Production of Dissolved Oxygen due to Presence of Algae in Hilly Stream–A Case Study

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ABSTRACT: Himalayas are the cradle of a large number of streams and mighty rivers, which ensure all the year round availability of water. Seer is one of such streams in outer Himalayas. It is a sub-tributary of river Satluj. It is getting polluted due to wastewater of Ghumarwin town in District of Bilaspur in Himachal Pradesh, India. The pollution impact is severest in the low flow months of summer. Steep slopes, pools, riffles, shallow depth and small waterfalls are the main characteristics of the stream. The stream bed consists of stones and cobbles. All the stones in the stream bed are heavily coated with a greenish layer of algae. Greenish filamentous attached algae also grow in abundance in the stream. Some aquatic plants have also been observed in the stream. The paper describes the quantification of Oxygen production due to the presence of attached algae in the stream.

I. INTRODUCTION

Himalayas are the cradle of a large number of streams and mighty rivers, which ensures all the year round availability of water. Seer is one of the sub tributaries of river Satluj Himachal Pradesh (India). It lies at latitude of $31^{\circ}25'59''$ N and $76^{\circ}43'11''$ East longitude. The Ghumarwin town is located on left Bank of a Seer stream. It is a small rain fed perennial stream taking its orgin from near Sarkaghat in District Mandi and meandering over 20 kms in the district of Bilaspur. It ultimately joins river Satluj, It swells during rainy season but gets reduced to a narrow stream in the summer. The stream serves as a drinking water source for the region. For want of proper sewerage system, the night soil from the houses is being treated through septic tanks. The water from kitchens and baths flows in open drains and is being discharged into local Nallahs named as Ghumarwin Nallah - I and Ghumarwin Nallah - II. The wastewater of the town is polluting the stream. (Sharma *et al.,* 2002).

Water quality models has gained wide acceptance as valuable tools to support the effective management of pollution-impacted streams and lakes. The credibility of the model is accomplished through model calibration and verification. The verified model can be used to forecast the water quality, when any control measure is implemented.

During the water quality modeling of Seer stream, it was observed that the water quality model stream-1 assumes very high values of Deoxygenation coefficient (K_1) and Reaeration coefficient $(K_2)^3$. The paper describes the quantification of Oxygen production due to the presence of attached algae in the stream. Thus there is a need to modify the existing water quality models to predict the water quality of hilly streams.

Stream Geometry: Seer stream has a steep slope which varies greatly on different reaches. The stream is having different velocity and cross-section in different reaches. The stream comprises of small waterfalls and tiny pools. Steep slopes, pools, rimes and small waterfalls thus characterize the stream. The stream bed consists of stones and cobbles. All the stones in the stream bed are heavily coated with a greenish layer of algae. There are also plentiful greenish filamentous attached algae in the stream.

II. MATERIALS AND METHODS

To assess the contribution of solar energy to DO, a section of Seer stream, 500m in length i.e. Reach-1 (Fig.1) was selected and DO was monitored for one year, round the clock and diurnal variation in DO was observed.

Fig. 1. Location plan of sampling station on steer stream.

Since the entire bed of reach-1 is covered with attached algae it has been assumed that the bed of stream is covered with a uniform, thin layer of algae growing on stones and rocks and the entire bed is contributing to the oxygen production. An attempt has been made to correlate diurnal DO variation with solar energy and algal growth. Algal growth converts solar energy to chemical energy in the organic form. It has been assumed that 6% of the visible light energy will get converted to algal growth in the Seer stream. This is parallel to the assumption universally made for oxidation pond design. The chemical energy contained in an algae cell has been found taking average of 6000 calories per gram of algae, on ash free. The light energy received on a surface has been stated as gram calories per cm^2 per day (langleys / day). Visible radiation, which can penetrate the water surface, is limited to 4000-1000 $A^{0.5}$. Typical values for latitudes from $12^°$ to $34^°$ North have been taken from standard tables. These ideal values have been adjusted for cloudiness and elevation. The "maximum" values relate to clear sky condition, while "minimum" values occur when the sky is cloudy, depending on the "sky clearance factor" for the area. The sky clearance factors (SKF) values for the Indian cities have been taken from standard tables (Bajwa, 1993). Since the SKF values for all the months and the site under study were not available, these values have been assumed very close to the values given for Roorkee city which is situated at about the same latitude and has similar weather conditions as Bilaspur (Ghumarwin).

The possible day light hours for a particular month have been taken from standard Table 7 (Michael, 1992). These values have been compared with the local almanac available for the region. The average visible radiation received has been estimated as follows:

Average Radiation = Mill radiation + (Max. radiation- Min. radiation) x sky clearance factor correction for elevation above mean sea level = Visible radiation at sea level {1+0.003EL}, where EL is elevation in 100m. Applying this empirical formula average algae production in gram per square meter per day have been found for Reach-1 of the Seer stream (Fig.1) i.e. 500m in length and oxygen production has been calculated by multiplying the algae production by a factor of 1.3. The oxygen consumed for algae respiration at the rate of 10% of oxygen produced has been deducted from it. Average discharge of the stream in the stretch has been observed. The volume of the water passing that stretch has been calculated for the entire day light time. Average oxygen produced has been found out by multiplying the net oxygen produced with surface area of the reach. The value of oxygen available has been found out by dividing the average oxygen produced for the entire day light period by volume of water passing the bed area of stream during day light hours. This has been compared with the observed value of Do variation at site. The percentage deviation from the calculated values has been found out.

Keeping in view the fact that stream flow and concentration do not change rapidly, grab samples Dissolved Oxygen were collected at two stations from the center of steam at 0.6 depth. The guidelines given by USEPA in "A Methods Manual for Volunteer Stream Monitoring were followed for samplings All the samples were analyzed following Standard Methods.

III. RESULT AND DISCUSSIONS

During the study it has been observed that the bed of Seer stream is heavily coated with attached algae. In addition to it filamentous algae is also present in the stream water. The presence of rooted and attached macropytes has also been noticed in Seer stream as welt as in Ghumarwin Nallah-I. As a result of presence of attached algae in the water the diurnal variability DO in the stream is high. The net effect of photosynthesis and respiration contributes to the average DO resources of the stream.

Seer is a shallow stream and light can reach up to the bottom, the plants (algae and macropytes) would tend to make up most of the plant biomass. Heavy algal growths have been observed at the bed of stream growing on stones and rocks. Filamentous algae are also common at unpolluted and slightly polluted sites in the stream. Table 1 gives the month-wise diurnal dissolved oxygen variation in Seer stream at Reach-1. Table 2 gives the month-wise calculation of Oxygen production in Seer stream at Reach-1, i.e. from RD 0 to 500m.

Illustration. The sample calculations for the month of January are given below:

1. Visible Solar Radiation for the month of January, Maximum = 124
Minimum = 62
2. Sky Clearance factor (S.K.F.) = 60%
3. Average Radiation = Min. Rad. (Max. Radiation – Min Radiation) × S.K.F. = 63 + (126-63) 0.60 = 99.2
4. Applying correction for elevation for 600m above mean sea level = Visible Radiation at sea level [1+0.003 EL], where, EL is elevation in 100m= 99.2[1 + 0.003 × 7] = 101.28
5. Average algae production in kg/ha-day = {99.2 x 108 × 0.06} × (1/6000) × (1/103) = 102.75 kg/bs-day
6. Average algae production in g/m2-day = 102.75 × 1000 × (1/10000) = 10.20 g/Sq.m
7. Average oxygen production at the rate of 1.3 times the algal production = 10.20 × 1.3 = 13.26 g/Sq.m
8. Oxygen consumed for algal respiration = 0.025×13.26 = 0.3315 g/sq.m
9. Net oxygen available in g/sq.m per day = 13.26 – 0.33 = 12.93 g/Sq.m
10. Average day light hours during the month of January at Ghumarwin = 1030 hrs.
11. Average discharge in liter per second during the month at Reach-1 = 75.02 l.p.s.
12. Volume of water passing the bed area of stream during the day light hours at Reach-1 = 2807000 liters
13. Surface area of the Reach contributing to algae/oxygen production = 530 Sq.m
14. Average oxygen produced in mg and available for mass trawler in Reach-1 of stream = (Net oxygen available in g/Sq.m) × 1000 × (Surface area of Reach-1) = 12.93 × 1000 × 530 = 685290 mg
15. Calculated value of oxygen available in mg and available for mass transfer in Reach – 1 of stream) (Net oxygen available in g/Sq.m × 1000 x surface area of Reach – 1) = 685290 + 2807000 = 2.49 mg/L
16. Observed value of D.O. variation in mg/l at Reach-1 in stream = 2.9 mg/l
17. Percent deviation from the calculated value = (0.6/2.49) × 100 = 24%

Table 1: Diurnal Dissolved Oxygen (DO) variation in Seer Stream.

Day Time Hours

Date	6.00	8.00	10.00	12.00	14.00	16.00	18.00	20.0	22.0	24.00	2.00	4.00	Mean	Max	Min	Max variaiton
	DO	In	mg/L													
Jan-15	8.9	9.4	11.1	1.9	11.0	10.8	10.6	10.4	9.8	8.8	8.8	8.8	10.0	11.9	8.8	3.1
Feb-15	7.7	8.9	10.6	11.6	11.1	9.6	9.4	9.4	7.7	7.7	7.7	7.7	9.1	11.6	7.7	3.9
Mar-15	7.1	8.3	10.1	11.0	106	9.1	8.9	8.7	7.1	7.1	7.1	7.1	8.5	11.0	7.1	3.9
Apr-15	6.8	7.3	7.8	8.9	9.9	8.7	7.3	6.4	6.4	6.4	6.4	6.4	7.4	9.8	6.4	5
May-15	5.2	6.5	7.3	8.2	8.8	10.8	9.2	7.7	6.2	5.2	5.2	5.2	7.1	10.7	5.2	5.6
Jun-15	5.3	7.1	7.8	9.2	9.8	8.9	7.5	5.3	5.3	5.3	5.3	5.3	6.8	9.8	5.3	4.5
Jul-15	5.1	5.3	7.0	7.0	6.5	6.5	5.9	5.6	5.4	5.3	5.3	5.3	5.9	7.0	5.1	1.9
Aug-15	5.4	6.2	7.6	7.6	7.2	6.8	6.4	5.9	5.4	5.4	5.4	5.4	6.2	7.6	5.4	2.2
Sep-15	6.0	75	9.0	9.3	9.0	8.0	7.6	6.0	6.0	6.0	6.0	6.6	7.2	9.3	6.0	3.3
Oct-15	6.3	7.5	8.5	8.8	7.5	6.3	6.0	6.0	6.0	6.0	6.0	6.0	6.7	8.8	6.0	2.8
Nov-15	8.0	U	9.5	10.5	16	8.4	8.3	7.9	7.9	7.9	7.9	7.9	8.6	10.5	7.9	2.6
Dec-15	8.5	9.2	10.2	10.8	10.8	9.5	8.6	8.5	8.5	8.5	8.5	8.5	9.2	10.8	8.5	2.3

Table 2: Solar Radiation and Algal Production / Oxygen Production in Seer Stream in Reach # # 1.

Sr. No.	Month	Max	Min	Sky clearance factor	Average radiation	Correction for elevation for 600m	Average algal production in kg/ha-day	Average algal production in g/sqm-day	Average Oxygen produced in g/sqm per day	Oxygen consumed for algal respiratory at the rate of 0.025	Net Oxygen available in mg/sqm per day	Average day light hours during the month at ghumarwin.	Average Discharge in l.p.s. during the month in Reach - 1	Volume of water passing bed area during the day light hrs of stream in Reach - 1	Surface area of the Reach producing algal oxygen	Average oxygen produced & available for mass transfer in Reach -1 of the stream	Calculated value of oxygen in mg/l	Observed value of oxygen in mg/l
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	Jan	126	63	60	100.8	102.95	102.95	10.30	13.38	0.33	13.05	10.30	76	2818080	534	6968403	2.5	3.1
2	Feb	169	87	60	138.2	139.11	139.11	13.91	18.08	0.45	17.63	11.00	77	3049200	528	930e847	3.1	3.9
3	March	212	126	60	177.6	181.40	181.40	18.41	23.58	0.69	22.99	11.90	60	2510400	428	9840524	3.8	3.9
4	April	258	146	10	224.40	229.20	229.20	22.	29.80	0.74	29.06	12.80	30	1382400	314	912:1812	6.6	3.5
5	May	290	181	60	286.2	27$.93	273.93	21.39	35.61	0.89	34.72	13.60	10	485600	176	6110888	12.5	5.8
6	June	296	186	66	25c<.50	255.85	255.85	25.	33.26	0.83	32.43	14.00	30	1512000	232	7523626	5.0	4.5
7	July	289	178	65	250.16	255.50	255.50	25.55	33.21	0.83	32.38	13.81	350	17400600	982	318001198	1.8	1.9
8	Aug	269	183	66	231.90	236.88	236.88	23.69	30.79	0.17	30.02	13.15	500	23870000	1350	40529011	1.1	2.2
9	Sep	226	140	50	208.80	213.26	213.26	21.33	27.22	0.69	27.03	12.25	250	11025000	900	24327893	2.2	3.3
10	Oct	185	104	90	176.90	180.68	180.68	18.07	23.49	0.59	22.90	11.15	200	8028000	850	19486069	2.4	2.8
11	Nov	138	80	85	1290.30	132.06	132.0$	13.21	17.17	0.43	18.74	10.50	123	4649400	615	10294497	2.2	2.6
12	Dec	114	60	85	105.90	108.16	108.16	10.82	14.06	0.35	13.71	10.10	85	3090600	543	7444359	2.4	2.3

Table 3: Seasonal Average of Diurnal DO variation in Seer Stream at un-polluted site.

Sr. No.	Season	Month	Observed value of diurnal variation of DO in the stream in mg/l	Remarks
1	Winter	October	2.7	Observed values have been taken from table 2
2	Winter	November	2.8	
3	Winter	December	2.4	
4	Winter	January	3.0	
5	Winter	February	3.8	
		Min. value of season	2.4	
1	Summer	March	3.9	
2	Summer	April	3.4	
3	Summer	May	5.7	
4	Summer	June	4.6	
	Summer	Min. value of season	3.4	
1	Monsoon	July	1.8	
2	Monsoon	August	2.3	
3	Monsoon	September	3.4	
		Min. value of season	1.8	

Table 4: Maximum Dissolved Oxygen at various temperature at sea level & at a height of 600m above mean sea level i.e. mean level of Seer stream.

Temperature in Degrees Celsius	D.O. at sea level (mg/l)	D.O. at a height of 600m above mean sea level (mg/l)	Temperature in Degree celsius	D.O. at sea level (mg/l)	D.O. at a height of 600m above mean sea level(mg/l)
0	14.6	13.42	23	8.56	7.87
1	14.19	13.04	24	8.40	7.72
2	13.81	12.70	25	8.24	1.58
3	13.44	12.36	26	8.09	7.43
4	13.09	12.04	27	7.95	7.31
5	12.75	n.73	28	7.81	7.18
6	12.43	11.43	29	7.67	7.05
7	12.12	11.14	30	7.54	6.93
8	11.83	10.88	31	7.41	6.81
9	11.55	10.62	32	7.28	6.69
10	11.27	1036	33	7.16	6.58
11	11.01	10.12	34	7.05	6.48
12	10.76	9.26	35	6.93	6.37
13	10.52	9.67	36	6.82	6.27
14	10.29	9.46	37	6.71	6.17
15	10.07	9.26	38	6.61	6.07
16	9.85	9.06	39	6.51	5.99
17	9.65	8.87	40	6.41	5.89
18	9.45	8.69	41	6.31	5.80
19	9.26	8.51	42	6.22	5.72
20	9.07	8.34	43	6.13	5.64
21	8.90	8.18	44	6.04	5.55
22	8.72	8.02	45	5.95	5.47

Source. Volunteer stream monitoring – A methods manual, (1997) EPA 841-B-97-033, p.140

Note *Saturation Concentration of D.O. at 'p' Atmospheric pressure = Saturation Conc of DO at 1 atm $\{1-0.1148 \times elev. (km)\}$

Where, elev is elevation above mean sea level (Zison 1978). It can be observed from Table 2. that with the exception of values for the month of April, May & September, the observed values of Oxygen variation range from 90% to 130% of the calculated values. For the month of April and May the observed values are only 52% and 44% of the calculated values respectively.

It is due to the reason that oxygen level during day, in the month of April and May reaches a peak value of 9.8 and 10.7 mg/L respectively, which is much higher than the saturation values of oxygen (Table 4) at that particular temperature. Since the stream is flowing the dissolved oxygen may be escaping to the atmosphere.

In general, values of average daily, areal production rate range from about 0.3 to 3 g Om-2d-1 for moderately productive streams. Highly productive systems can range from 3 to 20 gm Oxygen per square meter per day (Chapra 1997). Thus it can be concluded that the algal biomass is major contributor of oxygen in the stream and must be taken into account during water quality modeling of the stream.

CONCLUSIONS

The streams in hilly regions of outer Himalayas are generally small having shallow depth with steep and variable slopes. The stream beds of these rivulets are covered with attached algae. The floating algae are generally insignificant due to swift and shallow nature of streams. These streams have high diurnal as well as seasonal variation in DO levels. Though QUAL-2e water quality model takes into account the effect of floating algae in rivers but the effect of attached algae has not been considered in any of the known models (Athens, 1987). Since the effect of attached algae on DO levels in shallow streams are quite significant, there is need to modify the models to take into account the presence of periphyton i.e. benthic algae.

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