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# Studies in assessment of environmental degradation and tourism in the Karakoram Mountain Ranges using water quality characterization

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**Abstract**

This research aims to investigate the relationship between environmental degradation focusing on water pollution in three different tourism spots (Hunza-Nager, Bagrote Valley and Haramosh Valley) highly touristic, medium touristic and low touristic areas respectively in the Central Karakoram National Park (CKNP) area. The potential drinking water sources in the test area were assessed for certain physical parameters (pH, Conductivity, Turbidity, TDS). A diverse range of sources (Streams, springs, Rivers etc.) were taken in to account. The High Turbidity and conductivity speaks of an accelerated melting rate of glaciers which ultimately fed the water sources (Hoper and Haramosh Valley). The open drinking water sources in Haramosh Valley are highly vulnerable to anthropogenic activities as the Total Dissolved Solids are at higher end as compare to other localities. The drinking water sources at medium touristic areas (Bagrote valley) were in accordance with the protected pattern and the spring sources of the villages along the trek to Glaciated region are drinkable water sources to tourists. The crux is to manage the fragile drinking water sources in the high touristic areas within CKNP with proper protection of sources .to make them pollution free for local populace and the tourists.

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## Introduction

Mountainous areas in the Karakorum Ranges are fragile towards their natural balance existing in wild ecosystems (Breu and Hurni, 2003). Besides sensitive ecological niche extensive and the greatest glacial mass outside polar spheres residing in the Karakoram Ranges and unique cultural mosaic make these areas more attractive towards local and international tourists equally (Khan et. Al. 2014; Jeanneret 2001). However, irresponsible tourism approach towards ecosystems and unique contextual unplanned developmental realities create difficulties in their wilderness (Murphy and Price, 2005; Müller, 1994).

There is a need for generating systematic information on various environmental issues in mountain areas for guiding, planning and managing mountains and tourism development (Fischer, 2010; Deegan and Rankin,1996). Once an assessment of the environmental degradation of tourism is made, then it would be possible to attain a balance between appropriate tourism development, tourism management and protection of the mountain environment in the mountain ranges. Environmental issues, unexpected change in weather conditions particularly due to climate change are shocking for millennia long inhabitants of these areas (Thompson et. al. 2011).In order to introduce concept of sustainable resources use into practice, it is very important to know the current level of environmental degradation especially in the mountainous areas.

According to the World Tourism Organization (2003) global international tourist arrivals are likely to reach over 1.56 billion by the year 2020. South Asia, East Asia and the Pacific, the Middle East and Africa are estimated to increase at rates of over 5% per annum, compared to the world tourist's flow increase of 4.1% for the similar period (Nawaz *at el.,* 2009). The escalating volume of tourists leads to increasing strain on the brittle environment (Nawaz *at el.,* 2009). The large quantity of solid waste left by the tourists on all popular tourism destinations is not only a monstrosity for the tourists, but also severe intimidation to the natural environment. These mountain tourism activities also have harmful impacts on these mountainous areas (Ata and Siddiqui, 1993). Prop up the ecologically sustainability is now rising sturdily in the tourism sector as the consistent way of balancing environmental apprehension with growth and development (Niazi, 2002).

Tourists frequently use the trekking roots, trails, tracks, caravans, vehicles and other transport to walk around at the destinations which cause traffic congestion, noise pollution and scattering of litter. Large number of tourists at low carrying capacity destination effects the environment negatively. Inadequately tourism infrastructure and badly administered activities of tourists eliminate different plants and animal species (UNEP, 2007).At the entrance of 21$^{st}$ century, ecological system, plant and animal species, water, natural resources and the mankind itself started to confront different threats by its own exploitations (Banskota, 2000).

The bulky quantity of mountaineering gears, rubbish, plastic bags, left over by trekking parties, expedition groups and other adventure tourist on trekking trails is not only painful situation for visitors but also sever threat for local habitat, There is no any suitable waste discarding structure to protect these trekking routes. Most of the tourism suppliers like, tour guides, porter, travel agents, and hoteliers have no any idea of responsible tourism activities (trekking, mountaineering, hard and soft adventure) (Ahmed, 2003). Harmful and negative impacts from tourism arise when the tourists over use the destination more than its carry capacity. When it goes beyond the coping capability of the environment then it starts to spoil the nature. Poorly managed tourism created more problems and possible pressure on numerous protected destinations around the world. It can put massive strain on different areas and negative effects can be scattered rubbish around the trekking routes, environmental fumes, soil corrosion, polluted water fell into the sea, loss of plant and animal species.

Tourism can also be cause of traffic congestion, air pollution and infrastructure damage and visual loss as other industries also effect in the same way (Kakar & Khalil, 2004).

Long stays of tourists or visitors at naturally sensitive destinations can deteriorate the natural resources like beauty, landscapes, glaciers and wildlife (Maroudas *et al.,* 2004). The environmental impact can be related to the intensity, of site development, the resilience of the ecosystem and degree of site transformation because of tourism development. The sources of concern about potential environment impact include: disturbance of ecological balance, effect on especially sensitive environments, impact of vandalism, pollution and waste (Jamieson, 1999).

Tourism is said to have a direct impact on the state of resources and the environment. This impact is felt on the critical resources as well as on the state of environment (land, water, and air). However the overall impact may be the result not only of tourist activities but also of the behaviour of the local communities and all the actors in the tourism sector, such as tour operators, hoteliers/catering industry and service sector, who together have a considerable impact on resources, tourism has both a negative and positive impact (Al-Jalaly *et al.,* 1995). Mountain adventure tourists often leave behind waste that contains various non-recyclable materials, which constitute source of infection, potential fire sources, while at the same time disturbing ecological balance (Maroudas *et al.,* 2004). Tourism activities in Pakistan are currently far from sustainable, as in many other mountain regions worldwide: deforestation, uncontrolled land utilization, unplanned growth of tourism, mushrooming growth of accommodations (Haroon, 2002). This research is aimed at assessment of current situation of environmental exploitation in the mountainous region of Karakoram using water quality characterisation as an indicator of environmental degradation due to touristic influence.

## Material and methods

*Study Area*

The Karakorum extends 350km parallel to the Himalayas, from the Siachen glacier in the east along the border between Pakistan and China to the Ishkoman River, which divides the Karakorum range from the Hindu Kush in the west (Ives, 2004). The development of tourism in the region of the Karakorum has been influenced in large part by the geographic conditions, most notably by the high concentration of tall mountains – four of them above 8000 m: K2 (8611m), Gasherbrum I (8063m), Broad Peak (8047m) and Gasherbrum II (8035m. The longing to ascend the world's highest peaks in the mid-20th century became a driving force for the development of tourism in this region, which was at first limited to exploration and mountaineering expeditions, and only considerably later was followed by a boom in trekking as one of the most popular forms of adventure tourism in the broader region of the Himalayas more generally (Mrak, 2011).

*Sample and Sampling*

The water quality analysis was carried out with the help of water samples collection from 51 sites in three areas in CKNP based on touristic significance of the sites. Hunza-Nager was taken as high touristic area whereas Haramosh as medium touristic area and Bagrote as low touristic area in Central Karakoram National Park area.

Non probability convenience samples) are used to characterize the spatial and temporal distribution of general water-quality and constituent transport in relation to hydrologic conditions and contaminant sources. Fixed-Site sampling is a primary source of information for meeting water-column assessment objectives for temperature, salinity, suspended sediment, major ions and metals, nutrients and organic carbon (NAWQA, 1998). The source of the drinking water, from the distribution head was sampled together with intermediate sampling where required with the last point of usage.

*Sample Processing and Analysis*

High Density Polyethylene sterile Bottles (HDPE) of 500 ml were used to collect water sample from different drinking sources of the touristic points. Bottles were labeled /tagged and transported to water quality lab Karakoram International University Gilgit-Baltistan, Pakistan in cool boxes for further investigations peculiar to physical characteristics of drinking water sources. The necessary data pertaining to source ecology, topography and other important attributes including coordinates were mustered in a pre-designed data sheet. Sampling was done in closer conformity with general guide to the sampling techniques and recommendations for preservation and handling of samples (ISO 2006 and 2012).

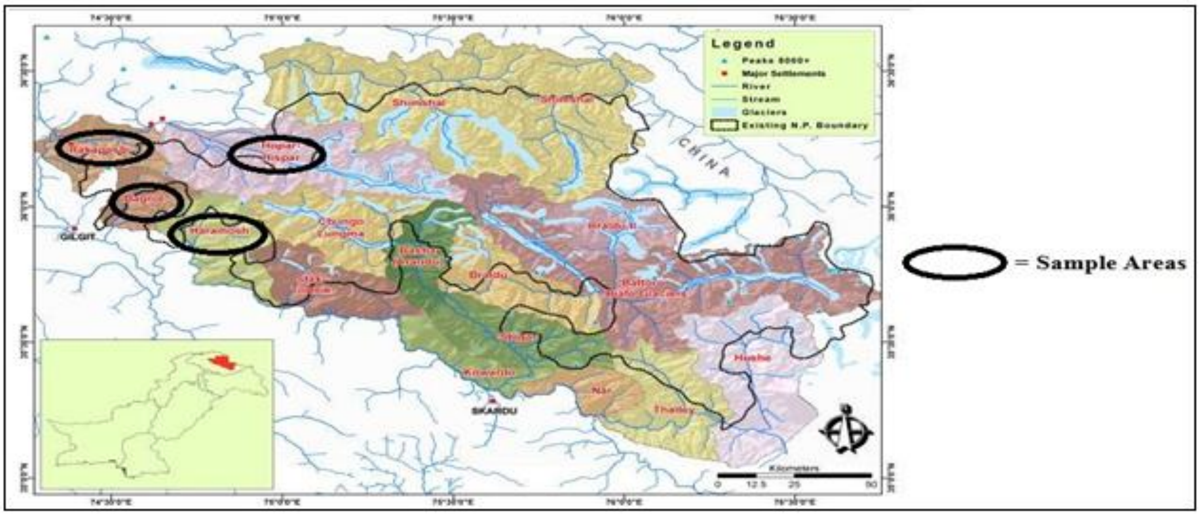


**Fig. 1.** Map of the Study Area.

*Analytical Procedures*

The Physico-chemical parameters including pH, Turbidity, Conductivity, Total dissolved Solids (TDS) of each sample were analysed in Lab according to fallowing methods.

*Parameters*

*pH*

The pH of the each sample was determined using a pH meter (Adwa, AD 1020) in the Water quality laboratory KIU. (Degree of accuracy 0.01) equipped with a temperature probe. The pH meter was initially calibrated by dipping the electrode into Known buffer solution of known pH 4,7 and 9 respectively. The whole process of pH determination was in consonance with international standards for the determination of pH (ISO, 2006). The temperature of each sample was determined on the site of collection with a Mercury Thermometer.

*Determination of turbidity*

Turbidity of the collected samples was determined in Lab with Turbidimeter (Velp Scientifica, Model TB-1). Turbidity in water is caused by suspended and colloidal matter such as clay, silt, finely divided organic and inorganic matter, and plankton and other microscopic organisms. In the current method the instrument was calibrated by the known solutions of 20, 100,400 and 800 NTU, (Nephalometric Turbidity Unit) and then placed the required amount of sample in Turbid meter slot which read the value through scattered light detectors located at 90 degrees to the incident beam.

*Measurement of Electrical Conductivity (EC)*

A conductivity meter (model AD 3000, Adwa) was used to determine electrical conductivity. Respective reference solutions for above mentioned equipment were used for calibration of equipment and accuracy of readings with a degree of accuracy of 0.01. The instrument was initially calibrated using standard solution of conductivities 500 µs/cm and 1500 µs/cm.

Duplicate values were taken and units were in micro siemens per centimetre.

*Total Dissolved Solids (TDS)*

Total Dissolved Solids in each water sample were measured in KIU water Quality Lab using a conductivity meter (model AD 3000, Adwa). One hundred millilitres of the sample was poured into a 250 ml beaker. The probe was then immersed into the sample and the respective value read on the digital screen. The values were expressed in ppm (parts per million).

**Results and discussion**

Given water samples assessed for pH are in neutral range (pH=7); samples from Hunza-Nager and Haramosh are slightly basic while samples of Bagrote are slightly acidic. These values inhibit pathogens and toxic metals. Total conductivity is indirect measure of total dissolved solids and indicates the presence of ionic specie.

**Table 1.** Descriptive Results.

| Measured Parameters | Sample Areas | | | WHO Standard Values |
|---|---|---|---|---|
| | Hunza-Nager Mean Scores | Haramosh Mean Scores | Bagrote Mean Scores | |
| pH | 7.30 | 7.63 | 6.68 | 6.5-8.5 |
| Total conductivity (µs/cm) | 465.39 | 444.27 | 890.39 | 400-1200 |
| Turbidity(NTU) | 5.75 | 1.450 | .246 | 5 |
| Total Dissolved Solids (TDS) (mg/l) | 142.78 | 74.73 | 141.06 | 1000 |

**Table 2.** ANOVA Results.

| | **F** | **Sig.** |
|---|---|---|
| pH | 17.961 | .000 |
| Turbidity | 4.381 | .018 |
| Conductivity | 18.821 | .000 |
| TDS | 13.954 | .000 |

Conductivity of distilled water is < 3 µs/cm while water with conductivity >500 µs/cm indicates contamination. Water samples of Hunza-Nager and Bagrote are not contaminated for drinking while sources in Haramosh indicate the presence of ionic contaminants which may be from anthropogenic (animal waste, *fecal coliform*) sources or may be from natural sources( ionic mineral rocks). Also, lower pH of water at Bagrote make it susceptible to contain ionic and metallic species.

**Table 3.** Results Physical Parameters of Water in Hunza-Nager.

| Sample Area (Hunza-Nager) | Sikandarabad I Then | Sikandarabad Khantip | Sikandarabad Tehsil | Hakalshal, Hoper | Hakalshal Mid Tape | Hakalshal Last Tape | Broshal Tank, Hoper | Broshal Doulat House | Broshal School Tap | Ratal Tank, Hoper | Ratal Ghulam House | Ratal Roadside Tap | Sholay, Pisan | Ismail House,Pisan | Dainy,Pisan | Sholay,Minapin | Dasgumi, Minapin | kot masjid,Minapin |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pH | 7.2 | 7.3 | 7.3 | 6.6 | 6.6 | 6.6 | 7.3 | 7.4 | 7.4 | 7.4 | 7.2 | 7.2 | 7.7 | 7.7 | 7.7 | 7.6 | 7.6 | 7.6 |
| Turbidity (NTU) | 4.03 | 2.52 | 4 | 2.25 | 1.24 | 1.75 | 24.7 | 37.1 | 11.29 | 1.62 | 5.71 | 4.02 | 0.40 | 0.70 | 0.76 | 0.61 | 0.57 | 0.32 |
| Conductivity (µS) | 420 | 460 | 430 | 397 | 333 | 474 | 684 | 442 | 470 | 457 | 1191 | 392 | 221 | 554 | 194 | 248 | 455 | 555 |
| TDS | 125 | 124 | 123 | 108 | 107 | 105 | 133 | 135 | 132 | 212 | 210 | 209 | 141 | 135 | 143 | 140 | 144 | 144 |

Turbidity measures particulate matter. Water samples from Hunza-Nager haves turbidity above WHO recommendation which may be due to runoff from rain, flood or from soil erosion or even due to road besides water canals and it is risky for health. On the other hand, samples assessed for turbidity in Haramosh and Bagrote have lower values comparatively.

**Table 4.** Results Physical Parameters of Water in Bagrote.

| Sample Area (Bagrote) | Sanikar Tank | Sanikar Mid Public | Sanikar Lower Tape | Hopey Tank | Hopey, Ihsan Ali | Hopey ,Ghulam Raza | Datuchi Tank | Datuchi, Ali Ghulam | Datuchi,public Tape | Farfu Tank | Farfu Azhar House | Farfu lower Tap | Bulchi Tank | Bulchi,M.Hussain | Bulchi,Adil House | Chira Tank | Chira,Ashur Ali House | Chira,Mehboob House |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pH | 7.5 | 7.2 | 8 | 6.1 | 6.2 | 6.1 | 7.1 | 7.2 | 7.1 | 6.2 | 6.2 | 7.5 | 6.3 | 6.1 | 6.1 | 6.6 | 6.6 | 6.2 |
| Turbidity (NTU) | 0.08 | 0.25 | 0.09 | 0.04 | 0.08 | 0.4 | 0.14 | 0.07 | 0.03 | 0.07 | 0.05 | 0.04 | 0.33 | 0.04 | 0.17 | 0.59 | 0.58 | 1.39 |
| Conductivity (µS) | 1147 | 1451 | 1245 | 505 | 502 | 550 | 992 | 945 | 933 | 712 | 674 | 743 | 621 | 658 | 578 | 1243 | 1162 | 1366 |
| TDS | 124 | 125 | 125 | 85 | 88 | 88 | 155 | 156 | 155 | 121 | 120 | 121 | 105 | 104 | 104 | 255 | 254 | 254 |

**Table 5.** Results Physical Parameters of Water in Haramosh.

| Sample Area (Haramosh) | Brumday Source | Brumday Mid | Brumday Last | Shatot Source | Shahtot Mid | Shahtot last | Hurban Source | Hurban Mid | Hurban last | Sassi Source | Sassi Mid | Sassi last | Hanuchal Source | Hanuchal Mid | Hanuchal last |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pH | 7.7 | 7.5 | 7.5 | 8.1 | 8 | 8 | 7.8 | 7.7 | 7.3 | 7.9 | 7.9 | 7.8 | 7.1 | 7.2 | 7 |
| Turbidity (NTU) | 1.36 | 1.07 | 1.86 | 3.21 | 2.7 | 2.81 | 1.45 | 0.59 | 0.46 | 0.96 | 0.28 | 0.27 | 1.94 | 2.18 | 0.72 |
| Conductivity (µS) | 672 | 676 | 702 | 255 | 250 | 282 | 322 | 371 | 319 | 509 | 497 | 492 | 496 | 418 | 403 |
| TDS | 116 | 115 | 116 | 50 | 50 | 48 | 49 | 48 | 49 | 76 | 78 | 76 | 83 | 84 | 83 |

Highest electric conductivity and lowest turbidity of Bagrote indicates that water flows over mineral rock. Total dissolved solids indicate ionic and molecular pollutants from natural sources (water runoff) or from anthropogenic sources (animal waste). All samples from Hunza-Nager and Bagrote (142.78mg/l and 141.06mg/l respectively) have higher level of total dissolved solids as compared to Haramosh (74.73mg/l). But water of all areas has lower values from WHO recommendations.

All samples in given study are palatable as pH, electric conductivity, turbidity and TDS are below WHO standard except slight to medium turbid water of Hunza-Nager ,(11 to 37 NTU).

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