International Journal of Advanced Science and Research
ISSN: 2455-4227; Impact Factor: RJIF 5.12
Received: 01-11-2018; Accepted: 03-12-2018
www.allsciencejournal.com
Volume 4; Issue 1; January 2019; Page No. 01-03

Determination of Nemerow's Pollution Index (NPI) of Alaknanda River at Garhwal, Uttarakhand

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Abstract
NPI is a powerful tool for assessing the water quality of a fresh water ecosystem. Water samples were collected seasonally from eight sampling stations during Sep. 2016 - Aug. 2017. NPI was calculated for the water samples in different seasons. Physico-chemical parameters such as water temperature, velocity, pH, EC, TDS, TSS, TAl., TH, DO, BOD, COD, Ca, Mg, Na, K, Cl, F, NO3 and SO4 were measured in this study. Nemerow's pollution index was calculated some selected water quality variables as pH, Electrical Conductivity, TH, TDS, Cl, Mg, F, Ca, NO3 and SO4. The results were compared with standards of BIS. The Nemerow's pollution index calculated from the observed parameters, it indicates that an average pH, EC, TH and TDS values of NPI on all sampling stations were 0.90, 0.55, 0.20 and 0.25 respectively. Main cations and anions values were observed below NPI limit as per standards by which pollutant status occurred. All observed values were found under permissible limit. NPI values indicates that river water is in good quality condition throughout the year.

Keywords: water quality, Nemerow's pollution index, Alaknanda river

1. Introduction
Water quality is the chemical, physical, biological, and radiological characteristics of water. It is a measure of the condition of water relative to the requirements of one or more biotic species. Water quality is any human need or purpose. The most common standards used to assess water quality relate to health of ecosystems, safety of human contact, and drinking water. Environmental water quality, relates to water bodies such as lakes, rivers, and oceans. It's standards for surface water vary significantly due to different environmental conditions, ecosystems, and intended human uses. Toxic substances and high populations of certain microorganisms can present a health hazard for non-drinking purposes such as irrigation, swimming, fishing, rafting, boating, and industrial uses Johnson *et al*., (1997) [4]. Pollution index is a powerful tool for processing analyzing, and conveying raw environmental information to decision makers, managers, technicians and the public (Caeiro *et al*., 2005), the aim of this work is to calculate NPI value for river in study region. Considering this effect, assessment method of Nemerow's pollution index, which combine average value of pollutants with that of maximum value, was used to evaluate the water quality of Mahanadi River by Li Ya-nan *et al*., (2008) [5] and Guang *et al*., (2010) [3], used the 2006-2007 monitoring data to evaluate and characterize the water quality condition of a landscape river in Tianjin based on the comprehensive index methods such as Nemerow Index and Single-factor assessment. To provide scientific basis for water environment management and river basin water resources development, single-factor evaluation method and integrated Nemerow pollution index analysis was used to assess the water quality status of M river by monitoring data of 2006-2007. Many calculation methods have been presented to assess the environmental quality, such as pollution index, principle component analysis, in Zhejiang Province, China (Cheng *et al*., 2007). The aim of this study, determined the water quality and NPI status of river Alaknanda.

2. Materials and Methods
2.1 Study Area
The Alaknanda river system extends from Satopanth glacier to Devprayag in Garhwal region of Uttarakhand. Geographically the study area is situated between altitude 30º17'37.48''N and longitude 79º33'37.24''E in between Chamoli to Devprayag (30º08'45.04″N, 78º35'58.39″E). The Alaknanda is a sixth order stream within the study area, calculated on the basis perennial rivers which form the Alaknanda (Mittal, *et al*., 1999), but on basis of seasonal rivers flowing into the basin it is calculated to be an eighth order stream. Saraswati, Dhauliganga, Nandakini, Pindar and Bhagirathi are the main tributaries of river Alaknanda. Devprayag is the confluence point of Bhagirathi and Alaknanda, where river Ganges starts. Eight sampling stations have selected in the study area.

Table 1: Hydrological characteristics of the river Alaknanda

Sampling station	Location	Latitude	Longitude	Pollution source
A1	Chamoli	30°29′	79°34′	Sewage
A2	Nandprayag	30°19′	79°19′	Human bathing, sewage
A3	Karanprayag	30°17′	79°11′	Human bathing
A4	Rudraprayag	30°17′	78°58′	Human bathing, sewage
A5	Dharidevi temple	30°15′	78°52′	Not altered
A6	Chauras	30°14′	78°47′	Sewage, human bathing
A7	Kirtinagar	30°12′	78°44′	Sewage, washing of clothes
A8	Devprayag	30°08′	78°35′	Human bathing, sewage

Sampling points

Total of 125 km stretch of Alaknanda river has been covered in this study. Eight sampling points have been selected for the study (Fig-1)

1. Chamoli- The major portion of river Alaknanda falls in Chamoli district. This is located about 54 km distance from the origin of river. It is second largest district of Uttarakhand.
2. Nandprayag- This is the confluence point of Nandakini and Alaknanda river. This station gives us opportunity to examine the biodiversity of water as mention above confluence points support a good biodiversity in water.
3. Karanprayag- This is one of the panchprayag. Here, Pindar river meets with Alaknanda river. This is situated from 120 km distance from origin of river.
4. Rudraprayg- This is the confluence point of Mandakini and Alaknanda.
5. Dharidevi temple- This is the upstream station of Srinagar electric hydropower dam. The site has been chosen for monitoring water quality and biodiversity of river.
6. Chauras- This station chosen for evaluation of effect of dam on river. This station is located 20 Km downstream from the Srinagar Hydropower Plant.
7. Kirtinagar- This station is located 35 km upstream of famous Panchprayag is Devprayag.
8. Devprayag- This is the confluence point of Alaknanda and Bhagirathi, the river turns into the holy river Ganga after travelling almost 192 km from Satopanth glacier to Devprayag.

2.2 Methodology

The water samples were collected from all sampling sites in three seasons i.e. monsoon, summer and winter. Sample was collected carefully in 500ml polyethylene plastic bottles. The Plastic bottles were labeled and immediately few drops of HNO3 was added to prevent loss of metals, bacterial and fungal growth (Sudhakr and Swarnalatha, 2013) [8]. The suitability of river water for drinking and other purposes can be assessed by comparing physical and chemical parameters with the guidelines of World Health Organization (WHO, 2004) [10]. Due to the importance of water quality issues, better management of water systems is required for regional supply of water for irrigation, industrial and domestic uses (Sudhakar *et al*., 2015) [6].

Nemerow's Pollution Index -NPI

Chen Jie *et al.*, (2012) [2] intend to introduce a method by joining the improved Nemerow index method. Zheng *et al.*, (2011) assessed the problem of lacking good quality of water in Jia county, Shaanxi, China. River water should be assessed objectively and reasonably. The Nemerow index evaluation method used to analysis the quality of water. The pollution causing parameters are determined through Nemerow's pollution index using the average values of three monsoon season physico-chemical parameters indicated in Table 2. NPI is evaluated for all the parameters for each sample analyzed, thus identifying the pollution causing parameters. The equation used in evaluating the NPI is reproduced below:

$$NPI = Ci / Li,$$

Where;
Ci = observed concentration of i parameter
Li = permissible limit of i parameter.

In above expressions unit of Ci and Li should be identical. Each value of NPI shows the relative pollution contributed by single parameter. It has no units. Li values for different water quality parameters are indicated in Table 3. NPI value exceeding 1.0 indicate the presence of impurity in water. As per Nemerow's Pollution Index (NPI), the pollution parameters at each station is calculated and presented in Table 3.

3. Results and Discussion

River water is one of widely distributed, renewable and most important natural resource. According to various studies, it indicates that some river water is not suitable for drinking purpose without proper treatment (Sudhakar Gummadi *et al*., 2014) [7]. The pH NPI values varies from 0.85 to 0.92 in all sampling stations. NPI is in permissible range. EC value varies from 0.39 to 0.60 at all sites. The observed total dissolve solids NPI range from 0.15 to 0.35. The TDS result revealed that NPI values were beyond the limit range of NPI value. Total Hardness range from 0.14 to 0.26 in all sampling stations. NPI value is below range indicated in the table. Cl NPI range varies from 0.002 to 0.005 indicated in table 3. All sampling stations are showed that the permissible range of NPI. Mg range from 0.08 to 0.15 in all sampling stations had recorded below permissible limit of NPI Value.

Table 2: Average value of water quality parameters for river water samples during Sep 16-Aug 17 and the permissible limit of BIS

S. No.	Permissible value BIS (Li) Sample ID	pH	EC	TDS	TH	Ca	Mg	Cl	F	SO_4	NO_3
		6.5-8.5	300	2000	600	200	100	1000	1.5	400	100
1	A-1	7.8	170.2	107.6	60.3	22.0	4.1	1.2	0.1	23.0	1.1
2	A-2	7.7	162.9	106.1	68.2	20.7	3.8	0.7	0.2	16.2	0.8
3	A-3	7.3	156.2	99.2	80.2	18.6	4.3	0.8	0.1	10.9	0.8
4	A-4	7.8	158.2	98.8	71.8	20.6	3.1	0.8	0.1	13.8	0.9
5	A-5	7.6	162.0	103.0	73.2	19.6	3.7	1.4	0.1	12.5	0.9
6	A-6	7.6	161.8	108.1	77.9	23.0	3.3	1.4	0.2	16.6	1.1
7	A-7	7.9	180.9	115.9	79.4	23.2	4.5	1.3	0.2	20.2	1.0
8	A-8	7.7	144.8	93.5	55.0	14.6	4.5	1.3	0.2	20.6	0.8

Table 3: NPI value of parameters of water sample

S. No.	Sample ID	pH	EC	TDS	TH	Ca	Mg	Cl	F	SO_4	NO_3
1	A-1	0.91	0.56	0.21	0.20	0.29	0.13	0.004	0.06	0.11	0.02
2	A-2	0.90	0.54	0.35	0.22	0.27	0.12	0.002	0.13	0.08	0.01
3	A-3	0.85	0.52	0.19	0.26	0.24	0.14	0.003	0.06	0.05	0.01
4	A-4	0.91	0.52	0.19	0.23	0.27	0.10	0.003	0.06	0.06	0.02
5	A-5	0.89	0.54	0.15	0.24	0.26	0.12	0.005	0.06	0.06	0.02
6	A-6	0.89	0.53	0.20	0.25	0.30	0.11	0.005	0.13	0.08	0.02
7	A-7	0.92	0.60	0.17	0.26	0.30	0.15	0.005	0.13	0.10	0.02
8	A-8	0.90	0.48	0.18	0.18	0.19	0.15	0.005	0.13	0.10	0.01

Fluoride concentration in all sampling stations range from 0.06 to 0.13 of NPI level. Ca level was observed in the range of 0.19 to 0.30 at all sampling stations. NO3 NPI range from 0.01 to 0.02 in all sampling stations were shows below NPI limit. Sulphate NPI value had been calculated through the average values of three monsoon season of river water, the range varies from 0.04 to 0.11, all sampling stations showed that below the NPI value (Table 3). Chen Jie *et al.*, (2012) [2], Nemerow index evaluation method compared with this result. The analysis reveals that the quality of river water is better than pour quality water Zheng *et al*., (2011). The results show that the method is correct and reasonable. All physico-chemical parameters values indicate that water is good for drinking, commercial and irrigation purpose.

4. Conclusion

This study revealed that NPI values of various physico-chemical parameters observed below the permissible BIS range. Water samples values which is recorded, indicates that the Alaknanda river is not polluted.

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