IJEP 26 (6) : 481-487 (2006) (Received on November 14, 2005)

Algal Contribution to Dissolved Oxygen in Small Hilly Streams-A Case Study

M.R. Sharma and A.B. Gupta

Hathli is sub-tributary of river Beas in outer Himalayas. It is getting polluted due to wastewater of Hamirpur town in Himachal Pradesh, India. The pollution impact is severest in the low flow months. Steep slopes, pools, riffles and small waterfalls thus characterize the stream. The streambed consists of stones and cobbles. All the stones in the streambed are heavily coated with a greenish layer of algae. There are also plentiful greenish filamentous attached algae in the stream. Some aquatic plants have also been observed both in stream. The paper describes the quantification of oxygen production due to the presence of attached algae in the stream and need to modify the existing models to predict the water quality of hilly streams.

KEYWORD

Water quality, Water quality modelling, Hathli stream.

INTRODUCTION

Hathli is one of the sub tributaries of river Beas in Hamirpur district of Himachal Pradesh (India). It lies at latitude of 31°-25'N and 76°-19' East longitude. The Hamirpur town is located on Right Bank of a Hathli stream. It is a small rain fed perennial stream taking its origin from near Townidevi and meandering over 10 km in the district of Hamirpur. It ultimately joins Kunah stream, which is a tributary of river Beas. It swells during rainy season but gets reduced to a narrow stream in the summer. The stream serves as 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 kitchen and baths flows in open drains and is being discharged into local nallahs named as Manji nallah and Gaura nallah. The wastewater of the town in polluting the stream (Sharma *et al.,* 2002, 2003).

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 medeling of Hathli 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) (Sharma and Gupta, 2004). 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

Hathli 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, riffles and small waterfalls thus characterize the stream. The streambed consists of stones and cobbles. All the stones in the streambed are heavily coated with a greenish layer of algae. There are also plentiful greenish filamentous attached algae in the stream.

MATERIAL AND METHOD

To assess the contribution of solar energy to DO, a section of Hathli stream, 400 m in length, that is Reach-1 (Figure 1) was selected and DO was monitored for one year, round the clock and diurnal variation in DO was observed. Since the entire bed of reach-1 is covered with

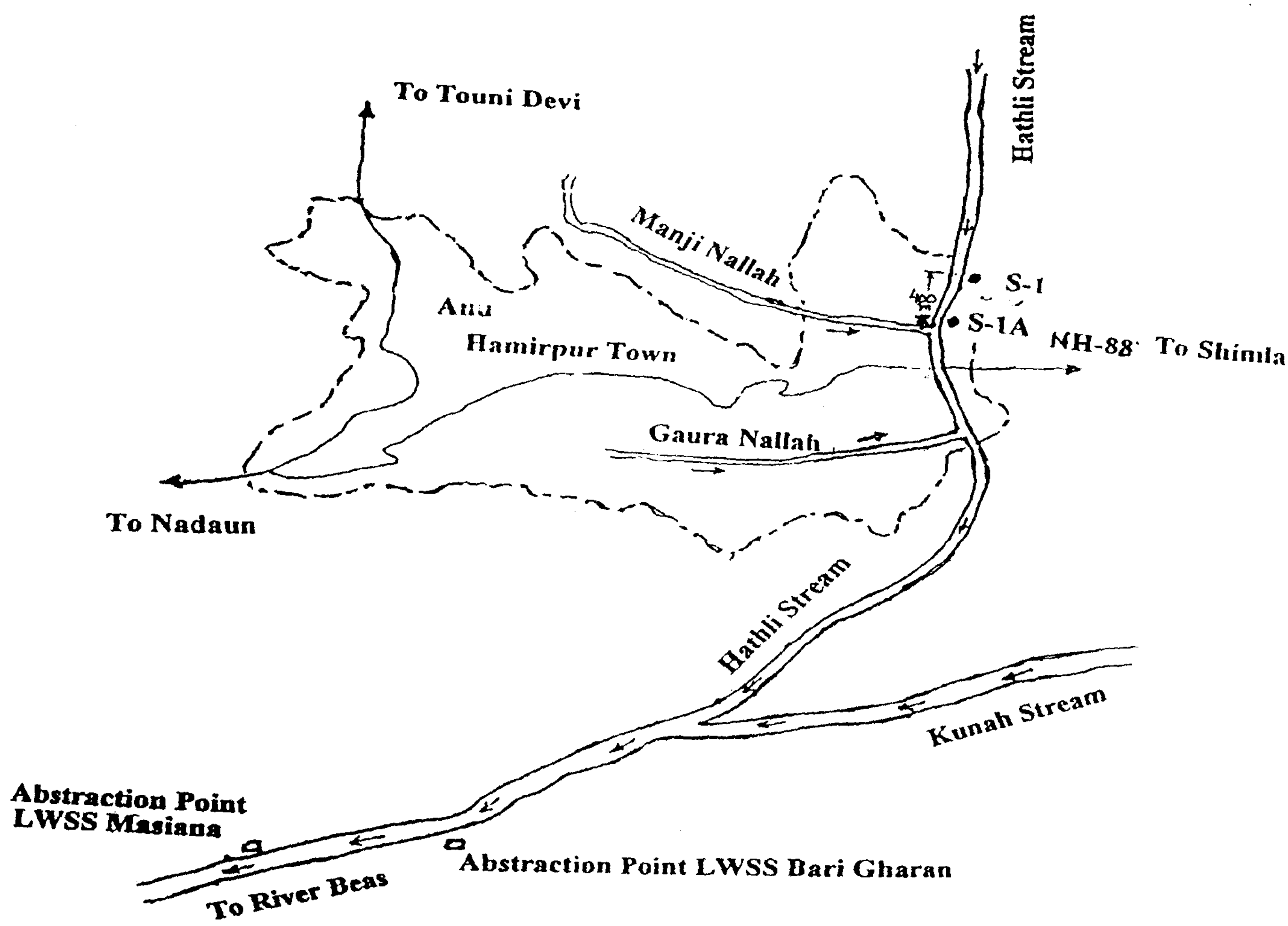

Figure 1. *Location plan of sampling stations for diurnal DO measurement in Hathli stream (un-polluted site)*

Table 1. *Diurnal dissolved oxygen (DO) variation in Hathli stream*

Date	Day Time, hours												Mean	Max	Min	Variation
	6.00	8.00	10.00	12.00	14.00	16.00	18.00	20.00	22.00	24.00	2.00	4.00				
	DO, mg/L															
Jan-02	8.9	9.4	11.1	11.9	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-02	7.7	8.9	10.6	11.6	11.1	9.6	9.4	9.2	7.7	7.7	7.7	7.7	9.1	11.6	7.7	3.9
Mar-02	7.1	8.3	10.1	11.0	10.6	9.1	8.9	8.7	7.1	7.1	7.1	7.1	8.5	11.0	7.1	3.9
Apr-02	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	9.9	6.4	3.5
May-02	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	10.8	5.2	5.6
Jun-02	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-02	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-02	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-02	6.0	7.5	9.0	9.3	9.0	8.0	7.6	6.0	6.0	6.0	6.0	6.0	7.2	9.3	6.0	3.3
Oct-02	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-02	8.0	8.8	9.5	10.5	10	8.4	8.3	7.9	7.9	7.9	7.9	7.9	8.6	10.5	7.9	2.6
Dec-02	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 Hathli stream in Reach-1*

32 Degree N Latitude										
Month	Visible radiation		Sky clearance factor	Average radiation	Correction for elevation for 700m	Average algal production, kg/ha-day	Average algal production, g/m²-day	Average oxygen produced, g/m²-day	Oxygen consumed for algal respiration at the rate of 0.025
	Max	Min							
Jan	126	63	60	100.8	102.95	102.95	10.30	13.38	0.33
Feb	169	87	60	136.2	139.11	13.911	13.91	18.08	0.45
March	212	126	60	177.6	181.40	181.40	18.14	23.58	0.59
April	258	146	70	224.40	229.20	229.20	22.92	29.80	0.74
May	290	181	80	268.2	273.93	273.93	27.39	35.61	0.89
June	296	166	65	250.50	255.85	255.85	25.59	33.26	0.83
July	289	178	65	250.15	255.50	255.50	25.55	33.21	0.83
Aug	269	163	65	231.90	236.86	236.86	23.69	30.79	0.77
Sept	226	140	80	208.80	213.26	213.26	21.33	27.72	0.69
Oct	185	104	90	176.90	180.68	180.68	18.07	23.49	0.59
Nov	138	80	85	129.30	132.06	132.06	13.21	17.17	0.43
Dec	114	60	85	105.90	108.16	108.16	10.82	14.06	0.35

Table 2. *(continue)*

Net oxygen available, mg/m²-day	Average day light hours during the month at Hamirpur	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 and available for mass transfer in Reach-1 of the stream	Calculated value of oxygen, mg/L	Observed value of oxygen, mg/L
13.05	10.30	76	2818080	534	6968403	2.5	3.1
17.63	11.00	77	3049200	528	9309847	3.1	3.9
22.99	11.90	60	2570400	428	9840524	3.8	3.9
29.05	12.80	30	1382400	314	9121872	6.6	3.5
34.72	13.60	10	489600	176	6110868	12.5	5.6
32.43	14.00	30	1512000	232	7523626	5.0	4.5
32.38	13.81	350	17400600	982	31801198	1.8	1.9
30.02	13.15	500	23670000	1350	40529011	1.7	2.2
27.03	12.25	250	11025000	900	24327893	2.2	3.3
22.90	11.15	200	8028000	850	19466069	2.4	2.8
16.74	10.50	123	4649400	615	10294497	2.2	2.6
13.71	10.10	85	3090600	543	7444359	2.4	2.3

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

Table 3. *Seasonal average of diurnal DO variation in Hathli stream at un-polluted site*

Season	Month	Observed value of diurnal variation of DO in the stream, mg/L	Remarks
Winter	October	2.8	Observed values have been taken from table 2
	November	2.6	
	December	2.3	
	January	3.1	
	February	3.9	
	Min. value of season	2.3	
Summer	March	3.9	
	April	3.5	
	May	5.6	
	June	4.5	
	Min. value of season	3.5	
Monsoon	July	1.9	
	August	2.2	
	September	3.3	
	Min. value of season	1.9	

growth in the Hathli stream. This is parallel to the assumption universally made for oxidation pond design. The chemical energy contained in an algal cell has been found taking average of 6000 calories per gram of algae, on ash free basis (Oswald, 1972).

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 4000-7000 A^0 (Arceivala, 1981). Typical values for latitudes from 12^0 to 34^0 North have been taken from standard tables. These ideal values have been adjusted for cloudiness and elevation. The "maximum" values relate to clear sky conditions, while "minimum" 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 latitutde and has similar weather conditions as Hamirpur. The possible day light hours for a particular month have been taken from standard tables (Michael, 1992). These values have also been compared with the local almanac available for the region. The average visible radiation received has been estiamted as follows :

Average Radiation = Min. Radiation + [(Max. Radiation-Min. radiation)]x Sky Clearance factor

Correction for Elevation above mean sea level = Visible Radiation at sea level [1 + 0.003 EL], where EL is elevation in 100 m

Applying the empirical formula average algal production in gm/m^2 per day have been found for Reach-1 of the Hathli stream (Figure 1), that is 400m in length and oxygen production has been calculated by multiplying the algal production by a factor of 1.3. The oxygen consumed for algal respiration at the rate of 10% of oxygen produced has been deducted from it. Average discharge of the stream in that 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 that 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

Table 4. *Maximum, dissolved oxygen at various temperature at sea level and at a height of 700 m above mean sea level, that is mean level of Hathli stream*

Temp., °C	DO at sea level, mg/L *	DO at a height of 700m above mean sea level, mg/L
0	14.6	13.42
1	14.19	13.04
2	13.81	12.70
3	13.44	12.36
4	13.09	12.04
5	12.75	11.73
6	12.43	11.43
7	12.12	11.14
8	11.83	10.88
9	11.55	10.62
10	11.27	10.36
11	11.01	10.12
12	10.76	9.89
13	10.52	9.67
14	10.29	9.46
15	10.07	9.26
16	9.85	9.06
17	9.65	8.87
18	9.45	8.69
19	9.26	8.51
20	9.07	8.34
21	8.90	8.18
22	8.72	8.02
23	8.56	7.87
24	8.40	7.72
25	8.24	7.58
26	8.09	7.43
27	7.95	7.31
28	7.81	7.18
29	7.67	7.05
30	7.54	6.93
31	7.41	6.81
32	7.28	6.69
33	7.16	6.58
34	7.05	6.48
35	6.93	6.37
36	6.82	6.27
37	6.71	6.17
38	6.61	6.07
39	6.51	5.99
40	6.41	5.89
41	6.31	5.80
42	6.22	5.72
43	6.13	5.64
44	6.04	5.55
45	5.95	5.47

Source : Volunteer Stream Monitoring- A Methods Manual (1997) EPA 841-B-97-003, pp140

Note: *Saturation concentration of DO at 'p' atmospheric pressure = Saturation conc. of DO at 1 atm {1-0.1148 x elev. (km)}

Where, elev is Elevation above mean sea level (Zison, 1978).

concentration do not change rapidly, grab samples dissolved oxygen were collected at two stations from the center of stream at 0.6 depth. The guidelines given by USEPA in 'A Methods Manual for Volunteer Stream Monitoring were followed for sampling, (USEPA, 1997). All the samples were analysed following Standard Methods (APHA, 1992).

RESULT AND DISCUSSION

During the study it has been observed that the bed of Hathli 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 macrophytes has also been noticed in Hathli stream as well as in Manji nallah. As a result of presence of attached algae in the water the diurnal variability of DO in the stream is high. The net effect of photosynthesis and respiration contributes to the average DO resources of the stream. Hathli is a shallow stream and light can reach up to the bottom, the bottom plants (algae and macrophytes) 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 Hathli stream at Reach-1. Table 2 gives the month-wise calculation of oxygen production in Hathli stream at Reach-1, that is from RD 0 to 400 m.

Illustration

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

1. Visible solar radiation for the month of January,

Maximum = 126

Minimum = 63

2. Sky clearance factor (S.K.F.) = 60%

3. Average radiation

=Min. Rad. (Max. Ra diation-Min Radiation)x S.K.F.

= 63+(126-63) 0.60=100.8

4. Applying correction for elevation for 700 m above mean sea level

= Visible Radiation at sea level [1+0.003 EL], where, EL is elevation in 100 m

=100.8 [1+0.003x7]=102.95

5. Average algal production in kg/ha-day

$=\{100.8\text{x}10^8\text{x}0.06\}\text{x}(1/6000)\text{x}(1/10^3)$

=102.95 kg/ha-day

6. Average algal production in g/m^2-day

=102.95x1000x(1/10000)=10.30 g/m^2

7. Average oxygen production at the rate of 1.3 times the algal production

=10.30x1.3=13.38 g/m^2

8. Oxygen consumed for algal respiration

= 0.025x13.38=0.33 g/m^2

9. Net oxygen available in g/m^2 per day

=13.38-0.33=13.05 g/m^2

10. Average day light hours during the month of January at Hamirpur = 10.30 hr

11. Average discharge during the month at Reach-1 =76.0 L/sec

12. Volume of water passing the bed area of stream during the day light hours at Reach-1

= 2818080 L

13. Surface area of the Reach contributing to algal/oxygen production= 534 m^2

14. Average oxygen produced in mg and available for mass transfer in Reach-1 of stream

=(Net oxygen available in g/m^2)x1000x (Sur face area of Reach-1)

=13.05x1000x534=6968700 mg

15. Calculated value of oxygen available in mg/L =(Average oxygen produced in mg and available for mass transfer in Reach-1 of stream) ÷ (Net oxygen available in g/m^2x1000x Surface area of Reach-1)=698700 ÷ 2818080=2.5 mg/L

16. Observed value of D.O. variation at Reach-1 in stream = 3.1 mg/L

17. Percent deviation from the calculated value =(0.6/2.5)x100=24%

It can be observed from table 2, that with the exception of values for the month of April, May and 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 53% and 45% 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 9.9 and 10.8 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 the average daily, areal production rate range from about 0.3 to 3g O m^{-2} d^{-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 modelling of the stream.

CONCLUSION

The streams in hilly regions of outer Himalayas are generally small, having shallow with steep and variable slope. The streambeds 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 (Qual-2E UNIAS, 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, that is benthic algae.

ACKNOWLEDGEMENT

The authors are grateful to Er. R.N. Sharma, Engineer-in-Chief, Er. P.S. Verma, Er. O.P. Chauhan XENs of I and P.H Deptt., and Sh. Vishnu Prashad Lab Attendant, for their help during the study.

REFERENCE

APHA. 1992. Standard methods for the examination of water and wastewater (18th edn). American Public Health Association, Washington, D.C.

Arceivala, S. 1981. Wastewater treatment and disposal. Marcel Dekker, New York.

Bajwa, G.S. 1993. Practical handbook on public health engineering. Deep Publishers, Shimla.

Chapra, S.C. 1997. Surface water quality modelling. McGraw Hill, N.Y.

EPA. 1997. Volunteer stream monitoring : A methods manual. Office of Water, U.S. Environmental Protection Agency. 4503F, EPA 841-B-97-003.

Michael, A.M. 1992. Irrigation, theory and practice. Vikas Publishing House, New Delhi.

Qual-2E UNCAS. 1987. Documentation and user model. USEPA, Athens.

Oswald, W.J. 1972. Complete waste treatment in ponds. 6th International water pollution research conference. Pergamon Press, London.

Sharma, M.R. and A.B. Gupta. 2004. Prevention and control of pollution in streams of outer Himalayas-A case study. 36th Annual Convention of IWWA. Ahmedabad. Proceedings, pp 77-85.

Sharma, M.R., A.B. Gupta and J.K. Bassin. 2002. Water quality management of Hathli stream in lower Himalayas. *Indian J. Env. Prot.,* 22(9):1014-1025.

Sharma, M.R., J.K. Bassin and A.B. Gupta. 2003. A pollutional profile of Hathli stream in lower Himalayas. *J. Poll. Res.,* 22(2):237-240.

AUTHOR

1*. Dr. M.R. Sharma, Executive Engineer, Irrigation and Public Health Department, M-26, H.B. Colony, Hamirpur - 177001.

2. Dr. A.B. Gupta, Professor, Department of Civil Engineering, Malaviya National Institute of Technology, Jaipur - 302 017.