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Research Article

MEASUREMENT OF UNCERTAINITIES IN BIO-MONITORING OF WATER QUALITY OF GLACIAL FED HIMALAYAN RIVER BHAGIRATHI IN UTTARAKHAND, INDIA

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ABSTRACT
Uncertainities in measurement of Saprobic score and Diversity score were mainly due to substratum composition of Boulders, Cobbles and Pebbles, Size of Gravel ,Sand, Silt and Clay, which ascertained the biological establishment of rare and endangered nymph\ larvae of benthic macro-invertebrates suchas, Iron, Ironodes, Epeorus/Ironopsis and Rithrogena, Oligoneuriella, Kyphopteryx, Leuctra, Perlomiya and Eucapnopsis used for bio-monitoring of water quality of River Bhagirathi in Uttarakhand during year 2004 to 2008. Thus, during winter in November, 2004 when flow velocity and water temperature was lowest, combined uncertainties in Saprobic score was ± 4.7, and Diversity score was ± 0.41 contributed through random sampling during collection of benthic macro-invertebrates from River Bhagirathi at Gangotri. Whereas, during extreme summer of April, May and June, glacial melt water contributed uncertainties in measurement of Saprobic and Diversity score indicating clean water quality of class 'A' of BWQC. Uncertainties increased to ± 7.12 for Saprobic score and ± 0.45 for Diversity score at upstream of Uttarkashi whereas, at Tehri uncertainties were reported ± 5.1 for Saprobic score and ±0.5 for Diversity score consequent upon habitat degradation.

Key Words: *Saprobic Score, Diversity Score, Bio-Monitoring, Benthic Macro-Invertebrates, Random Error, Systematic Error, Uncertainty*

INTRODUCTION
The pollution levels in rivers have been detected by monitoring limited number of physico-chemical parameters using Primary Water Quality Criteria. However, with the growing concern for loss of bio-diversity in Indian rivers on account of habitat degradation over the years, the concept of bio-monitoring was introduced in water quality network in India. Among all the biotic components, benthic macro-invertebrates were considered as best suitable biological parameters and as cost-effective measures for surface water quality management, using Biological Water Quality Criteria (BWQC). Glacial fed River Bhagirathi is an important river in Garhwal Himalayas, originating from Gaumukh in Gangotri glacier at an altitude of 3892 msl and passes via thickly populated towns like Uttarkashi, Tehri and Devprayag. At Devprayag, it meets the River Alaknanda and from the confluence downstream at Devprayag (475 msl), it is called the River Ganga. River Bhagirathi has a steep gradient with an altitudinal difference of 3038 msl from Gangotri to Jhulapul in Maneri (1298 msl). From Uttarkashi at downstream Triveni (1036 msl), river flows with a gradual slope in altitude, and reaches New Tehri (1550 to 1950 msl) which was earlier known as Old Tehri (755 msl). From Tehri Dam further downstream at Kaudiyala (467 msl), river Ganga enters the foothill of Himalayas and acquires an altitude of 292 msl at Haridwar. Due to an advantage of gradient available within a 225 km stretch, River Bhagirathi has been extensively harnessed for various anthropogenic activities, thus influencing the water quality of river in terms of its biological characteristics. Studies on uncertainty measurement during random sampling were carried out on River Bhagirathi subjected to different stages of development of Joshiyara Barrage and Tehri hydro project on River Bhagirathi during year 2004-2008 (Semwal and Akolkar, 2011). The uncertainty associated with glacial melt flow rate determinations which depend on the value of the melt flow rates of River Bhagirathi

during winter will in general be different from uncertainties associated with very high melt flow rate during summers (Thomas, 2002). Based upon anthropogenic disturbances on natural flow, depth of river, water temperature, pH, dissolved Oxygen, percent distribution and size of substratum composition of River Bhagirathi, the random errors and systematic errors were identified for estimation of uncertainties in evaluation of Saprobic score and Diversity score used for biological water quality assessment of River Bhagirathi using Biological water Quality Criteria (BWQC). Thus, keeping in view the importance of River Bhagirathi in terms of protecting and restoring the ecological status in the threatened habitats, the present studies were undertaken.

MATERIAL and METHODS

It is important to distinguish between error and uncertainty. Error is defined as the difference between an individual result and the true value of the measurand whereas; uncertainty takes the form of a range. (Ellison *et.al*., 2000). By 'random errors' the assumption is made that repeated measurement can reduce the estimation of this error (Wellum). Flow velocity contributes maximum random errors followed by depth of river which is directly related with flow rate. Other random errors may be contributed through distribution of substratum composition and other field parameters such as water temperature, pH, and Dissolved oxygen of water.

Uncertainty Sources

In practice the uncertainty of the results of Saprobic score and Diversity Score may arise from many possible sources including, Flow velocity (Meter /Seconds) Depth (Meter), substratum composition %, Water Temperature (^{0}C) Dissolved Oxygen (mg/l) and pH. Standard Uncertainty (Us) is the uncertainty of the result of a measurement as a Standard deviation (Table 1).

Table 1: Calculation for Relative Standard Uncertainty for random errors

Variables	Calculation
n	Number of observation
X	Value of individual parameter
Average value of X	$\Sigma X/n$
Standard Deviation, SD	$\sqrt{(X_1 - X)^2}/n-1$
Standard Uncertainty U_s	$SD/\sqrt{n}$
Relative Standard Uncertainty (Ur)	U_s / X

Systematic Error

The measurement usually contain systematic contributions which cannot be reduced by repetitive measurement. Systematic error is defined as the difference between the true value and measured value (Wellum). Various substratum sizes contribute systematic error by not sampling all the substrata for collection of benthic macro-invertebrates. Systematic Error/ Uncertainty due to Size of River bed substratum was calculated as (Table 2).

Table 2: Calculation for Relative Standard Uncertainty for systematic error

Variables	Calculation
n	Number of observation
X	% substratum
Average value of X %	$\Sigma X/n$
$\sqrt{n}$	SQRT (n)
Size of substratum	mm
Standard Uncertainty U_s	Substratum size in $mm/\sqrt{n}$
Relative Standard Uncertainty (Ur)	U_s / X

Table 3: Spread sheet of Uncertainty measurement (Quantification) at Gangotri

S.No.	Uncertainty component	Average Value X	Standard Uncertainty (U_s)	Relative Standard Uncertainty (U_r)
1.	Saprobic score	7.286	0.488176198	0.067001949
2.	Diversity sore	0.4272	0.133640712	0.312829383
3.	Flow velocity (Meter /Seconds)	1.572	0.425892005	0.270923667
4.	Depth(Meter)	0.7086	0.059841123	0.084449793
5.	Water Temperature (0C)	4.2	0.784219357	0.186718895
6.	Dissolved Oxygen (mg/l)	7.816666667	0.19078784	0.024407826
7.	pH	7.008	0.248503521	0.035459977
8.	Boulders %	28	6.442049363	0.230073192
9.	Cobbles %	21	1.870828693	0.089087081
10.	Pebbles %	19	4	0.210526316
11.	Size of Gravel	15-2mm	0.074535599	0.005555556
12.	Size of Sand	0.0625 -2.0mm	0.02795085	0.001455773
13.	Size of Silt	0.002 mm	0.000894427	0.002236068
14.	Size of Clay	<0.002 mm	0.000894427	0.002236068

Table 4: Spread sheet of Uncertainty measurement (Quantification) Upstream Uttarkashi

S.No.	Uncertainty component	Mean Value X	Standard Uncertainty (U_s)	Relative Standard Uncertainty (U_r)
	Saprobic score	6.04	1.536424421	0.254374904
1	Diversity score	0.362	0.124955992	0.345182299
2.	Flow velocity (Meter /Seconds)	0.904	0.311233032	0.344284327
3.	Depth(Meter)	1.04	0.395727179	0.380506903
4.	Water Temperature (0C)	13.6	0.620483682	0.0456238
5.	Dissolved Oxygen (mg/l)	9.13	0.648274633	0.071004889
6.	pH	7.412	0.312912128	0.042216963
7.	Boulders %	27	8.602325267	0.31860464
8.	Cobbles %	17	5.385164807	0.3167744
9.	Pebbles %	20	4.472135955	0.223606798
10.	Size of Gravel	15-2mm	0.894427191	0.149071198
11.	Size of Sand	0.625 – 2.0mm	0.02795085	0.000977302
12.	Size of Silt	0.002 mm	0.000894427	0.000745356
13.	Size of Clay	<0.002 mm	0.000894427	0.000745356

Combined Standard Uncertainty (Uc) of the result of a measurement, is an estimated standard deviation equal to the positive square root of the total variance obtained by combining all the uncertainty components (SLOVENSKA AKREDITACIZA OA03).

Table 5: Spread sheet of Uncertainty measurement (Quantification) Downstream Uttarkashi (Triveni)

S.No.	Uncertainty component	Mean Value X	Standard Uncertainty (U_s)	Relative Standard Uncertainty (U_r)
	Saprobic score	7.17	0.318433667	0.044411948
1	Diversity score	0.552	0.117830387	0.213460845
2.	Flow velocity (Meter /Seconds)	1.15	0.199649693	0.173608429
3.	Depth(Meter)	0.9932	0.269084076	0.270926375
4.	Water Temperature (0C)	13.2	0.583095189	0.044173878
5.	Dissolved Oxygen (mg/l)	9.637725159	0.828724851	0.0859876
6.	pH	7.132	0.194869187	0.027323217
7.	Boulders %	29.2	12.77262698	0.437418732
8.	Cobbles %	14.4	4.567274899	0.317171868
9.	Pebbles %	24.4	7.166589147	0.29371267
10.	Size of Gravel	15-2mm	0.894427191	0.106479427
11.	Size of Sand	0.0625 -2.0mm	0.02795085	0.001330993
12.	Size of Silt	0.002 mm	0.000894427	0.00034401

Table 6: Spread sheet of Uncertainty measurement (Quantification) Old Tehri

S.No.	Uncertainty component	Mean Value X	Standard Uncertainty (U_s)	Relative Standard Uncertainty (U_r)
	Saprobic score	1.573571429	0.858164158	0.54536079
1	Diversity score	0.151428571	0.085496977	0.56460268
2.	Flow velocity (Meter /Seconds)	0.277142857	0.160111323	0.577721269
3.	Depth(Meter)	102.3335714	22.36205714	0.267261242
4.	Water Temperature (0C)	24.85714286	1.570179324	0.063168134
5.	Dissolved Oxygen (mg/l)	9.894888251	0.21207314	0.021432596
6.	pH	8.162142857	0.351477538	0.043061919
7.	Boulders %	9.785714286	7.143104391	0.729952274
8.	Cobbles %	5.785714286	5.709235406	0.986781428
9.	Pebbles %	6.571428571	4.384932099	0.667272276
10.	Size of Gravel	15-2mm	0.534522484	0.680301343
11.	Size of Sand	0.0625 -2.0mm	9.891979372	0.000537594
12.	Size of Silt	0.002 mm	0.000534522	8.04658E-05
13.	Size of Clay	0.002 mm	0.000534522	1.3606E-05

Table 7 : Spread sheet of Uncertainty measurement (Quantification)) Zeropoint

S.No.	Uncertainty component	Mean Value X	Standard Uncertainty (U_s)	Relative Standard Uncertainty (U_r)
	Saprobic score	0.0	0.0	0.0
1	Diversity score	0.0	0.0	0.0
2.	Flow velocity (Meter /Seconds)	1.346	0.528753251	0.175680269
3.	Depth(Meter)	2.2	1.350925609	0.274614681
4.	Water Temperature (0C)	15.25	0.853912564	0.055994266
5.	Dissolved Oxygen (mg/l)	9.443023256	0.383969264	0.040661688
6.	pH	7.09	0.2656125	0.037462976
7.	Boulders %	42.2	17.88337217	0.423776592
8.	Cobbles %	0.8	0.489897949	0.612372436
9.	Pebbles %	4.4	3.906404997	0.887819317
10.	Size of Gravel	(15-2mm)	0.894427191	0.212958855
11.	Size of Sand	(0.0625 -2.0 mm)	0.02795085	0.000577497

Table 8 : Spread sheet of Uncertainty measurement (Quantification) Dev Preayag

S.No.	Uncertainty component	Mean Value X	Standard Uncertainty (U_s)	Relative Standard Uncertainty (U_r)
	Diversity score	0.0	0.0	0.0
1	Saprobic score	0.0	0.0	0.0
2.	Flow velocity (Meter /Seconds)	0.74	0.024494897	0.033101213
3.	Depth(Meter)	1.496	0.205757138	0.137538194
4.	Water Temperature (0C)	13.212	3.431988345	0.259762969
5.	Dissolved Oxygen (mg/l)	10.77035941	1.463557715	0.135887547
6.	pH	7.372	0.26395833	0.035805525
7.	Boulders %	42	19.84943324	0.472605553
8.	Cobbles %	4	1	0.447213595
9.	Pebbles %	9	3.366501646	0.374055738
10.	Size of Gravel	(15-2mm)	0.894427191	0.447213595
11.	Size of Sand	(0.0625 -2.0 mm)	0.02795085	0.00065002

Table 9 : Calculation of Combined Uncertainty

S.No.	Variables	Calculation
1.	Average value	X
2.	Combined Relative Standard Uncertainty of Saprobic score (CUr)	$=\sqrt{\Sigma(Ur)^2}$
3.	Combined Standard Uncertainty (CU_c)	$CU_r \times X$
4.	Expanded Uncertainty	(CUc) × 2
5.	The Sample Saprobic score Uncertainty	X± Expanded Uncertainty
6.	The Sample Diversity score Uncertainty	X± Expanded Uncertainty

Expanded Uncertainty (U) provides an interval within which the value of the measurand is believed to lie with a defined level of confidence. U is obtained by multiplying Uc (the Combined Standard Uncertainty) by a coverage factor k. The choice of the factor k is based on the level of confidence desired (for an approximate level of confidence of 95%, k is 2).

RESULTS AND DISCUSSION

Gangotri

Gangotri Glacier Is located between 30^0 45'N-30^0 55'N and $79^0$5'E-$79^0$15'E at an elevation of about 3,900, pm the western slope of the Chaukhamba peak. The glacier is about 30 km. long and 2 km. wide. It is fed by a system of tributary glaciers known as *Rakta Varna, Swet Varna, Nilambar, Pitambar and Chaurangi*, depending upon the Colour of the surrounding rocks. Gaumukh, the snout, is a gray blue wall more than 100m high. Below the snout, there are a series of recessional moraines for a few kilometers. The Garhwal Himalaya serves as the perpetual reservoirs of water for most of the main rivers which are for immense value to the northern India. Most parts of the northern parts of the district of Uttarkashi, lie under the snow-covered zone, which provide the most important reservoirs of water especially during summer. At Gangotri, percent distribution of rare genera of family Heptageniidae like, *Iron, Ironodes, Epeorus/Ironopsis* and *Rithrogena* were observed and rare genera of stonefly nymph such as, *Kyphopteryx, Leuctra, Perlomiya* and *Eucapnopsis* are known from the Oriental region and the Himalayas at high altitude required special attention for habitat degradation at Gangotri.

Due to extreme snow fall in winter and Glacial melt during summer at Gangotri, bio-monitoring was carried out during pre-winter in November, Post winter in February and May, June in summer during Year 2004 to 2008. The river flow and depth variations were more during summer due to contribution of

glacial melt water from surroundings to River Bhagirathi. Thus, uncertainties of Saprobic score and Diversity score due to proper collection of benthic macro-invertebrates increased at Gangotri. Variations were also due to change in Substratum composition as a result of various human activities and land slide due to environmental conditions. Therefore, the collection of benthic macro-invertebrates were confined to , Boulders, Cobbles and Pebbles.. thus uncertainties were also included due to gravel, sand, silt and clay which remained untouched.

River Bhagirathi at Gangotri possessed average 28% boulders, 21% cobbles, 19% pebbles, 12% gravel, 19.2% sand and remaining 0.4% of silt and 0.4% clay. Instead of percentage, proportions are used as a useful convention. Then the substratum composition of river Bhagirathi at Gangotri, consists of 0.28 boulders, 0.21 cobbles, 0.19 Pebbles, 0.12 gravel, 0.192 sand and remaining 0.004 silt, and 0.004 clay. The total substratum composition, corresponding to 100% is therefore represented by the figure 1.0. If all the substrata is assembled and if we sample 100 animals out of them at random, it is intitutively expected that on the average, 28 animals may be collected from boulders, 21 from cobbles, 19 from pebbles, 12 from gravel, 19 from sand and may or may not be single from silt and clay. However, the actual outcome might vary. There might not be a single from silt and clay among all the substrata sampled or there may be quite a few more than one. The ratio of the number of animals sampled from silt and clay might therefore vary from zero to considerably greater than 0.004. If we increase our sample size to 500 or 1000, it is less likely that the ratio will fluctuate widely around 0.004. The greater the sample taken, the closer the ratio of animals sampled from silt and clay to the total substrata sampled will approach 0.004.

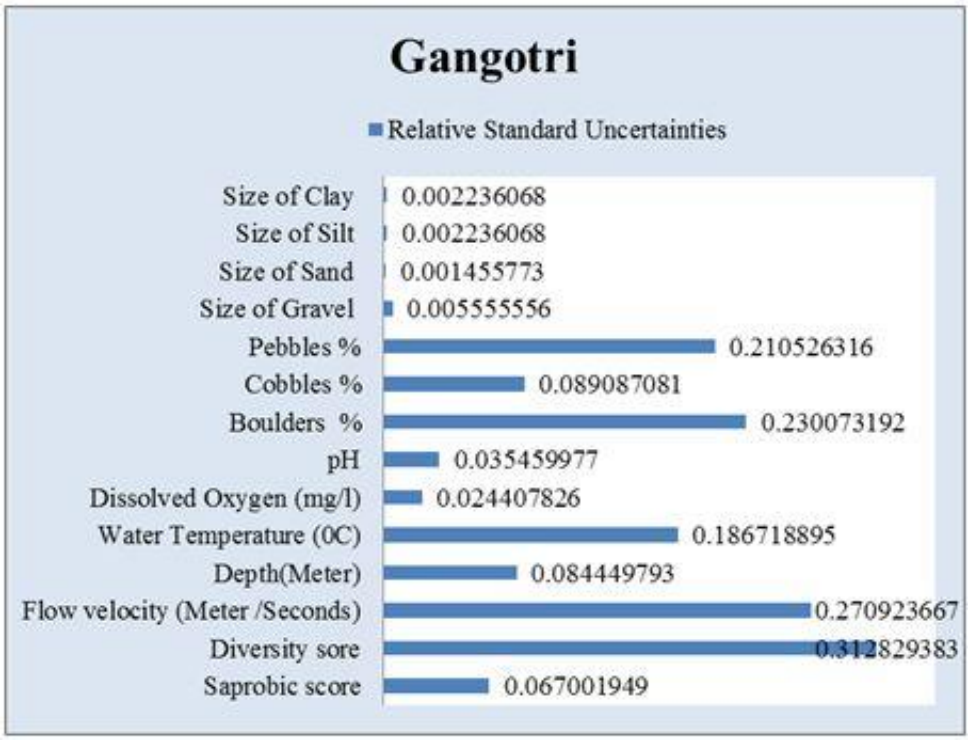

Figure 1: Contribution of Relative Standard Uncertainties in River Bhagirathi at Gangotri

In fact, the probability of sampling an animal from silt and clay substratum can be defined as limit reached by the ratio of animals from silt and clay to the total number of animals sampled, as sample size keeps increasing. Thus, we may formally summerize the situation by stating that the probability of an animal collected from silt is p[silt] =0.004, p[clay] = 0.004 which is very low. Whereas, the probability of sampling from boulders p[boulders] = 0.28, p[cobble] = 0.21, p [pebble] = 0.192. p[sand] =0.192 and

p[gravel]=0.12, is higher. As a result, most sampling was carried out from boulders, cobbles and pebbles. Thus random errors were due to gravel, sand, silt and clay. Figure 1 show maximum uncertainties were identified due to random errors in evaluation of Diversity score, since the observation was taken once in a year. The error could be reduced by repeated observations. Thus , the combined uncertainties could be reduced by discarding flow velocity and depth parameters from the calculation of combined uncertainty for Saprobic score and Diversity score. The expanded uncertainty was ± 4.7 for Saprobic score (Table 10) and ±0.41 for Diversity score (Table 11).

Upstream Uttarkashi

Major part of the Uttarkashi and Tehri districts is drained by the Bhagirathi Sub-system. The Bhagirathi originates from the Gaumukh (3,940m) and after flowing for about 18 km. westwards; river Janhavi meets it at Bhaironghati. The uppermost tip-tributary of the Janhavi originates from Sumer, near Thamla pass (5,843m). The main tributaries of the Janhavi are Barigun Gad and Chor Gad. The Bhagirathi flows almost in north-south direction between Harsil and Maneri and between Maneri and Dunda, the river flows in almost east-west direction for about 30 km. After Dunds, the course of Bhagirathi is from northwest to southwest till it meets the Alaknanda at Devparayag. The Jalandhari Gad, Siya Gad and Pilang Gad are main tributaries of the Bhagirathi between Harsil and Maneri. The Dhaneri, Naugaon Gad and Jalkur River are main tributaries between Dunda and Tehri.

The river bed of River Bhagirathi was getting disturbed from the stretch from Upstream Uttarkashi due to construction of Joshiyara Barrage. Variations were mainly due to substratum composition, flow velocity and depth of water body. Before construction of barrage, the benthic macro-invertebrates were collected mainly from Boulders, cobbles and Pebbles. Since the river bed was totally covered by these substrata the uncertainties of collection of animals was mainly due to size of gravel, sand, silt and clay particles which remained untouched.

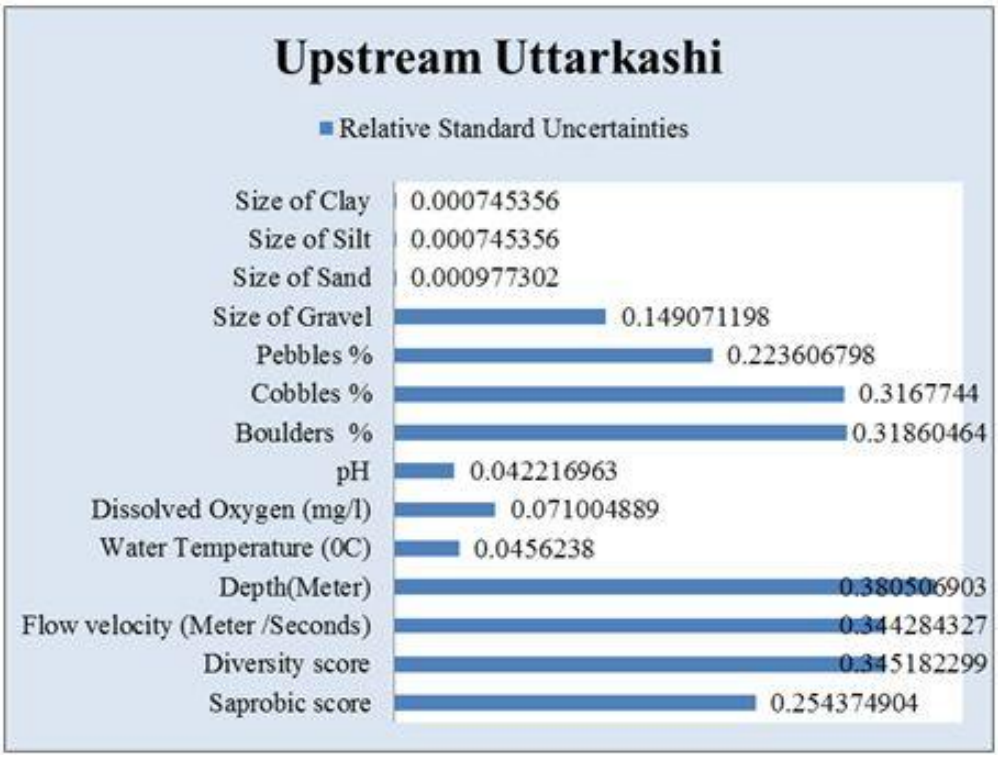

Figure 2: Contribution of Relative Standard Uncertainties in River Bhagirathi at Upstream Uttarkashi

Habitat of a rare genera *Oligoneuriella* of family Heptageniidae was observed at Upstream Uttarkashi observed during year 2007 which gradually disappeared with the construction of Joshiyara barrage on River Bhagirathi during year (semwal *et. al.*, 2008).

River Bhagirathi at upstream of Uttarkashi possessed 27% boulders, 17% cobbles,20% pebbles, 6% gravel, 28.6% sand, 1.2 % silt and 0.2% clay. Instead of percentage, proportions are used as a useful convention. Then the substratum composition of river Bhagirathi at Upstream Uttarkashi, consisted of 0.27 boulders, 0.17 cobbles, 0.20 Pebbles, 0.06 gravel, 0.286 sand and remaining 0.012 silt, and 0.02 clay. Thus, we may formally summarize the situation by stating that the probability of an animal collected from silt is p[silt] =0.012, p[clay] = 0.02, p[gravel] = 0.06 which is very low. Whereas, the probability of sampling from boulders p[boulders] = 0.27, p[cobble] = 0.17, p [pebble] = 0.20. p[sand] =0.286 and, is higher. As a result, most sampling were carried out from boulders, cobbles and pebbles and sand. Thus random errors were due to gravel, silt and clay before the construction of barrage. Figure 2 indicates that random errors were maximum due to contribution of uncertainties in collection of low number of benthic macro-invertebrates as a result of depth and flow variation and substratum composition in water body resulting from construction of Joshiyara Barrage at this location. The expanded uncertainty was ± 7.12 for Saprobic score (Table 10) and ±0.45 for Diversity score (Table 11).

Downstream Uttarkashi

Discussion : The downstream johiyara Barrage stretch of river Bhagirathi at Triveni remained undisturbed throughout except for flow and depth variations. After the construction of barrage the river flow and depth of water body was regulated at downstream of barrage which also contributed to availability of % Boulders, cobbles and Pebbles, a major uncertainty of Saprobic score and Diversity score of benthic macro-invertebrates. Gravel, Sand and Silt were not sampled contribution to the high uncertainty.

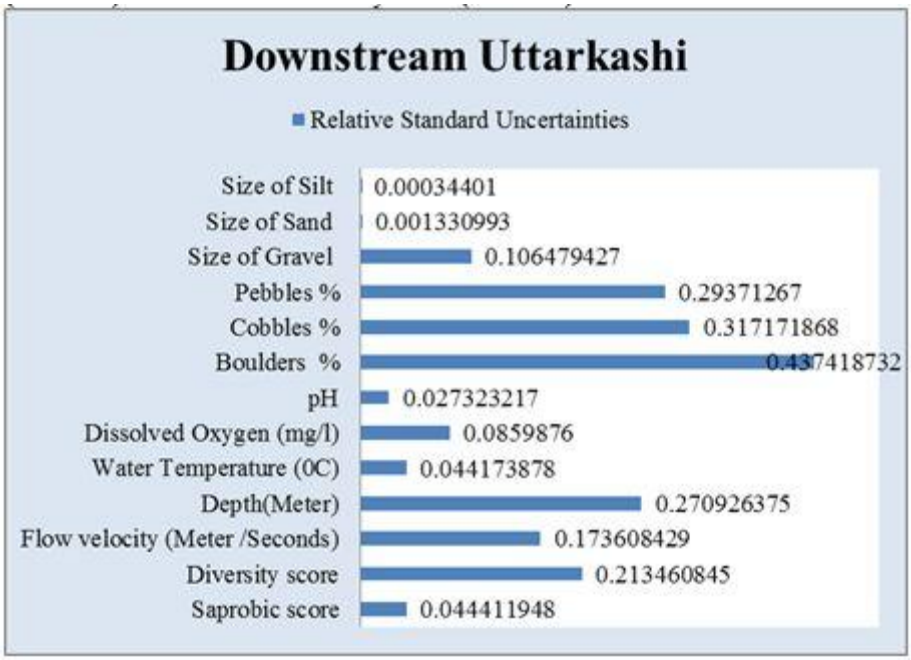

Figure 3: Contribution of Relative Standard Uncertainties in River Bhagirathi at Downstream Uttarkashi

River Bhagirathi at downstream of Uttarkashi possessed 29.2% boulders, 14.4% cobbles,24.4% pebbles, 8.4% gravel, 21% sand, 2.6 % silt. Instead of percentage, proportions are used as a useful convention. Then the substratum composition of river Bhagirathi at Downstream Uttarkashi, consisted of 0.292

boulders, 0.144 cobbles, 0.244 Pebbles, 0.084 gravel, 0.21 sand and remaining 0.026 silt. Thus, we may formally summarize the situation by stating that the probability of an animal collected from silt is p[silt] =0.026, p[gravel] = 0.084 which is very low. Whereas, the probability of sampling from boulders p[boulders] = 0.292, p[cobble] = 0.144, p [pebble] = 0.244, p[sand] =0.21 and, is higher. As a result, most samplings were carried out from boulders, cobbles and pebbles and sand. Thus random errors were due to gravel, silt and clay before the construction of barrage. Figure 3 indicates that uncertainty increased due to change in depth of water body. However, the river stretch at this location at Triveni remained undisturbed throughout the sampling period. The expanded uncertainty was ± 4.74 for Saprobic score (Table 10) and ±0.43 for Diversity score (Table 11).

Old Tehri (Malideval)

The Bhilangana, the only sizeable tributary of the Bhagirathi, takes its origin from the Bharti Kantha in the northeastern part of the Tehri district and joins the Bhagirathi at Ganeshprayag, near Tehri. The Balganga (renamed as Balkhila) rising from the Shastratal is the main tributary of the Bhilangana, which meets it at Pilkhi. Other tributaries are Dharamganga, Chanji Gad, Nailchami Gad, etc. The Bhilangana system drains eastern part of Tehri District. The Bhagirathi and the Bhilangana have formed deep and broad valleys with extensive river terraces like chham, Pilkhi, Chamiyala, Sirain, etc. Tehri is located 200 miles north-east of Delhi, in the state of Uttarakhand. With a height of 260 meters (855 feet), the dam is the fifth tallest in the world.

Tehri Dam is a major power project located near Tehri in the state of Uttarakhand in India. The dam's projected capabilities include a power generation capacity of 2400 MW, stabilize irrigation to an area of 6000 $km^{2,}$ and a supply of 270 million gallons of drinking water to industrialized cities in Delhi, Uttar Pradesh and Uttarakhand.

The main dam of the project is built near the old Tehri town that lies at the confluence of the rivers Bhagirathi (one of the major tributary of the River Ganga) and Bhilangana. The main dam will produce 2000 MW of Electricity. There is another smaller dam 14 km downstream at Koteshwar that will produce 2000 MW of electricity. The main reservoir comprises of an area of 42km^2Materials and Methods.

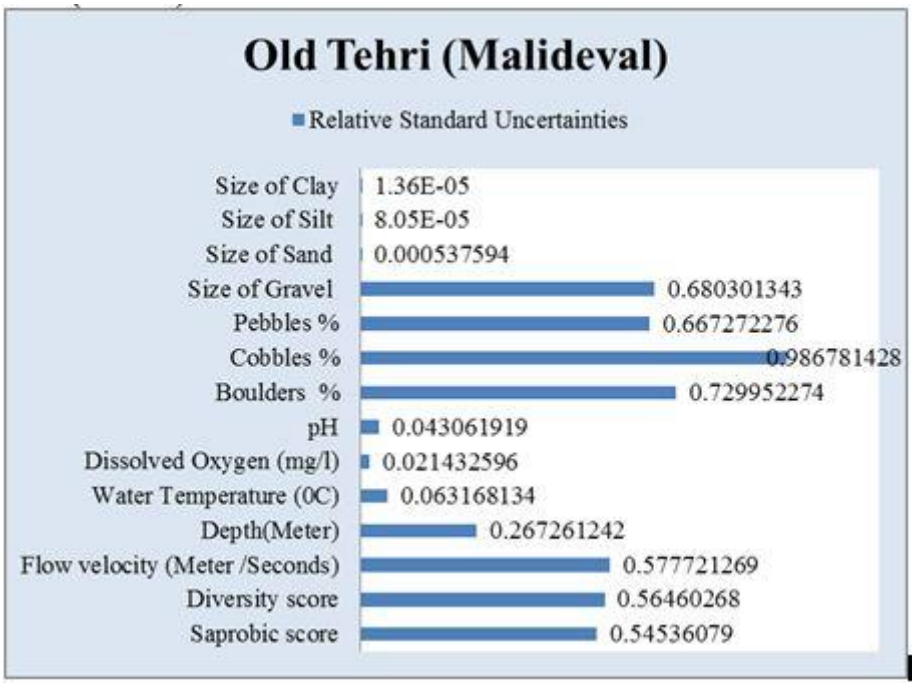

Figure 3: Contribution of Relative Standard Uncertainties in River Bhagirathi at Tehri

During year 2004 to 2006, River Bhagirathi at Old Tehri (Malideval) possessed 9.78% boulders, 5.78% cobbles,6.57% pebbles, 0.785% gravel, 31.07 % sand, 6.64 % silt and 39.28% clay. Instead of percentage, proportions are used as a useful convention. Then the substratum composition of river Bhagirathi at Tehr, consisted of 0.0978 boulders, 0.0578 cobbles, 0.0657 Pebbles, 0.00785 gravel, 0.3107 sand and remaining 0.0664 silt and 0.3928 clay. Thus, we may formally summarize the situation by stating that the probability of an animal collected from silt is p[silt] =0.0664, p[gravel] = 0.00785, p[pebble]= 0.0664 and p[cobble]= 0.0578 which is very low. Whereas, the probability of sampling from boulders p[boulders] = 0.0978, p[sand] =0.3107 and p[clay]=0.3928, is higher. As a result, most samplings were carried out from boulders and sand. Thus random errors were due to cobble, pebble, gravel, silt before the construction of barrage. Figure 4 indicates that flow velocity in River Bhagirathi at Old Tehri, was mostly affected due to development of Tehri Reservoir and thus uncertainty increased due to submergence of river bed substratum. The expanded uncertainty was ± 5.1 for Saprobic score (Table 10) and ±0.5 for Diversity score (Table 11).

Zeropoint

River Bhagirathi at Zeropoint possessed 80 % boulders and 20 % sand. Instead of percentage, proportions are used as a useful convention. Then the substratum composition of river Bhagirathi at Zeropoint consists of 0.8 boulders and 0.20 sand. Thus, we may formally summarize the situation by stating that the probability of an animal collected from sand is p[sand]= 0.2 which is low. Whereas, the probability of sampling from boulders p[boulders] = 0.8 is higher. As a result, most sampling were carried out from boulders and sand. Thus random errors were due to cobble, pebble, gravel, silt.This was the downstream location of Tehri Dam and was completely disturbed and influenced by the regulated flow. As a result none of the benthic invertebrates were collected from this location. Figure 5 shows that contribution of maximum uncertainities due to percent distribution of substratum composition of Pebbles and Cobbles.

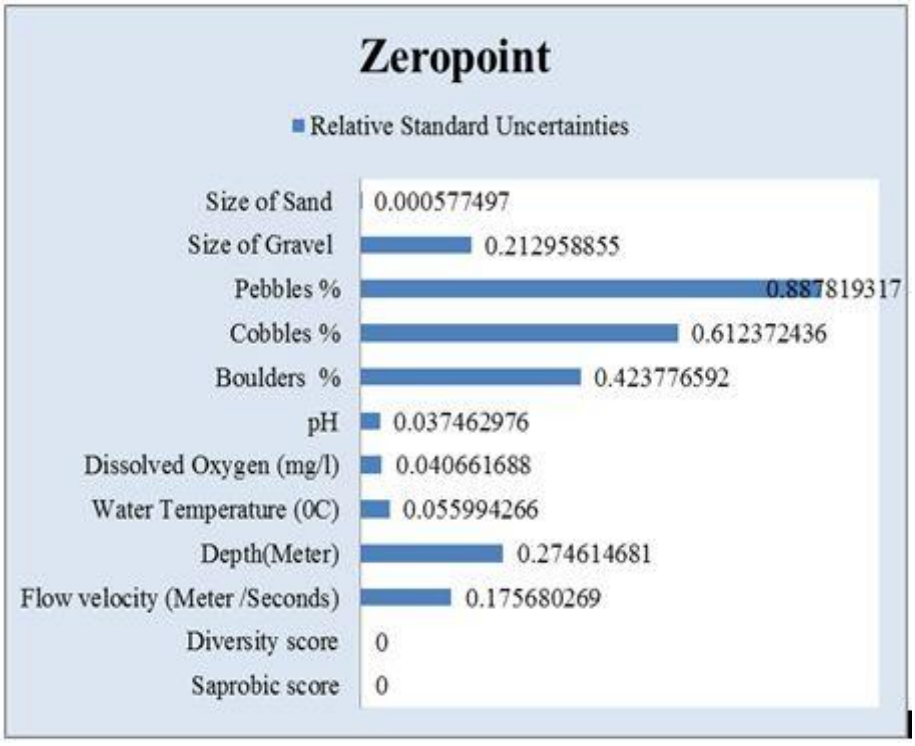

Figure 4: Contribution of Relative Standard Uncertainties in River Bhagirathi at Zeropoint

Dev Prayag

The Ganga System: The whole of Garhwal Himalaya, except western parts of Uttarkashi and Dehradun districts and a small tract lying in the eastern margin of the Garhwal district, is drained by the Ganga system. The Alaknanda and the Bhagirathi after joining at Devparayag is conclusively called the Ganga and it finally descends into the plains at Haridwar. The Bhagirathi and the Alaknanda originate from the opposite sides of the Chaukhamba peak (7,138m). After flowing in the opposite directions they bend towards Devparayag, forming a garlanded shape. According to Hindu mythology, River Bhagirathi is the actual Ganga, through the name of Ganga, is assumed only after the river Bhagirathi meets river Alaknanda and Devprayag.

River Bhagirathi at Dev Prayag possessed 42 % boulders, 4% cobbles, 9% pebbles, 2% gravel and 43% sand. Instead of percentage, proportions are used as a useful convention. Then the substratum composition of river Bhagirathi at Dev Prayag, consists of 0.42 boulders, 0.04 cobbles,0.09 pebbles, 0.02 gravel and 0.43 sand. Thus, we may formally summarize the situation by stating that the probability of an animal collected from sand is p[cobble]= 0.04, p[pebble] = 0.09, p[gravel]=0.02 which is low. Whereas, the probability of sampling from boulders p[boulders] = 0.42 and p[sand]= 0.43 is higher. As a result, most sampling were carried out from boulders and sand. Thus random errors were due to cobble, pebble, gravel. Figure 6 indicates that at this location, maximum uncertainty was contributed through substratum composition. The river bed was devoid of boulders, cobbles, pebbles and gravel and as a result no benthic macro-invertebrates were collected throughout the sampling period at this location.

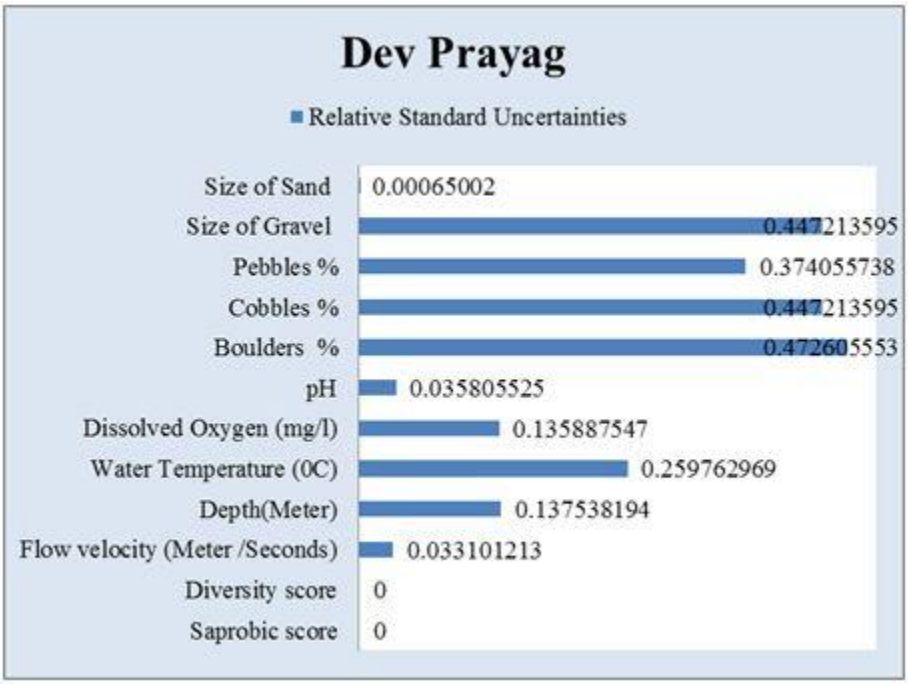

Figure 4: Contribution of Relative Standard Uncertainties in River Bhagirathi at DevPrayag

Biological assessment of river is a footprint of the actual health of a water body provided it is performed carefully. The assessment depends totally upon proper collection of benthic macro-invertebrates by exploring all the possible micro and macro habitats in the river. While sampling, a number of errors are encountered among them the major one is due to random sampling from river bed substratum. These errors can be removed by quantifying the sampling procedures from boulders, cobbles, pebbles, gravels, sand, silt and clay. In practice, it may not be possible in the field to cover all the habitats and thus uncertainties are added in measurement of Saprobic score and Diversity score for bio-monitoring of water

quality. Quite often, it leads to a wrong assessment of water quality and becomes a spurious error in measurement(Ellison *et.al*., 2000). Selection of a reference location on a river thus, based upon measurement of highest Saprobic and Diversity score with minimum range of uncertainties.

Table 10: Uncertainties in measurement of Saprobic score in River Bhagirathi

S.No.	Sampling replicates	Measurement Uncertainty of Saprobic score range ± (1-10)					
		Gangotri	Upstream Uttarkashi	Down stream Uttarkashi	Old Tehri, Malideval	Zeropoint	DevPrayag
1.	November,2004	8.0± 4.7	8.6±7.12	7.6±4.74	7.7±5.1	0.0±0.0	0.0±0.0
2.	May, 2005	6.66± 4.7	7.0±7.12	7.0±4.74	9.0±5.1	0.0±0.0	0.0±0.0
3.	June, 2006	7.66±4.7	7.5±7.12	7.5±4.74	5.33±5.1	0.0±0.0	0.0±0.0
4.	April, 2007	5.71±4.7	7.1±7.12	6.0±4.74	0.0±0.0	0.0±0.0	0.0±0.0
	April,2007				0.0±0.0		
	April,2007				0.0±0.0		
	April,2007				0.0±0.0		
	April,2007				0.0±0.0		
	April,2007				0.0±0.0		
5.	May, 2008	8.4± 4.7	0.0±0.0	7.75±4.74	0.0±	0.0±0.0	0.0±0.0
	May, 2008				0.0±0.0		
	May, 2008				0.0±0.0		
	May, 2008				0.0±0.0		

Table 11: Uncertainties in measurement of Diversity score in River Bhagirathi

S.No.	Sampling replicates	Measurement Uncertainty of Diversity score range ± (0.1-1.0)					
		Gangotri	Upstream Uttarkashi	Downstream Uttarkashi	Old Tehri, Malideval	Zeropoint	DevPrayag
1.	November,2004	0.42±0.41	0.69±0.45	0.61±0.43	0.67±0.5	0.0±0.0	0.0±0.0
2.	May, 2005	0.08±0.41	0.43±0.45	0.43±0.43	0.45±0.5	0.0±0.0	0.0±0.0
3.	June, 2006	0.86±0.41	0.16±0.45	0.16±0.43	1.0±0.5	0.0±0.0	0.0±0.0
4.	April, 2007	0.54±0.41	0.53±0.45	0.81±0.43	0.0±0.0	0.0±0.0	0.0±0.0
	April, 2007				0.0±0.0		
	April, 2007				0.0±0.0		
	April, 2007				0.0±0.0		
	April, 2007				0.0±0.0		
	April, 2007				0.0±0.0		
5.	May, 2008	0.236±0.41	0.0±0.45	0.75±0.43	0.0±0.0	0.0±0.0	0.0±0.0
	May, 2008				0.0±0.0		
	May, 2008				0.0±0.0		
	May, 2008				0.0±0.0		

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