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Water Quality Assessment of Hingol River, Balochistan, Pakistan

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Abstract: The present study was conducted to analyze physical, chemical and microbiological quality of Hingol River. In all 22 samples were collected from 11 sampling points from the entire stretch of the River from the areas beginning from mountains which were accessible, to the Hingol River bridge. Samples were collected during pre-and post-monsoon seasons in 2012. The samples of surface water quality were analyzed using Standard Methods of American Public Health Association. The samples were subjected to two multivariate methods, namely Cluster analysis (Ward's method) and Principal Component Analysis (PCA). It was found that the water available in the River is not absolutely safe and contaminated with human and animal wastes. Physical parameters including pH, chloride and hardness are well within the permissible limit as per NSDWQ (National Standards for Drinking Water Quality, 2008, Ministry of Environment, Government of Pakistan). No significant change in DO concentration was observed during the two Seasons. The mean value of total suspended solids was relatively high during post monsoon season which can also contribute to high BOD values which is an indication of organic pollution. The mean values of all the metals during pre-monsoon season are within the permissible limits except Pb. The concentrations of the heavy metals in the pre-monsoon samples were found to be in the order Pb>Ni>Zn>Mn>Fe>As>Cr>Cu. Also in post-monsoon season the concentrations of Pb and Mn was relatively higher and they were available as Pb>Mn>Zn>Ni>Fe>Cu>Cr>As. The study reveals that the water quality of Hingol River is not safe for human consumption. Long term accumulation of heavy metals is also detrimental to the biodiversity of the area.

Key words: Water quality · Pollution · Microorganisms · Heavy metals

INTRODUCTION

The Hingol National Park (HNP) is located in Lasbella, Awaran and Gwadar districts of Balochistan and the second largest National Park out of 22 National Parks available in Pakistan.

The park is situated at 65° 32' 12'' East and 25° 42'16" North that covers an area of 619,043 hectares (6.190km^2). The importance of the park is mainly due to its unique habitat types and associated biodiversity. In addition, to the unique biodiversity there are 5000 households spread in scattered villages [1]. The park area can be divided into West and East of Hingol River that runs parallel to the River. The mountain ranges at the West of the Hingol River are the Shur Mountain Range, Hinglaj-Nani Mountains, Gurangatti and Rodaini Kacho-Dhrun area, whereas, at the East of River the Tranche Block and the Deo-Beharo Block exist [2]. In 1997 Dhrun, Hingol and the area in between Rodani Kacho were declared as Hingol National Park. The climate of the area is mostly hot and dry. In summer the mercury usually reaches up to 40° C. The area extends severe drought from 1997 to 2004. The rainy season is mostly under the influence of monsoon and extended from July to September. The winter rains in February and March are also common but usually scanty. The average was rainfall hardly exceeds 150 mm. However, the River exposed to heavy flood in 2005, 2010 and 2011.

The Park comprises of a variety of ecosystems that include fresh water, terrestrial and marine that contain diversified fauna and flora species. Among the mammal species the important ones are Ibex (*Capra aegagrus*), Urial (*Ovis vignel*), Chinkara (*Gazell abennettii*). The avifauna includes Dalmatian Pelican (*Pelecanus crispus*), spotted-billed pelican (*Pelecanus philippinus*), Houbara Bustard (*Chlamydotis undulata*), imperial eagle (*Aquila heliaca*), sooty falcon (*Falco concolor*) and

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flamingo (*Phoenicopterus roseus*). From the Hingol National Park 158 species of birds are reported out of which 8 are threatened. The reptiles and amphibian species, are marsh crocodile (*Crocodylus palustris*), green sea turtle (*Chelonia mydas*), skittering frog (*Rana cyanophlyctis*) etc. [2].

The park area is mainly drained through the Hingol River. Hingol River is an ephemeral river located at the centre of the Hingol National Park and finally falls into the Arabian Sea [3]. The area of Hingol River basin is 35736 km^2[4].The River is approximately 1000 km long and is the largest River in Balochistan. The River crosses the tightly faulted and folded Makran coastal ranges of Makran [4]. The major source of water in the River is the rain water which comes from the mountains, therefore, except from rainy spell the flow in the River is insignificant which hardly reaches to the Arabian Sea. The survival of microorganisms in surface water is influenced by physico-chemical characteristics. Therefore, the water quality of the River was thoroughly examined through physico-chemical and microbiological parameters.

MATERIALS AND METHODS

Sampling: The study area focuses on the Hingol River situated at Hingol National park. The sampling area includes the River basin extending from the mountain up to the plain where the River enters into the Arabian Sea. During the study 22 samples were collected during pre (11 samples) and post monsoon (11 samples) seasons in 2012. Samples were collected in pre-acid washed plastic bottles and transported in ice box to the laboratories of the Institute of Environmental Studies, University of Karachi. Samples for microbiological analysis were collected in sterilized glass bottles and preserved in an ice box. All samples were grab collections, taken from the pre-designated locations as mentioned in Fig. 1.

Sample Analysis: The samples were analyzed for pH, biological oxygen demand (BOD_5) chloride, dissolved oxygen (DO), hardness as $CaCO_3$, sulphate, turbidity (NTU) and TSS (Total Suspended Solids).

Fig. 1: Sampling points at Hingol River
(HR-1=25°29'23.20"N: 65°31'40.31"E, HR-2=25°29'18.52"N: 65°31'10.62"E, HR-3=25°29'12.71"N: 65°30'53.59"E , HR-4=25°28'39.98"N: 65°30'37.79"E, HR-5=25°28'12.93"N: 65°31'12.10"E, HR-6= 25°27'39.79"N:65°32'11.63"E, HR-7=25°27'26.91"N: 65°32'15.02"E, HR-8=25°27'11.53"N: 65°32'9.04"E, HR-9=25°27'4.54"N: 65°32'12.35"E, HR 10=25°26'47.59":N 65°32'28.77"E, HR-11=25°26'15.54"N: 65°32'40.70"E

pH and DO were determined on site. pH was determined by Hanna portable pH meter (HI98107) while DO was measured by DO meter (Jenway 970).

Biological oxygen demand was measured using azide modification method as mentioned in the Standard Methods for the Examination of Water and Wastewater [5].

Chloride was estimated by Argentometric method [5]. Hardness as $CaCO_3$ of river water samples was measured by EDTA titrimetric method (5). Sulphate and TSS in the samples were measured by gravimetric method in accordance with Standard Methods for the Examination of Water and Wastewater [4]. Turbidity was ascertained by EUTECH meter, Model No. TN-100.

The public health quality of water samples was also assessed using following parameters: total coliforms (TC) and faecal coliforms (FC). The samples were processed in laminar flow hood using sterilized culture media. The sterility of media was checked prior to use. The TC was estimated using lactose broth (Merck, Germany) of single and double strength. The positive lactose tubes were used for the determination of FC using EC broth (Merck, Germany). The bacterial load of water samples was estimated by Most Probable Number (MPN) technique as per Standard Methods for the Examination of Water and Wastewater [5].

The samples were also analyzed for heavy metals including As, Cr, Cu, Fe, Pb, Mn, Ni and Zn. The above mentioned parameters were analyzed using appropriate kits on a Merck NOVA 60.

Statistical Analysis: The data were statistically analyzed using STATISTICA (99 Edition) software. Descriptive statistics including mean, standard deviation, standard error, lower quartile and upper quartile were computed for each of the variables. Cluster analysis and principal component analysis were performed using the appropriate software mentioned above. For cluster analysis Ward's method was employed.

RESULTS AND DISCUSSION

The public health quality of Hingol River water was determined through microbiological and chemical analysis. In all 22 water samples were collected from the entire stretch of the River up to the Hingol River bridge. Very little water was available at pre-monsoon in December. The results of water quality are reported in Table 1-3. As such no previous data is available that pertains to quality of water at Hingol River to compare with. The water available in the River is not absolutely safe and contaminated with human and animal wastes. From the Table 1 it can be seen that all water samples were contaminated with the organisms of public health importance. It has been reported that the faecal coliforms up to 10^6cfu/100 ml are commonly found in Pakistan, India, Indonesia and Pakistan [6]. These organisms are the continuous source of ailment in the local people. Infectious water related diseases are most important in the developing countries and unless drinking water supplies are improved there is a little hope of controlling communicable diseases in the population [7].

The people of 170 villages are living within the vicinity of Hingol National Park whereby majority of them are leading nomadic life style [8, 9] and are consuming the water of the River as no alternative water resources are available. Since the people have no choice except to consume the contaminated water, therefore, water borne diseases are common among the population. Bacteriological analysis reveals that there is an increase in contamination due to organisms of public health importance after rain. This could possibly be due to the runoff from the surroundings providing favorable conditions for the organisms to sustain and multiply. Since the number of faecal coliforms and faeal streptococci discharged by human beings and animals are significantly different, therefore it is suggested that the ratio of faecal coliforms (FC) to faecal streptococci (FS) count in a given sample can be used to detect whether the suspected microorganisms are derived from the human or from animal wastes. The FC/FS ratio in water in animal origin is generally considered to be less than 1.0 whereas, it is more than 4.0 for human beings. If the ratio is within 1 to 2 the interpretation is uncertain. This ratio is very helpful in determining the source of pollution [10]. However, faecal streptococci were absent in all the samples. The reason of faecal contamination could be the anthropogenic activities near the reservoir. Proper selection and protection of water sources as in the present case are of prime importance in the provision of safe drinking water. Shar *et al.* [11, 12] also reported that the quality of surface water is generally poor as compared to groundwater from the public health point of view. Aziz [13] reported that most of the drinking water supplies in Pakistan are faecally contaminated and result in high incidence of water borne diseases. In general, during the rainfall and flood conditions the microbial load of the flowing water increases which depreciates the water quality [14]. It is always better to protect water from contamination than to treat it after it has been contaminated. Protection of surface water is however, a problem, if water supplies are to remain potable, both the

Table 1: Descriptive statistics of physical, chemical and microbiological parameters of Hingol River water in pre-monsoon

Variable	Mean	Median	Min.	Max.	Lower Quartile	Upper Quartile	Std. Dev.	SE	*NSDWQ mg/l
pH	7.16	7.20	7.00	7.30	7.10	7.20	.092	.027	6.5-8.5
Turbidity (NTU)	33.45	33.90	30.10	37.30	31.10	35.20	2.471	.745	< 5 NTU
TSS (mg/L)	159.09	159.00	150.00	173.00	153.00	164.00	6.905	2.08	N/A
Chloride (mg/L)	93.18	96.00	83.00	98.00	88.00	98.00	5.134	1.54	<250
Hardness (mg/L)	134.00	138.00	111.00	147.00	123.00	142.00	11.610	3.50	<500
Sulphates (mg/l)	80.00	80.00	71.00	89.00	75.00	84.00	5.215	1.57	N/A
DO(mg/l)	4.23	4.20	4.10	4.50	5.10	4.30	.120	.036	N/A
BOD_5 (mg/l)	46.45	51.00	10.00	58.00	44.00	55.00	13.80	4.16	N/A
TCC MPN/100ml	1305.27	1100.00	23.00	2400.0	240.00	2400.0	1084.24	326.9	Must not detectable in any 100 ml sample
TFC MPN/100ml	424.45	75.00	3.00	2400.0	21.00	460.00	729.969	220.093	N/A

*NSDWQ=National Standards for Drinking Water Quality, 2008 , Ministry of Environment, Government of Pakistan

Table 2: Descriptive statistics of physical, chemical and microbiological parameters of Hingol River water in post-monsoon

Variable	Mean	Median	Min.	Max.	Lower Quartile	Upper Quartile	Std. Dev.	SE	*NSDWQ mg/l
pH	7.19	7.20	7.10	7.30	7.10	7.20	.070	.021	6.5-8.5
Turbidity (NTU)	37.07	36.90	35.30	39.20	35.60	38.30	1.32	.400	< 5 NTU
TSS (mg/L)	212.45	197.00	181.0	263.0	188.00	254.00	32.94	9.93	N/A
Chloride (mg/L)	94.63	96.0	90.00	101.0	91.00	97.00	3.47	1.04	<250
Hardness (mg/L)	137.90	138.0	121.0	152.0	134.00	143.00	7.99	2.41	<500
Sulphates (mg/l)	85.81	86.0	81.00	92.00	83.00	88.00	3.48	1.05	N/A
DO(mg/l)	4.61	4.60	4.30	5.10	4.50	4.70	.204	.061	N/A
BOD_5 (mg/l)	59.63	64.0	15.00	75.00	54.00	68.00	16.75	5.05	N/A
TCC MPN/100ml	1070.4	460.0	75.00	2400.0	460.00	2400.0	903.27	272.34	Must not detectable in any 100 ml sample
TFC MPN/100ml	299.36	240.00	15.00	1100.00	75.00	460.00	316.2190	95.3436	N/A

Table 3: Descriptive statistics of heavy metals of Hingol River water in pre-monsoon

Variable	Mean	Median	Min.	Max.	Lower Quartile	Upper Quartile	Std. Dev.	SE	*NSDWQ mg/l
As	.0038	.0030	.0010	.0110	.0020	.0030	.0036	.0010	< 0.05
Fe	.3063	.3100	.1500	.4200	.2200	.3800	.0942	.0284	N/A
Cr	.0018	.0010	.0010	.0040	.0010	.0030	.0010	.0003	<0.05
Cu	.0223	.0230	.0210	.0240	.0210	.0230	.0010	.0003	2.0
Pb	1.362	1.360	1.040	1.670	1.210	1.560	.1984	.0598	<0.05
Mn	.4345	.4200	.2800	.6200	.3800	.5100	.0969	.0292	< 0.5
Ni	1.266	1.290	1.080	1.670	1.110	1.310	.1630	.0491	<0.02
Zn	1.304	1.310	1.080	1.580	1.220	1.430	.1429	.0430	5.0

source and the catchments need protection. For this purpose, the River should be protected from contamination due to anthropogenic activities.

Table 1 and 2 show the descriptive statistics of physical, chemical and microbiological parameters of Hingol River during pre-monsoon and post-monsoon seasons. It is apparent that pH, chloride and hardness are well within the permissible limit as per NSDWQ (15). The guideline value for the sulphate is not available in NSDWQ however, concentration upto 500 mg/l is considered safe for dirking. The people consuming water containing sulfate in concentrations exceeding 600 mg/liter suffer from cathartic effects [16]. No significant changes in DO concentration was observed during the two seasons.

The mean value of total suspended solids was relatively high during post monsoon season. Suspended solids may include a wide variety of materials, such as silt, decaying plant and animal matter that can also increase the turbidity of water. If they are of biological origin they would tend to increase the biological oxygen demand. Water containing high concentration of TSS does not allow the light to penetrate which is detrimental to submerged vegetation. This would reduce the rate of photosynthesis and lesser amount of dissolved oxygen will be released into the water. In extreme conditions the submerged vegetation may even die due to unavailability of light. The dead vegetation will be decomposed by bacteria that will utilize more oxygen thereby creating a condition of suffocation detrimental to aquatic fauna.

High TSS can also increase surface water temperature as suspended particles absorbed more heat [17]. Generally the SS concentration is relatively high during high hydraulic load [13].

It can be noticed from the Tables 1-2 that BOD concentration is also relatively higher which could also be attributed to high SS concentration. The mean BOD_5 value of pre and post monsoon seasons are 46.45 and 59.63 mg/l respectively. High BOD level is an indication of organic pollution. EEA [18] reported that over 80% of Rivers in northern Europe have a biochemical oxygen demand of 2.0 mg/l, which indicates relatively clean Rivers. Sullivan, *et al.* 1[9] reported that particulate organic matter, especially the alga *A. flos-aquae*, is an important component of oxygen demand in the Klamath River, that would continue to exert an oxygen demand over longer time periods and as water travels downstream.

The mean values of all the metals during pre-monsoon season are within the permissible limit except Pb as reported in Table 3. It is apparent that Pb concentration was much higher than those of other heavy metals. The concentrations of the heavy metals in the pre-monsoon samples were found to be in the order Pb>Ni>Zn>Mn>Fe>As>Cr>Cu. Also in post-monsoon season the concentration of Pb and Mn was relatively higher and they were available as Pb>Mn>Zn>Ni>Fe>Cu>As. The heavy metal concentration during post monsoon season was in the order Pb>Zn>Hg>Cu>Fe>Cd (Fig. 2). Farooq *et al*. [20] reported the heavy metal concentrations found in Indus River. They also reported elevated concentration of Pb mainly attributed to anthropogenic activities. The quality of surface water is an important issue especially in the areas where it is used for drinking purposes. It was studied in details by many workers [21, 22]. The health risks associated with these metals are also of great concern and were noticed by many workers [23, 24].

Principal component analysis was applied on the normalized data sets of pre-monsoon season of different sites, (Fig. 2). Together the first three components explained 69.16 percent of the total variance. The first component that accounted for 30.56 percent of variance was primarily controlled by TSS, Cu and Hardness. The second component explaining 19.40 percent variance was regulated by BOD, Ni and Turbidity, whereas the third component contributing 15.94% percent variance was basically a function of chloride, sulphate and Zn. The result of principal component analysis of post monsoon data set is represented in Fig. 3. The cumulative variance explained was 58.69%. The first component was controlled by BOD, Cr and DO. The second component which explained 19.11% variance was regulated by TFC, TCC and TSS, while third component having percent variance 15.59% was basically a function of Cu, Hardness and Fe. From the Tables 3 and 4 it can be seen that the heavy metal concentrations were found to be well with in the permissible limit [15]. This could be mainly due to high hydraulic load during post monsoon season. Ismail *et al.* [25] estimated the Cr concentration in water of Indus delta and reported 0.291 ppb of Cr which was mainly attributed to anthropogenic activities. Since there is no industrial activity in the vicinity of the River, the heavy metal concentrations are well below the prescribed limits and thus would not produce any serious health risks. Relatively higher concentration of Fe and Cu is due to the geological formation of the area. The variability in spatial and temporal pattern in water chemistry of the rivers and streams is mainly dependent on local environmental conditions (light, temperature, discharge and water velocity) function of stream/river type and chemical parameters [26]. In Pakistan, the studies regarding the monitoring of surface water quality are scanty. The few studies that were conducted in recent years were of Tassadaque, *et al.* [27] on the seasonal variations of physic-chemical parameters of Indus River, Khan, *et al.* [28] monitored the water pollution of Hadira drain of River Ravi and Tehseen *et al.* [29] examined the water quality of Deg Nullah. The water pollution of surface water in Pakistan is mainly originated from anthropogenic sources as water pollution through natural processes is insignificant in Pakistan [30].

Dendogram derived from cluster analysis of pre-monsoon showed two main groups as presented in Fig. 4. Comparison of group 1 and group 2 derived from cluster analysis showed that TSS, Chloride, BOD, Pb, Ni, TCC and TFC had greater values for group 2 compared to group 1. However, no differences were found for pH, turbidity, TSS, Sulphate, DO and Zn. Similarly, Dendogram derived from cluster analysis of post-monsoon also showed two main groups as depicted in Fig. 5. TSS concentration of group 2 was relatively higher while BOD of group 1 was less as compared to group 2. The trend in all metal concentrations was towards higher side in group 1 except Ni. While Zn concentration in both the groups remained unchanged. It is interesting to note that the microbial load in terms of TCC and FC were quite low as compared to group 2.

Table 4: Descriptive statistics of heavy metals of Hingol River water in post-monsoon

Variable	Mean	Median	Min.	Max.	Lower Quartile	Upper Quartile	Std. Dev.	SE	*NSDWQ mg/l
As	.0016	.0020	.001	.0030	.0010	.0020	.0006	.0002	< 0.05
Fe	0.531	.5200	.350	0.100	.3900	.6100	0.3000	0.9046	N/A
Cr	.0025	.0020	.001	.0110	.0010	.0020	.00288	.00086	<0.05
Cu	.0234	.0230	.021	.0260	.0220	.0250	.00181	.00054	2.0
Pb	1.4390	1.410	1.010	1.860	1.230	1.7800	.28314	.08537	<0.05
Mn	.4927	4.800	.380	.630	.4300	.5600	.07511	.02264	< 0.5
Ni	1.5427	1.540	1.210	1.880	1.350	1.7900	.24307	.07328	<0.02
Zn	1.6809	1.690	1.450	1.820	1.590	1.7800	.11717	.03532	5.0

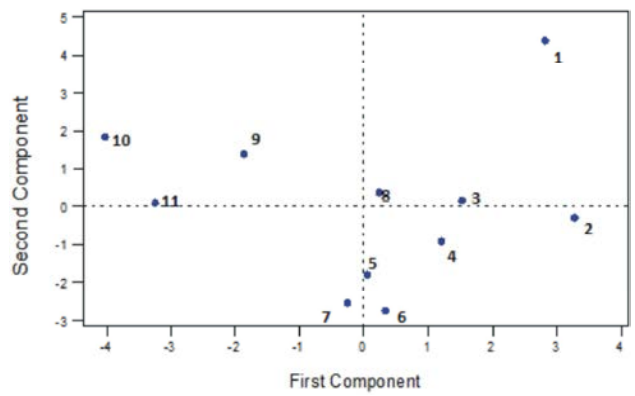

Fig. 2: Principal component analysis ordination (2D) of physical, chemical and microbiological parameters of Hingol River during pre-monsoon period

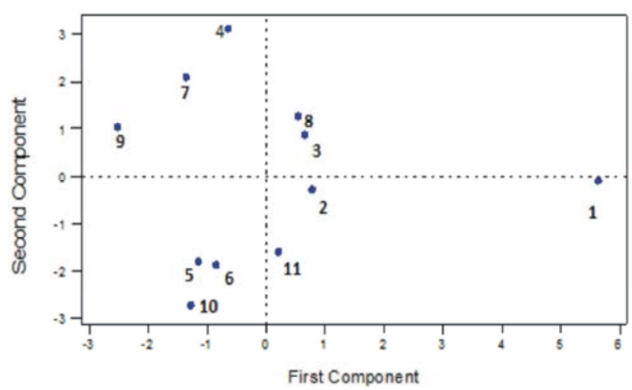

Fig. 3: Principal component analysis ordination (2D)of physical, chemical and microbiological parameters of Hingol River during post-monsoon period

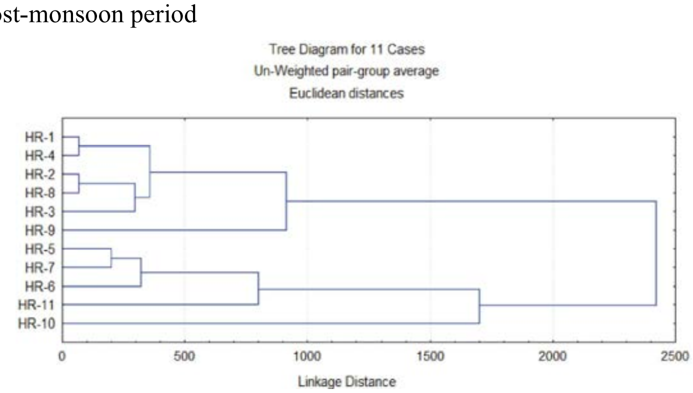

Fig. 4: Dendogram derived from Ward’s method of 11 sites based on physical, chemical and microbiological quality of Hingol River during pre-monsoon period

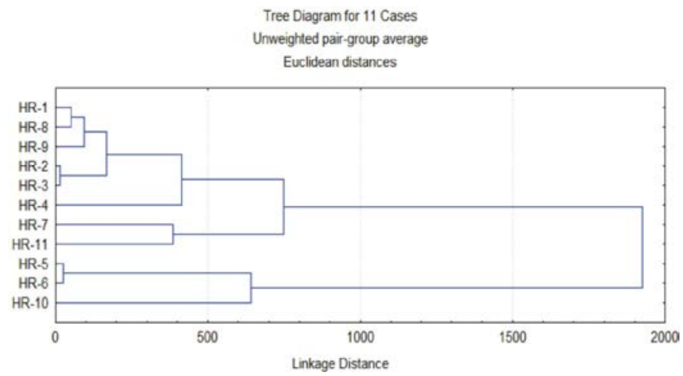

Fig. 5: Dendogram derived from Ward's method of 11 sites based on physical, chemical and microbiological quality of Hingol River during post-monsoon period

CONCLUSIONS

At present no surveillance programme exists to monitor the quality of Hingol River water. It is imperative that the concerned agencies should design the water quality programs that should be executed on regular basis. Institutional strengthening and coordination among relevant agencies is also necessary to formulate an effective management strategy. The study reveals that the water quality of Hingol River is not safe for human consumption. Long term accumulation of heavy metals is also detrimental to the biodiversity of the area. It is anticipated that from the viewpoint of quality and quantity the River may face critical problems arising from the following causes.

- There is insignificant rainfall throughout the year and therefore effective recharge will only be available during floods.
- Water may be polluted with the organisms of public health importance due to indiscriminate disposal of human and animal waste.
- So far no protection measures have been adopted to protect the reservoir from contamination from external sources. The study envisaged that quality of water is unfit for human consumption. However, this conclusion is based on the very limited number of samples therefore, it is suggested to carry out more extensive survey so as to identify the sources of pollution and to suggest mitigation measures.

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