Available Online at http://journalijcar.org

International Journal of Current Advanced Research
Vol 4, Issue 7, pp176-181, July 2015

ISSN: 2319-6505

International Journal of Current Advanced Research

ISSN: 2319 - 6475

RESEARCH ARTICLE

IMPACT OF DAMS ON RIVER WATER QUALITY

Dinesh Kumar Sharma

Senior Environmental Engineer, HP State Pollution Control Board, Phase-III, New Shimla-171009 India

A R T I C L E   I N F O

Article History:

Received 18th, June, 2015
Received in revised form 30th, June, 2015
Accepted 18th, July, 2015
Published online 28th, July, 2015

Dams, reservoirs, profile, dissolved oxygen, heavy metals, coliform, thermal stratification

A B S T R A C T

Dams are constructed on the rivers to meet the varying requirements of power, irrigation, drinking water and flood control. The foremost consequence of a dam project is creation of reservoir submerging large tracts of land, substantial amount of vegetation and bio-mass which undergoes decomposition taking on an average eight to ten years to degrade the initial stock. Change of aquatic system from riverine to lackustrine environment is, therefore, obvious. There is a consequent effect on the water quality due to alterations in the dynamics of oxygen transfer mechanism in the water of the river. In the impoundments having large depth, thermal stratification occurs dividing the vertical profile of the river in distinct zones known as epilimnetic and hypolymnetic zones.

Water quality of the impounded river is characterized by impacts along the longitudinal profile of the river also both upstream and downstream of the dam. The quality of water deteriorates towards the reservoir bed and also upstream and downstream of the reservoir due to several factors such as duration of storage, the nutrient load, the depth of reservoir, the turbidity and temperature. This study is carried out to assess the variation of water quality due to dams. For the purpose of study three dams having different design features have been selected to assess the water quality along the vertical profile of the impoundments and along the longitudinal profile of the rivers upstream as well as downstream of the dams. Depletion in Dissolved Oxygen content was observed both in the vertical and longitudinal water quality profile of the river. Similarly metals like Lead, Copper, Zinc, Manganese and Iron showed increased concentrations in the bed level samples as compared to samples of flowing water.

INTRODUCTION

Multipurpose river valley projects require construction of dams to store water and release it in a regulated manner according to the requirements of the downstream and in some instances upstream users. The immediate consequence of a dam project is creation of reservoir submerging large tracts of landmass and substantial amount of vegetation and bio-mass. Riverine system (free flowing river) is converted into lacustrine system (static water). The process of decomposition of submerged biomass sets in and acts as a trigger for change in water quality in combination with several other factors. It is reported that large impoundments created due to dams on rivers can create a green house effect comparable to an equivalent thermal power plant in terms of production and release of carbon dioxide (CO_2) into the atmosphere.

The biotic and morphological alterations in the flow regime are largely responsible for the water quality impacts. Decomposition of submerged biomass not only causes deoxygenation of water but also increases nutrients and acidification of water particularly near the bottom of the impoundment. Water in a reservoir invariably undergoes the process of thermal stratification which in simple terms connotes separation of vertical profile of a reservoir along the depth in two distinct layers. These layers are called *epilimnion* (top layer) and *hypolimnion* (bottom layer). A higher degree of nutrients further aggravate this situation through eutrophication of the reservoirs which leads to algal blooms and resultant depletion of oxygen. Dissolved oxygen is the primary determinant in the assessment of water quality as far as fresh water ecology is concerned. The level of depletion of dissolved oxygen in the reservoir is dependent primarily on the fact whether the impoundment is aligotrophic (poor in nutrients) or eutrophic (rich in nutrients).

Although water quality assessment is now required to be assessed as an integral part of environmental impact assessment, the study is often limited to the proposed river valley projects in India but existing projects do not have any mandatory requirement for such assessment. Dam spillway withdraws most of its water from the surface layer of the reservoir, where DO concentration and temperature are relatively high in the summer months and toxins, metals, and nutrients are relatively low. However for generation of hydro power, water is invariably withdrawn from the depths much below the surface of reservoir. Impact on water quality in downstream areas of dams in terms of dissolve oxygen (DO) is reported during summers. This is due to the withdrawal of reservoir water from lower level combined with reduced aeration because water is drawn from the deep intakes to operate the turbines. Many unsteady and complex hydraulic and biochemical processes are involved that affect water quality parameters [1].

Along the vertical profile of reservoir, water quality does not show marked variation or deterioration within the surface mixed layer called *epilimnion*. When the reservoir is stratified, the penetration of sunlight is limited to a particular depth called *thermocline.* Further deep, the water in the dark layer called *hypolimnion* below the surface mixed layer is colder and denser. Dissolved oxygen (DO) concentration tends to be low and in case DO concentration is reduced to less than 2 mg/l, nutrients, metals, toxins and other constituents may also be released from the sediments and colloids as they are ionized by bacteria under the anoxic conditions. Water withdrawn from this region of a large reservoir and discharged downstream may create an adverse impact on water quality for long stretch of river. The largest impact occurs during the summer months when stratification is stronger and DO saturation concentration is low. Higher water temperatures increase oxygen-consumption rates, which in turn result in generally lower DO in water. Moreover, the fish breeding also occurs in summers for which higher DO levels are needed. Ambient Water Quality Criteria for Dissolved Oxygen [2] published by U.S. Environmental Protection Agency demonstrates the effect of low DO on fish population and growth.

Water quality variations in the unstratified water impoundments created by shallower dams, the water quality variation along the vertical profile of the reservoir is much less as compared to the stratified reservoirs. However in a thermally stratified reservoir, the proportion of withdrawal of water from different depths of the dam (selective withdrawal) [3] may be needed to improve the water quality of the downstream releases. The older dams including those selected for study did not have the mechanism to draw water from various depths to maintain the required level of dissolved oxygen in the downstream area of dam.

quality [1]. In some cases the water from the reservoir is diverted into the tunnels and large stretches of the rivers downstream are left with very little or no water in the areas immediately downstream of dam.

The objective of this study was to assess the water quality impacts due to impoundments created due to construction of dams. The water quality changes due to alterations in river behavior due to physical and morphological characteristics of the flow regime have been studied. This study was conducted on three different dams and the sampling and analysis of water were carried out to assess the changes in the water quality in the reservoir, upstream and downstream stretches of rivers. For the purpose of discussions, these are referred to as Dam-1, Dam-2 and Dam-3. Dam-1 is a deep storage reservoir used for hydropower generation immediately downstream of dam. Dam-2 is low depth diversion reservoir from which the water is diverted through a tunnel and transferred into a different river basin. Dam-2 is different in design and water conductor system from Dam-1 & Dam-3. This is low depth diversion reservoir water is diverted from the main dam through underground tunnels & channel. The head race tunnel from dam is capable of carrying 254.85 cumecs water and 13.1 kilometres in length. Any excess incoming water is released downstream of the dam in the main course of river. This project involves inter-catchment transfer of water from Beas basin to Sutlej basin. Water quality assessment was carried out in upstream of dam and at the outfall of the diversion tunnel. Dam-3 is a medium depth high submergence reservoir with hydro-power generation immediately downstream of dam.

MATERIALS AND METHODS

Himachal Pradesh has vast potential for development of river valley. State has a potential to generate 20391.77 MW [4] of hydropower. Several projects are already operational in the State. For the study, three dams of distinct design features and

Table1 Features of Dams

Dam /River	Catchment area in km^2	Depth (m)	Altitude (m)	Length (m)	Annual Average Run-off (Million m^3)	Daily in flow (12 months average in cumecs)	Daily out flow (12 months average in cumecs)
Dam 1/ Sutlej	56980	185.93	518.23	518.16	16775	612.82	542.0
Dam2/Beas	5278.	12.5	999.16	255	8200	273	158.4
Dam 3/Beas	12562	49.07	435.86	1950.72	15338	337.29	287.06

Table2 Sampling Locations

Name of the Dam	Sampling Locations: Longitudinal Profile		Sampling Locations: Depth Profile	
Dam-1	i.	70 kilometres upstream	i.	Reservoir Surface
	ii.	2 kilometres upstream	ii.	Reservoir at 11.00 metres depth
	iii.	0.2 kilometres downstream	iii.	Reservoir at 32.00 metres depth
			iv.	Reservoir at 94.00 metres depth
Dam-2	i.	44 kilometres upstream		
	ii.	1.00 kilometres upstream	i.	Reservoir Surface
	iii.	13.1 kilometres at tunnel outfall	ii.	Reservoir at 11.00 metres depth
Dam-3	i.	95 kilometres upstream	i.	Reservoir Surface
	ii.	2 kilometres upstream	ii.	Reservoir at 10.00 metres depth
	iii.	0.2 kilometres downstream	iii.	Reservoir at 32.00 metres depth
			iv.	Reservoir at 48.00 metres depth

In addition to the water quality alterations in the reservoir, the water quality of river is also affected along the longitudinal profile of rivers on which dams are constructed. The impact on concentration of dissolved oxygen is reported from 6 to 40 kilometres in various studies as impact of dams on water hydrology on river Beas & Sutlej were selected. The features of the rivers /dams are given in Table-1.

Reconnaissance of River stretches upstream and downstream of the dams was carried out to finalize the sampling locations for water quality assessment. Depending on the depth of the dam, locations of sampling points along the vertical profile of each dam were selected. Sampling of water was carried out following the procedure prescribed in Bureau of Indian Standards [5] read with the methods described in the standard operating procedures by USEPA [6]. Sampling locations were determined with a view to assess most representative water quality at a particular location according to the methods discussed above. Details of sampling locations are given in Table-2.

analyzed at site for each sample. Although the standard prescribed [11] has mandate for testing many parameters for drinking water, the analysis in the study was confined to 32 parameters.

RESULTS AND DISCUSSIONS

Sampling was conducted quarterly for a year at each location for all the three dams to even out the seasonal variation if any

Table3 Water Quality along Longitudinal Profile of Rivers

S. No.	Parameter	Results (All values except Temperature, pH and Conductivity are expressed in mg/litre. Temperature is expressed in ^oC, pH is expressed as an index number of hydrogen ion concentration and conductance is expressed in µmho cm^{-1}.)								
		Dam-1			**Dam-2**			**Dam-3**		
		i	ii	iii	i	ii	iii	i	ii	iii
1.	Temperature	20.5	22.00	22.00	19.00	17.50	18.00	21.50	22.40	22.00
2.	Dissolved Oxygen	8.6	7.6	7.1	10.1	5.20	7.9	8.1	7.4	4.8
3.	pH	8.08	8.20	8.27	7.44	7.45	7.53	8.14	8.13	7.81
4.	Conductance	32.4	240.0	240.0	15.0	90.0	85.0	48.0	260.0	250.0
	Total Hardness	158.0	101.0	102.0	88.0	30.0	28.0	108.0	81.0	84.0
5.	$CaCO_3$	143.5	92.0	93.0	79.4	25.0	26.0	93.2	75.0	76.0
	$MgCO_3$	14.5	9.0	9.0	8.6	5.0	2.0	14.8	6.0	8.0
6.	Calcium	36.0	36.87	37.27	56.0	10.01	10.41	63.0	30.06	30.46
7.	Magnesium	22.0	2.19	2.19	32.0	1.22	0.49	9.0	1.46	1.95
8.	Chloride	7.01	14.0	15.0	12.01	10.0	11.0	108.0	10.0	23.0
9.	Nitrate	0.06	0.015	0.035	0.05	0.088	0.085	0.07	0.015	0.038
10.	Chemical Oxygen Demand	2.0	5.0	6.0	2.40	3.00	2.70	4.60	4.0	3.0
11.	Bio-chemical Oxygen Demand	0.06	0.60	0.40	0.05	0.50	0.20	0.07	0.90	0.90
12.	Total Dissolved Solids	205.0	142.5	139.25	72.0	15.0	57.5	293.0	122.0	127.5
13.	Total Suspended Solids	200.0	6.5	33.0	75.0	41.0	52.5	183.0	3.0	2.75
14.	Turbidity	18.0	3.0	31.0	3.6	1.5	2.0	13.0	1.8	0.8
15.	Total Alkalinity	100.0	85.0	85.0	55	32.5	30.0	85.0	90.0	68.0
16.	Sodium	6.0	6.0	5.0	6.0	1.0	1.0	5.0	16.0	16.0
17.	Potassium	0.8	1.0	1.0	0.70	2.0	Nil	1.50	1.0	Nil
18.	Total Phosphate	0.02	0.054	0.042	0.01	0.060	0.04	0.01	0.038	0.038
19.	Ammonia	0.90	0.022	0.081	0.20	10.5	0.04	1.20	0.044	0.003
20.	Total Acidity	0.80	1.0	1.0	0.30	0.43	0.30	0.40	0.25	1.0
21.	Total Coliform	140	22.0	110.0	180	49.0	70.0	920	11.0	12.0
22.	Faecal Coliform	7.6	2.0	23.0	17.0	13.0	11.0	110	2.0	5.0
23.	Sulphate	78.73	37.15	35.20	20.77	8.31	7.82	12.98	8.63	9.45

The Sterilized glass bottles (200 ml) were used for bacteriology and dissolved oxygen analysis. Low density polyethylene containers were used for other parameters as prescribed [7]. For deep water sampling, deep water sampler with a calibrated hoisting cable was used which had a control mechanism to open the sampler intake at a particular depth. Among other accessories, dissolved oxygen sampler, thermometer, standard glassware, laboratory grade reagents, preservatives and ice box were used during collection of water samples. Standard preservation techniques [8] were applied for the samples.

For analysis of metals nitric acid was used as preservative. All the samples were preserved at 4 ^oC during transit and transfer of the samples to the laboratory. Although the samples were delivered in the laboratory within 24 hours of collection, the above preservation technique ensured that the original composition of the samples is maintained similar to site conditions. Sampling at each location was conducted quarterly for taking into account the seasonal variations in the water quality Analysis of the water was carried out following the prescribed principles [9] and the broad guidelines prescribed by Central Pollution Control Board [10.] The samples were collected at different locations and analyzed for the field parameters in-situ. For detailed analysis, the samples were transported to the laboratory. DO, pH and temperature were

during the study period. It was observed that during different seasons March, June, September and December variation in the parameters particularly in DO, BOD and temperature was nominal. Although there are water quality variations in terms of almost all parameters of water quality, the discussions shall primarily focus on DO, BOD, Temperature and heavy metals concentration in the reservoirs because these are most amenable to influence due to change in the flow regime. Average values observed for parameters other than metals along the longitudinal profile are shown in Table-3. Similar to longitudinal profile of river, simultaneous sampling was conducted concurrently at quarterly interval for a year at each location for all the three dams to even out the seasonal variation if any during the study period. Average values observed for various parameters other than metals along the vertical profile of the reservoirs created by all the three dams where study was undertaken are shown in Table-4.

Free flowing regime of river is taken as the benchmark or baseline water quality for comparison of impacts due to dam. Distance of free flow regime in each river was determined corresponding to the FRL (Full Reservoir Level) of each dam. In the Water Quality survey of Dam-1 it is observed that the average value DO in the section where river flows in its natural regime is 8.6 mg/l. It drops to a minimum of 7.1 mg/l downs stream of the Power House with DO concentration as

Table-4 Water Quality along Vertical Profile of Reservoirs

S. No.	Parameter	Results (All values except Temperature, pH and Conductivity are expressed in mg/litre. Temperature is expressed in ^oC, pH is expressed as an index number of hydrogen ion concentration and conductance is expressed in µmho cm^{-1}.)									
		Dam-1				Dam-2		Dam-3			
		i	ii	iii	iv	i	ii	i	ii	iii	iv
1.	Temperature	22.00	21.50	20.50	19.50	17.50	16.50	22.50	21.50	20.20	20.5
2.	Dissolved Oxygen	7.60	7.20	6.80	5.00	5.20	3.90	7.4	5.6	4.80	3.10
3.	pH	8.20	8.19	8.10	8.04	7.45	7.49	8.13	7.75	7.47	7.57
4.	Conductance	240.00	240.00	250.00	300.00	90.00	95.0	260.0	240.0	260.00	240.0
	Total Hardness	101.0	100.0	91.00	73.0	30.0	32.0	81.0	80.0	76.00	76.0
5.	$CaCO_3$	92.0	91.0	83.00	67.0	25.0	30.0	75.0	72.0	69.00	71.0
	$MgCO_3$	9.0	9.0	8.00	6.0	5.0	2.0	6.0	8.0	7.00	5.0
6.	Calcium	36.87	36.47	34.50	26.85	10.01	12.01	30.06	28.85	25.60	28.45
7.	Magnesium	2.19	2.19	1.86	1.46	1.22	0.41	1.46	195.0	1.65	1.22
8.	Chloride	14.0	17.0	17.50	20.0	10.0	11.0	10.0	24.0	23.50	21.0
9.	Nitrate	0.015	0.023	0.24	0.31	0.088	0.11	0.015	0.035	0.05	0.13
10.	Chemical Oxygen Demand	5.0	6.0	14.00	81.0	3.0	20.0	4.0	13.5	25.70	104.0
11.	Bio-chemical Oxygen Demand	0.60	0.60	2.50	10.8	0.5	4.0	0.9	5.0	7.50	15.6
12.	Total Dissolved Solids	142.5	133.5	121.00	125.0	15.0	57.0	122.0	111.75	109.65	106.5
13.	Total Suspended Solids	6.5	31.75	44.00	2888.75	41.0	727.0	3.0	7.75	11.00	2388.0
14.	Turbidity	3.0	29.0	32.00	450.0	1.5	4.5	1.8	4.8	5.00	600.0
15.	Total Alkalinity	85.0	75.0	72.00	90.0	32.5	37.5	90.0	90.0	90.00	60.0
16.	Sodium	6.0	6.0	7.00	12.0	1.0	1.0	16.0	13.0	14.50	18.0
17.	Potassium	1.0	1.0	3.00	6.0	2.0	Nil	1.0	1.0	2.10	3.0
18.	Total Phosphate	0.054	0.042	0.51	0.066	0.060	0.040	0.038	0.035	0.02	0.030
19.	Ammonia	0.022	0.030	0.02	0.01	10.5	9.9	0.044	0.005	0.03	0.024
20.	Total Acidity	1.0	1.0	1.20	0.75	0.43	0.43	0.25	0.5	0.5	0.075
21.	Total Coliform	22.0	11.0	40.00	180.0	49.0	79.0	11.0	8.0	14.60	34.0
22.	Faecal Coliform	2.0	2.0	4.00	33.0	13.0	13.0	2.0	2.0	4.00	9.0
23.	Sulphate	37.15	34.55	35.60	37.2	8.31	10.75	8.63	10.27	15.50	19.72

Table5 Heavy Metals in the Water in Free Flow Regime & Reservoir Bed

Sr. No.	Parameter	Concentration (All values are expressed in mg/litre)					
		Dam-1		Dam-2		Dam-3	
		Baseline (Free flowing)	Bed Level	Baseline (Free flowing)	Bed Level	Baseline (Free flowing)	Bed Level
1	Lead as Pb	Nil	0.47	Nil	0.077	Nil	0.74
2	Chromium as Cr	Nil	Nil	Nil	Nil	Nil	Nil
3	Copper as Cu	Nil	0.02	0.01	0.041	0.01	0.082
4	Nickle as Ni	Nil	0.64	Nil	Nil	Nil	0.48
5	.Zinc as Zn	Nil	0.47	0.01	0.062	0.01	0.74
6	Manganese as Mn	0.20	0.67	0.04	0.13	0.03	0.86
7	Cadmium as Cd	Nil	0.062	Nil	Nil	Nil	0.015
8	Iron as Fe	0.01	0.67	0.01	0.12	0.01	0.61
9	Cobalt as Co	Nil	0.22	Nil	Nil	Nil	0.22

7.6 mg/l in reservoir surface water.

Corresponding values for BOD are observed as 0.06 mg/l which rises to 0.6 mg/l in reservoir and 0.4 mg/l downstream of the dam. In Dam-2, the results of water quality indicate that DO in natural flow conditions 44 kilometres upstream of dam has been observed to be 10.1 mg/l which drops to 5.2 mg/l at the reservoir and then gradually recovers to 7.9 mg/l at the diversion tunnel outfall respectively. Relatively high concentration of DO and low value of BOD is attributable to

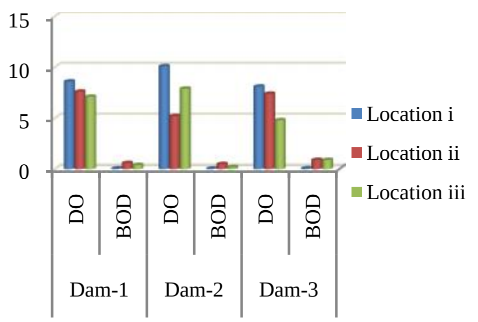

Figure 1 Longitudinal DO & BOD Variations

turbulence of water and its re-aeration in 12 kilometres tunnel and in the outfall cascade. Corresponding values of BOD are found to be 0.05 mg/l, 0.5 mg/l and 0.2 mg/l respectively.

For Dam-3 the results of water analysis along the longitudinal path of river at different points indicate that the concentration of dissolved oxygen (DO) in the river in its natural flow regime at a place 95 kilometres upstream of dam has been found to be 8.1 mg/l, in the reservoir surface 2 kilometres upstream of dam it is found to be 7.4 mg/l and 4.8 mg/l at a distance of 200 metres downstream of dam. There is progressive decline in the dissolved oxygen and corroborates the fact that due to high submergence depletion of DO is faster. The BOD concentration in natural flow conditions is found to be 0.07 mg/l which increases to 0.9 mg/l in reservoir and then remains 0.9 mg/l in the tail race channel at a distance of 200 metres downstream of dam. The variations of results in terms of DO and BOD are shown in Figure-1.

Analysis of heavy metals was also carried out in all the samples to assess their liberation due to ionization of biomass particularly at the deeper sampling locations. Average observed values for the metals in free flow regime of river and in the deepest point of sampling in the reservoirs are given in Table-5.

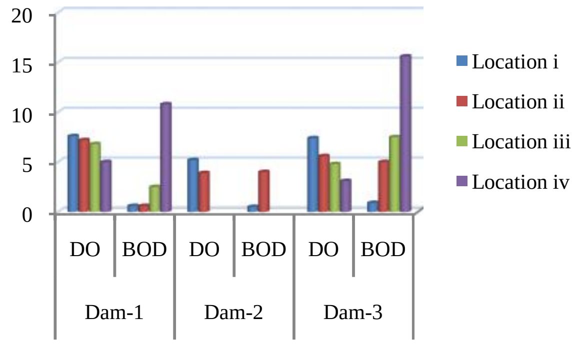

Figure 2 Vertical DO & BOD Variations

Vertical water quality profile of the reservoir indicates that the DO level at surface of reservoir in Dam-1 is observed to be 7.6 mg/l which drops to a minimum of 5.0 mg/l at reservoir bed level. Similarly the BOD level at surface of reservoir is found to be 0.6 mg/l and it shoots up to 10.8 mg/l near the reservoir bed. In the vertical profile of Dam-2, it is observed that this is a relatively low depth reservoir. The water quality profile along the depth profile in the reservoir shows DO content to be 5.2 mg/l and 3.9 mg/l at surface and bed level (11.00 metres) respectively. Rapid depletion over a relatively small depth is noted in this dam. The BOD concentration at the surface level of reservoir is found to be 0.5 mg/l and it increases to 4.0 mg/l in the reservoir bed which can be attributed to higher biomass in the bottom sediments or sewage discharge from urban areas in the upstream. Water quality analysis in the depth profile of reservoir in Dam-3 indicates that the reservoir level DO concentration of 7.4 mg/l reduces to 5.6 mg/l, 4.6 mg/l and 3.1 mg/l at 10 metres, 32 meters depth and 48 metres. The BOD levels also exhibit marked variations along the depth profile. From a concentration of 0.4 mg/l at the reservoir level, the BOD content shoots up to 15.6 mg/l at the reservoir bed with an intermediate concentration of 2.80 mg/l at 10.00 metres depth and 5.0 mg/l at 32 meters depth. This confirms that the bottom sediments are predominantly organic in nature responsible for high depletion of oxygen content in the water and higher concentration of BOD. Figure-2 represents the variation of BOD and DO along the depth of the reservoirs.

Though temperature variation along the longitudinal profile is not significant, thermal stratification is more predominant in deep reservoirs whereas surface temperature of water does not exhibit marked variation along the longitudinal axis of rivers. In Dam-1, the temperature varies from 25^{o}C at surface level to 19.5^{o}C at the deepest point of sampling i.e 94.00 metres. Dam-2 creates a shallower reservoir and the temperature varies from 19^{o}C at the reservoir surface to 16.5^{o}C at the bottom of the reservoir. Thermal stratification is not prominent in this reservoir. In Dam-3, the temperature varies from 25.5^{o}C at the surface of the reservoir to 20.5^{o}C at the reservoir bed. The intermediate temperatures at 10 metres and 32 metres are observed to be 22.5^{o}C and 21.5 ^{o}C respectively. Temperature variations along the longitudinal and vertical profile of rivers/reservoirs are shown in Figure-3.

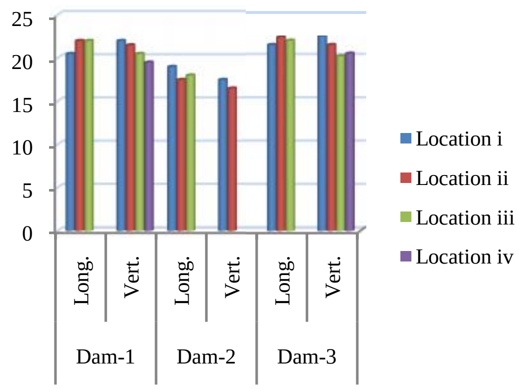

Figure3 Temperature Variations

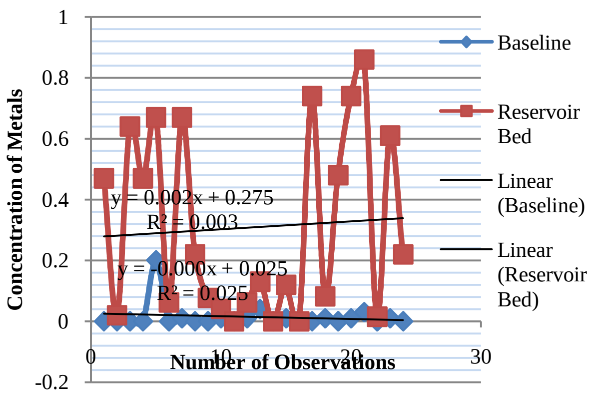

Figure 4 Range of Metal Concentrations

Analytical results for heavy metals show that lead content was found absent in baseline samples of water in the rivers in their free flow regime. However increased concentrations were found in river bed samples in all the three reservoirs created by Dam-1, Dam-2 and Dam-3. Similarly Copper, Zinc, Manganese and Iron show increased concentrations in the bed level samples as compared to baseline samples in free flow regime of rivers. In case of two reservoirs i.e. Dam-1 and Dam-3, Nickel, Cadmium and Cobalt were found in increased concentrations. The Chromium was found absent in all the samples. Variation range of the metals in the reservoirs is shown in Figure-4. Results of samples taken from the deepest points in the reservoirs show very high suspended solids which may be due to turbulence caused during sampling and also possibly due to eddies currents formed during withdrawal of water through the intakes. Comparison of three dams under study show that maximum DO depletion with reference to the first upstream monitoring point is found is observed as17.44% in Dam-1, 48.51% in Dam-2 and 40.74% in Dam-3 respectively. Similarly the increase in BOD concentration with reference to first upstream monitoring is point is observed to be 10 times in Dam-1 and Dam-2, 12.85 times in Dam-3 respectively.

Comparison of results obtained for the water quality along the vertical profile of reservoirs show that the depletion in DO levels along the depth of reservoirs with reference to surface water is found to be 34.21% in Dam-1, 25% in Dam-2 and 58.10% in Dam-3 respectively. It can be observed that maximum depletion in DO is found in Dam-3 reservoir.

Values of BOD are found to be higher by 18 times in Dam-1, 8 times in Dam-2 and 17.33 times in Dam-3 respectively at the deepest point of monitoring with reference to surface water. The decrease in water temperature along the depth at deepest point with reference to reservoir surface is observed to be 11.36% in Dam-1, 5.7% in Dam-2 and 8.9% in Dam-3 respectively.

CONCLUSIONS

Though results do not establish a definite correlation between DO depletion and BOD increase, the results are, however indicative of the fact that DO depletion is invariably accompanied by increase in the BOD concentration in all the three reservoirs. Central Pollution Control Board has published Water Quality Criteria[12] based on designated best use which classifies water quality as A, B, C, D, E and below E where A denotes best quality and E denotes poor water quality. Comparison of observed water quality with this criteria show that water quality of rivers correspond to Class-A in free flowing regime and it deteriorates to B or C in the reservoirs. It is observed that distinct thermal stratification and decrease in temperature along depth is more in the deeper reservoirs.

The thermal stratification and hence the vertical temperature gradient in the deeper reservoirs is more explicit then in the shallow reservoirs. It is seen from the results that ionization of bottom colloids and sediments due to oxygen reducing bacteria results in liberation of heavy metals in the water.

References

1. Water Quality Impact Assessment for Hydropower - Ekaterini I. Daniel et al
2. Ambient Water Quality Criteria for Dissolved Oxygen, Chapman G., USEPA
3. A Numerical One Dimensional Model for Selective Withdrawal - Wilhelms SC et al, 1998 pp-48.
4. EIA Report of Dhaula Sidh Hydroelectric Project, June, 2011 pp-1-3
5. Water & Wastewater-Methods of Sampling and Analysis, IS-3025-1989 Reaffirmed 2008
6. Wastewater Sampling. SESD Operating Procedure No. SESDPRO-306-R3, USEPA, February, 2013 pp-14
7. Waste Water Engineering, Metcalf and Eddy, 1993 pp-59.
8. Guidance manual for drinking water quality monitoring and assessment - A document by NEERI and NICD
9. Standard Methods for the Examination of Water and Wastewater, 1995, 19th Edition Published Jointly by American Public Health Association, American Water Works Association and Water Environment Federation, Washington DC. pp 1-24
10. Water and Wastewater Analysis – A Guide Manual by Central Pollution Control Board, Oct, 2011
11. Bureau of Indian Standard IS: 10500-1989 IS-10500
12. Water Quality Criteria published by Central Pollution Control Board, New Delhi.

****