wu, W. and Zuo, D. 2016. Effect of land use types on stream water quality under seasonal variation and topographic characteristics in the Wei River basin, China. *Ecological Indicators*, **60**:202-212.
78. Zutshi, D. P. and Khan, M. A. 1978.On lake topology of Kashmir.*Env.Physio. Ecol. Plants.*, 465-472.