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Self-Purification Capacity and Sag Curve of Qalachwalan-Leseer Zab River, in Sulaimanyah Governorate/Iraq

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ABSTRACT

Qalachwalan-Lesser Zab River receives varieties of domestic and chemical wastes from settlements, recreational and agricultural lands that located around the river. Those possibly affect the capacity of natural self-purification. Water samples have been collected from five different points between Qalachwalan to Qaladza district and sag curve were applied to analyzed water quality parameters for the periods of August 2016 to May 2017. The results showed that the dissolved oxygen values varied from 4.81 mg L^{-1} during August to 10.35 mg L^{-1} in February, biochemical oxygen demand values ranged from 1.47 mg L^{-1} during November to 8 mg L^{-1} in March along the river. The statistical analysis between predicted and measured dissolved oxygen and biochemical oxygen demand showed that the less value of root mean square errors was 1.09 mg L^{-1} for the month of April and the highest value was 3.92 mg L^{-1} for dissolved oxygen during May and the less value for biochemical oxygen demand was 0.77 mg L^{-1} for August and the highest value 5.08 mg L^{-1} for March. The predicted dissolved oxygen overestimated measured dissolved oxygen by percent bias 12.5% for April and 74.9% for May and the predicted biochemical oxygen demand overestimated measured biochemical oxygen demand as well by 23.4% for August and 98.9 % for February. The purification factor varied from 0.03 to 4.45 for all over the periods. The results, indicating that the river was temporarily polluted and has a poor capacity for self-purify particularly during April that the average factor was 0.14.

***Keywords*:** Purification, Sag Curve, DO Deficit, Lesser Zab

INTRODUCTION

Rivers play a crucial role in the uptake and carry of industrial, municipal outflows and organic loading made by runoff from agricultural fields, roads, and streets. Leaching and direct wastewater discharges are main causes of water pollution (Shrestha and Kazama, 2007).

Generally, a serious trouble of water pollution is witnessed world over through irregular urban outgrowth and without sufficient attention to sewage and waste disposal, brisk industrialization without suitable processing and disposal of waste outcomes, municipal dumping of refuse and other solid wastes near watercourses, extreme use of pesticides and fertilizers in agriculture (Pitchaiah, 1995). This problem is more series when the purification ability of river schemes is poor with respect to the received pollutants.

Water self-purification is a complex action involving physicochemical and biological processes that happen all together, permitting a river can restore its natural state through a specific distance (Demars and Manson, 2013).

Purification consists of various mechanisms like dilution, sedimentation, re-aeration, adsorption, absorption, and biochemical acting, and can be estimated by algebraic model (Bahadur *et al.*, 2013 and González *et al.*, 2014).

The necessary tools for improvement of designing and control appraise for water resources in river basins are water quality models (Panagopoulos *et al.*, 2012).

Water quality modeling has been demonstrated to be a helpful tool in strategic water quality management (Fan *et al.*, 2009).

Water quality modeling in a river has developed from the ambitious work of Streeter-Phelps (Streeter and Phelps, 1925) who improved a balance among the dissolved oxygen provide value from re-aeration and the depletion value of dissolved oxygen from equalization of an organic waste in which the biochemical oxygen demand de-oxygenation value was shown as an experimental first-order reaction, producing the classic dissolved oxygen sag model and it was really a big accomplishment when Streeter-Phelps, in 1925, were capable to design a mathematical equation that shows how dissolved oxygen in the Ohio River reduced with downriver distance by reason of deterioration of solvable organic biochemical oxygen demand.

These days there is intense attention in integrated procedures to the management of urban basins, whereas these systems are subject to a spacious range of environmental dilemma. The aims of this research are studying de-oxygenation rate, re-oxygenation rate, and predict the self-purification capacity of Qalachwalan-Lesser Zab River with Streeter-Phelps model.

MATERIAL AND METHODS

Site description

The study area is located northeast of Iraq, between latitudes 35º 41' 03" to 36º 10' 21" N and longitudes 45º 03'

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10" to 45º 39' 41" E Figure 1. The located is northeast to the north of Sulaimanyah city at an elevation ranges (501 to 868) meters above mean sea level, the whole studied area is (8166.93) km^2 Table 1.

Table 1. Site locations reading, watershed areas and distance of sections.

Sites	Elevation (m)	latitude N	longitude E	Area (km^2)	Distance (km)
Joga-Sur	849	35º 41' 46"	045º 32' 29"	553.54	0
Shakha-Sur	836	35º 42' 49"	045º 30' 32"	938.80	3.99
Qashan	736	35º 52' 02"	045º 24' 14"	2947.60	37.29
Kawe	537	36º 06' 37"	045º 10' 36"	7873.52	92.06
Sndollan	501	36º 10' 21"	045º 03' 10"	8166.93	113.48

The study area covers Qaladza, Mawat and Chwarta district. These sites feature deep, dramatic cliff and gorge, occasional waterfall, rocky mountain slope, and mixed oak woodland, and grassland habitat. The study area climate has a semi-arid and an average (700 to 800) mm annual rainfall, most of which falls from November to April (Najmaddin *et al.*, 2017a). Therefore, the period from November to April is defined as a high- flow period, during which the discharge at its highest, and the period from May to October is defined as a low-flow period, during which the discharge is at its lowest for the year (Najmaddin *et al.*, 2017b).

Water sampling

For showing a study of the purification capacity Qalachwalan-Lesser Zabmain river was divided into four sections, namely: (section I, from km 0 to 3.99; II, from km 3.99 to 37.29; III, from km 37.29 to 92.06 and IV, from km 92.06 to 113.48) Figure 1. The principle of describing and create each section was dependent on the hydraulic properties of the river, the location for polluting sources and merging to the river. Six field campaigns August 2016 to May 2017, in four periods (Summer, Autumn, Winter, and Spring) were managed out to find out the input variables of the self-purification model at five sampling sites with various degrees of anthropogenic impression and possible sources of pollution, three from Qalachwalan River, and two from Lesser Zab River that covered a distance of 113.48 kilometers downriver Figure 1.

Along with the river bank agriculture and sand washers activities, fish upbringing projects, addition of domestic and municipal dump waste could be viewed as normal human activity. Locations of the sites are given in Figure 1 and Table 1. The collected water samples were determined by using the procedures indicated in the standard methods for the examination of water and wastewater (APHA, 2005).

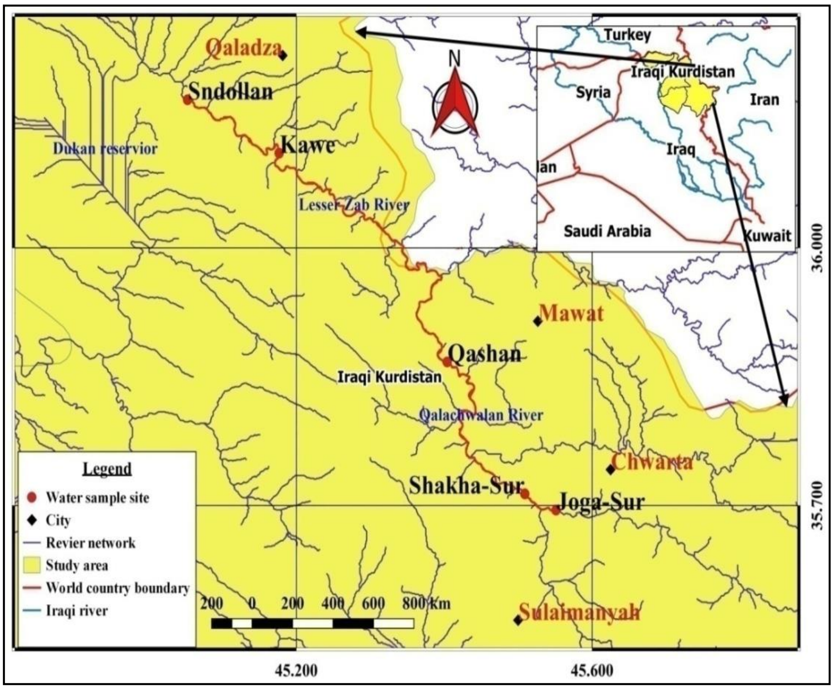

Fig. 1. Map of the study site with marked sampling sites.

In situ measurements

The in situ measured parameters: velocity (km hr^{-1}) by float method, temperature (^{o}C) and dissolved oxygen (DO, mg L^{-1}) were carried out by InoLab.OXi730, WTW Company-Germany.

Laboratory measurements

Biochemical oxygen demand (BOD$_5$, mg L^{-1}) was carried out by InoLab.OXi730, WTW Company-Germany.

Theory

The model of (Streeter and Phelps, 1925), for the river Ohio, identified the space-time change the concentration of DO and BOD to the downriver after pollution discharges, was suggested:

$$dD(t)/dt = k1L(t) - k2D(t) \quad \textbf{(Eq.1)}$$

$$D = Cs - C \quad \textbf{(Eq.2)}$$

where,

$dD(t)/dt$ = the rate of alter of the DO content of the river with time, $k1$ = de-oxygenation coefficient, $L(t)$ = BOD at the instantaneous time, $k2$ = re-aeration coefficient and $D(t)$ = dissolved oxygen at an instantaneous time, t = time in days, Cs = concentration of saturation of DO, C = concentration of DO deficit.

The model uses the coefficients $k1$ and $k2$ which is dependent respectively on the waste traits solo when the re-aeration coefficient $k2$, is dependent upon such factors as water temperature, velocity, and depth of the river. The equation (1), after integration (Fair *et al.*, 1971; Waite *et al.*, 1977; Kiely 1997; Longe and Omole, 2008; Omole, 2011) gives:

$$D = \frac{La}{f-1}10^{k2t}\left[1-10^{[-(f-1)k2t]}[1-(f-1)\frac{Da}{La}]\right] \quad \textbf{(Eq.3)}$$

where,

D = instantaneous DO, La = initial BOD, f is the self-purification factor (which varies for different types of surface water bodies), Da = initial DO and t is the instantaneous time.

The value of f is determined by dividing the computed value of $k2$ by the observed or tabulated value of $k1$ (Garg, 2006). The range of f at 20 °C is given in Table 2.

Table 2. The self-purification factor, f, of different water bodies at 20 °C.

Description of water body	Range
Small ponds and backwaters	0.5-1.0
Sluggish streams, Large Lakes and impounding reservoirs	1.0-1.5
Large stream of low velocity	1.5 - 2.0
Large streams of normal velocity	2.0 – 3.0
Swift stream	3.0 – 5.0
Rapids/ Water falls	Over 5.0

The saturation oxygen Cs concentration of water is calculated, depending on water temperature T, the following practical formula (Fair et al., 1971; Bowie *et al.*, 1985) is used:

$$Saturation\ DO(Cs) = 14.652 - 0.41022T + 0.0079910T^2 - 0.000077774T^3 \quad \textbf{(Eq.4)}$$

The coefficient of de-oxygenation $k1$ is determined by the following relation (Weiner *et al.*, 2003).

$$L = Lo10^{-k1t} \quad \textbf{(Eq.5)}$$

where, L = instantaneous BOD, Lo = ultimate BOD and t = time in days. Therefore,

$$k1 = \frac{1}{t}\log\frac{Lo}{L} \quad \textbf{(Eq.6)}$$

The re-oxygenation coefficient, $k2$ (day^{-1}), was computed from the following equations (Agunwamba *et al.*, 2007).

$$k2 = \frac{(\log DO - \log D)}{t} \quad \textbf{(Eq.7)}$$

Which is also the same as:

$$k2 = \frac{(\log DO / D)}{t} \quad \textbf{(Eq.8)}$$

Where

DO is the initial dissolved oxygen; D is the deficit DO is equal to the difference between saturation dissolved oxygen and the observed dissolved oxygen.

When these two coefficients are known, then the self-purification capacity, *f*, of any river can be derived by the following equation.

$$f = k2/k1 \quad \textbf{(Eq.9)}$$

Performance estimation of models

Performance measures are assessed by comparing predicted values with their corresponding measured values using the following criteria:

Coefficient of determination (R^2);

$$R^2 = \left[\sum_{i=1}^{n}(Oi-\overline{O})(Pi-\overline{P}) / \sqrt[2]{\sum_{i=1}^{n}(Oi-\overline{O})^2}\ \sqrt[2]{\sum_{i=1}^{n}(Pi-\overline{P})^2}\right]^2 \quad \textbf{(Eq.10)}$$

Root mean square errors (RMSE);

$$RMSE = \sqrt[2]{\frac{1}{n}\sum_{i=1}^{n}(Oi-\overline{Pi})^2} \quad \textbf{(Eq.11)}$$

Percent bias (PBIAS);

$$PBIAS = \frac{\sum_{i=1}^{n}Pi-Oi}{\sum_{i=1}^{n}Oi}*100 \quad \textbf{(Eq.12)}$$

where, Oi and Pi are measured and predicted values, respectively; $\overline{O}$ and $\overline{P}$ are the average of measured and predicted values, respectively; and n is the number of values recorded in the sample.

RESULTS AND DISCTION

Comparison between predicted and measured DO

Dissolved oxygen profile along the river at different sites is given in Table 3. High quantities of dissolved oxygen at some sites indicate high atmospheric re-aeration or presence of some extra source of oxygen in the river.

The quantity of measured DO along the distance (Joga-Sur to Shakha-Sur) and (Kawe to Sndollan) reduced and this indicating that the reduction of oxygen which possibly as a result of the addition of organic matter into the river. While the value of measured DO significantly increased at (Qashan) site all over the periods except in March. The statistical relationship between predicted and measured DO is shown in Table 4. It was clearly shown that however the measured DO values are more strongly correlated with the predicted DO during April than the other months, the value of RMSE and R^2 were 1.09 mg L^{-1} and 0.95 respectively for all sites, the predicted DO overestimated measured DO when the PBIAS 12.5%.

Figure 2 and 3 showed that the oxygen sag curves based on DO between (Joga-Sur) point km 0.0, (Shakha-Sur) point km 3.99, (Qashan) point km 37.29, (Kawe) point km 92.06, and (Sndollan) point km 113.48 along main Qalachwalan-Lesser Zab River. The data revealed that DO deficit increased with distance and the lowest point of the oxygen sag curve (critical point) is at the (critical distance) km 3.99 during August and November, when the PBIAS between predicted and measured DO range (27.7 to 34.8)% and RMSE were (1.92 to 2.69) mg L^{-1}. This point out that the de-oxygenation rate is higher than the re-oxygenation rate, from km (0.0 to 3.99) that deficit of DO increased from (1.81 to 3.61) mg L^{-1} during August and from (2.07 to 3.50) mg L^{-1} during November, then DO deficit reduced with distance. Consequently, after km 3.99 the re-oxygenation rate is increased than the de-oxygenation rate in both months toward the direction of river flow. It is clear that the first point on the oxygen sag curve where the DO deficit is less than the second point.

Table 4 summarizes the statistical analysis, varied from (1.09 to 3.92) mg L^{-1} for the (RMSE), from (12.5 to 74.9) % for (PBIAS), and from (0.03 to 0.95) for (R^2) were computed for predicted and measured DO.

The maximum de-oxygenation rates were recorded at second site during August and November and after that point the re-oxygenation increased with distance, it means self-purification occurred along the river after km 3.99 at (Shakha-Sur) point. But at the end of point km 113.48 (Sndollan) the de-oxygenation rates increased in small amount compared to (Kawe) point during November Figure 3. This may be related to the agricultural activities along the river bank, sand washers activities and waste discharge with a municipal dump of Qaladza city near the river.

Table 3. Modeling parameters for the studied periods of August 2016 to May 2017.

Sites	Temp. °C	Velocity km hr^{-1}	Time days $^{-1}$	BOD_5 mg L^{-1}	*DO* initial	*DO* Deficit	*Lo*	*k1*	*k2*	*f*
August 2016										
Joga-Sur	29.2	3.13	0	2.43	5.85	1.81	2.94	0	0	0
Shakha-Sur	24.0	4.14	0.04	2.81	4.81	3.61	3.75	3.12	13.88	4.45
Qashan	31.1	3.27	0.47	2.44	6.40	1.01	2.86	0.15	0.01	0.07
Kawe	27.6	5.40	0.71	4.13	6.85	1.03	5.13	0.13	0.02	0.15
Sndollan	29.2	4.79	0.99	3.93	6.65	1.01	4.75	0.08	0.01	0.13
November 2016										
Joga-Sur	16.6	4.54	0	2.41	7.68	2.07	3.85	0	0	0
Shakha-Sur	15.2	3.15	0.05	1.66	6.54	3.50	2.75	4.16	10.32	2.48
Qashan	11.8	4.18	0.37	1.47	7.77	3.06	2.69	0.71	1.31	1.85
Kawe	14.1	5.62	0.68	2.49	8.20	2.09	4.26	0.34	0.47	1.38
Sndollan	15.5	5.04	0.94	2.41	7.57	2.41	3.96	0.23	0.41	1.78
February 2017										
Joga-Sur	7.8	11.34	0	2.60	9.46	2.44	5.40	0	0	0
Shakha-Sur	10.8	3.96	0.04	2.36	8.84	2.24	4.45	6.57	8.35	1.27
Qashan	8.6	4.39	0.35	2.16	9.30	2.37	4.37	0.87	1.06	1.22
Kawe	8.9	5.94	0.655	5.73	10.25	1.34	11.48	0.47	0.20	0.43
Sndollan	9.6	5.36	0.88	4.64	10.35	1.05	9.09	0.33	0.02	0.06
March 2017										
Joga-Sur	12.2	15.01	0	3.66	8.95	1.78	6.62	0	0	0
Shakha-Sur	12.2	5.87	0.03	3.90	8.89	1.84	7.06	9.09	9.36	1.03
Qashan	11.6	5.54	0.28	4.28	8.42	2.46	7.88	0.95	1.39	1.46
Kawe	11.2	6.41	0.60	8.00	9.25	1.73	14.92	0.45	0.40	0.89
Sndollan	10.8	5.76	0.82	7.92	9.22	1.86	14.95	0.34	0.33	0.97
April 2017										
Joga-Sur	17.9	14.62	0	5.60	8.48	1.01	8.64	0	0	0
Shakha-Sur	19.8	3.97	0.04	2.42	8.12	1.01	3.56	4.00	0.12	0.03
Qashan	18.5	4.90	0.32	6.53	8.35	1.02	9.92	0.57	0.03	0.05
Kawe	14.2	6.55	0.59	6.36	9.20	1.07	10.85	0.40	0.05	0.13
Sndollan	14.7	5.98	0.79	7.82	8.87	1.28	13.15	0.29	0.14	0.48
May 2017										
Joga-Sur	21.3	11.05	0	3.25	4.85	4.01	4.61	0	0	0
Shakha-Sur	22.2	3.60	0.05	1.69	5.19	3.52	2.35	3.09	11.84	3.83
Qashan	22.2	4.68	0.33	2.82	5.42	3.29	3.92	0.43	1.56	3.63
Kawe	17.2	6.08	0.63	2.55	5.30	4.33	4.01	0.31	1.01	3.26
Sndollan	17.5	5.51	0.86	3.14	5.24	4.33	4.89	0.22	0.74	3.36

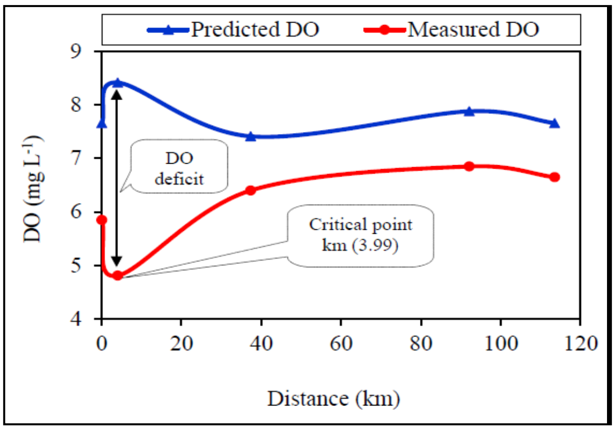

Fig. 2. Predicted and measured DO sag curve of studied River for August.

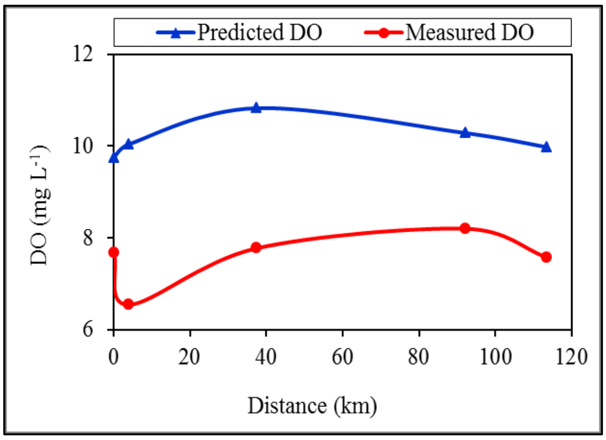

Fig. 3. Predicted and measured DO sag curve of studied River for November.

Table 4. Statistical analysis for DO at five different sites (Joga-Sur, Shakha-Sur, Qashan, Kawe, and Sndollan) during the studied months.

Month	RMSE	PBIAS	R^2
August	1.97	27.7	0.52
November	2.69	34.8	0.08
February	1.98	19.6	0.05
March	1.95	21.6	0.21
April	1.09	12.5	0.95
May	3.92	74.9	0.03

Figure 4 revealed the oxygen sag curve for the month of February. The data displayed that DO deficit had at the highest 2.44 mg L^{-1} at km 0.0 distances Table 3 when the RMSE and PBIAS were 1.98 mg L^{-1} and 19.6% respectively Table 4. In this point, the de-oxygenation rate is higher than the re-oxygenation rate. It is clear that the first point km 0.0 (Joga-Sur) on the oxygen sag curve where the oxygen deficit is higher than the other points. So, from the second point km 3.99 (Shakha-Sur) to fifth point km 113.48 (Sndollan) the re-oxygenation rate was increased. The continuous rise of DO from the lowest value denoted the capacity of the river for self-purification and lack of oxygen demanding wastes being disposed into the river during February.

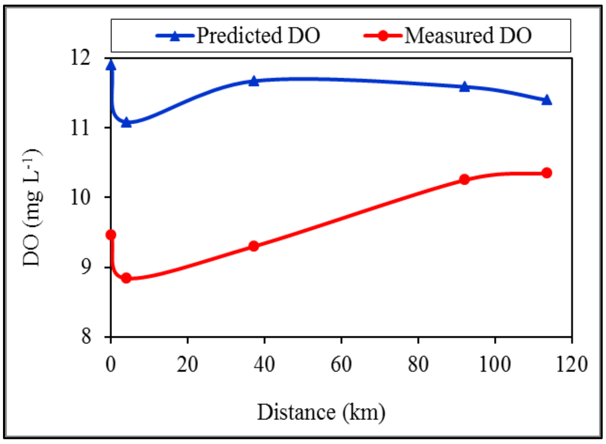

Fig. 4. Predicted and measured DO sag curve of studied River for February.

Figure 5 illustrates the oxygen sag curve. The data exhibited that DO deficit increased with distance and the lowest point of the oxygen sag curve (critical point) is at (critical distance) km 37.29 during March. This point out that the de-oxygenation rate is higher than the re-oxygenation rate then DO deficit decreased with distance, consequently after km 37.29. Therefore, the re-oxygenation rate is higher than the de-oxygenation rate. It is indicated that the maximum DO reduction occurs at km 37.29, after that point, the re-aeration increased with distance, but at the endpoint km 113.48 (Sndollan) the de-oxygenation rates increased a little compared to (Kawe) point at km 92.06, the reasons were mentioned before. Obviously natural self-purification occurred along the river after critical distance km 37.29 during March when the RMSE and PBIAS were 1.95 mg L^{-1} and 21.6% respectively Table 4.

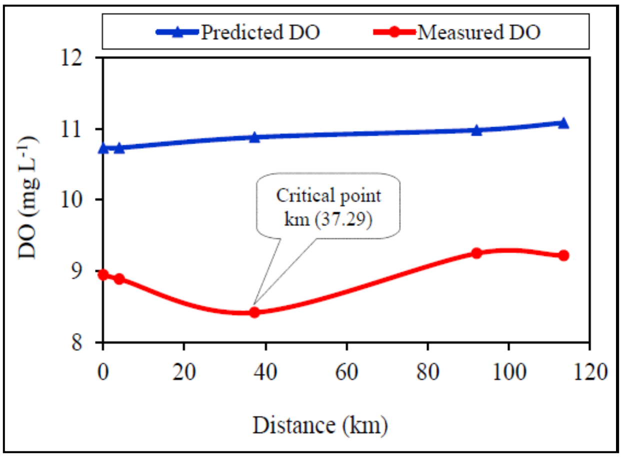

Fig. 5. Predicted and measured DO sag curve of studied River for March.

Figure 6 pointed out to the oxygen sag curve, have same trends for de-oxygenation and re-oxygenation rates, but at the fourth point (Kawe) km 92.06 with increasing distance to fifth point (Sndollan) at km 113.48 the de-oxygenation rate increased and higher than the re-oxygenation rate due to biodegradation of the organic matters in water during April and the reasons were mentioned before, when the RMSE and PBIAS between predicted and measured DO were 1.09 mg L^{-1} and 12.5% respectively Table 4.

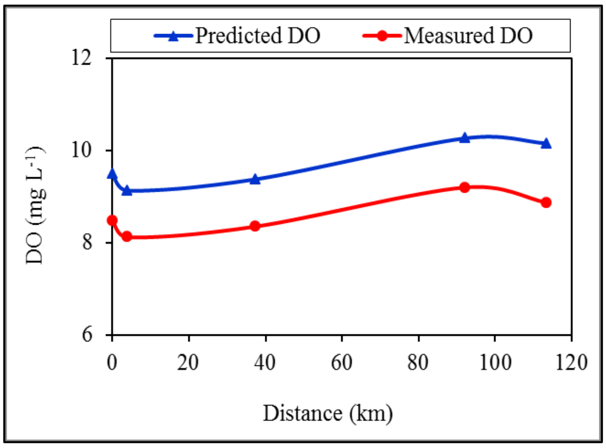

Fig. 6. Predicted and measured DO sag curve of studied River for April.

Figure 7 clarified the oxygen sag curve during the period of May. The data indicated that DO deficit decreased with distance from (0.0 to 37.29) km and DO deficit increased with distance from km (37.29 to 113.48) when the RMSE and PBIAS between predicted and measured DO were 3.92 mg L^{-1} and 74.9% respectively Table 4. It is clear that the fourth point (Kawe) and the fifth (Sndolland) on the oxygen sag curve have the oxygen deficit values higher than other points. It obviously cleared at point fourth and fifth re-aeration decreased due to increasing the waste and the decomposition and self-purifying have not occurred.

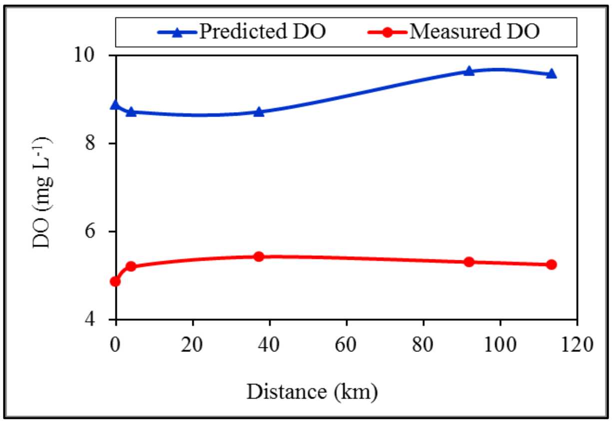

Fig. 7. Predicted and measured DO sag curve of studied River for May.

The same curves will be achieved between (predicted and measured DO) and time of travel ($days^{-1}$) was achieved between oxygen and distance as displayed before in Figure 2 to 7. From Table 3, it is fair that the natural self-purification process is time-dependent. With the development of time, the available DO has reduced with the outflow consequently a drop in DO to the critical level and then rise to the initial status of the river.

From the Table 3 and Figure 2 to 7 showed that the highest average values of DO deficit (de-oxygenation) during November (2.626) and May were (3.896), this is because of low flow river discharges, high temperature and the activity of bacteria in water and the lowest mean of DO deficit (re-oxygenation) during April was (1.078), this might be due to high dilution and low temperature. The concentration of DO is expressed as the resultant of two principal opposing progresses; (de-oxygenation and re-oxygenation).

Comparison between predicted and measured BOD

The plots of BOD versus point sites are presented in Figure 8 to 13. The BOD curves for studying river gave wavy shapes and the space between two shapes is ultimate BOD. From the Table 3 and Figure 8 to 13 it is clear that the highest ultimate BOD values were recorded at (Kawe) site during August was (5.13), November was (4.26) and February was (11.48), but during March was (14.95), April was (13.15) and May was (4.89) the highest ultimate BOD values were recorded at (Sndollan) site, when the statistical analysis between predicted and measured BOD is shown in Table 5. The minimum and maximum RMSE varied from (0.77 to 5.08) mg L^{-1}, PBIAS from (23.4 to 98.9) % and R^2 from (0.93 to 0.9) between predicted and measured BOD.

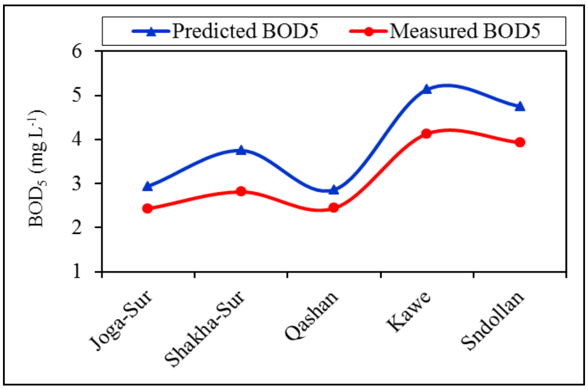

Fig. 8. Variation of BOD_5 with point sites in August.

The reason of increasing BOD with distance is associated with the inflow of the river and more pollutants in (Kawe and Sndollan) point sites comparing to the rest. This is similar to the results of (Al-Zboon and Al-Suhaili, 2009) who found that the relationship between BOD and pollutant is linear.

Table 5. Statistical analysis for BOD at five different sites (Joga-Sur, Shakha-Sur, Qashan, Kawe, and Sndollan) during the studied months.

Month	RMSE	PBIAS	R^2
August	0.77	23.4	0.97
November	1.44	67.7	0.96
February	3.74	98.9	0.99
March	5.08	85.2	0.99
April	3.76	60.5	0.98
May	1.32	46.9	0.93

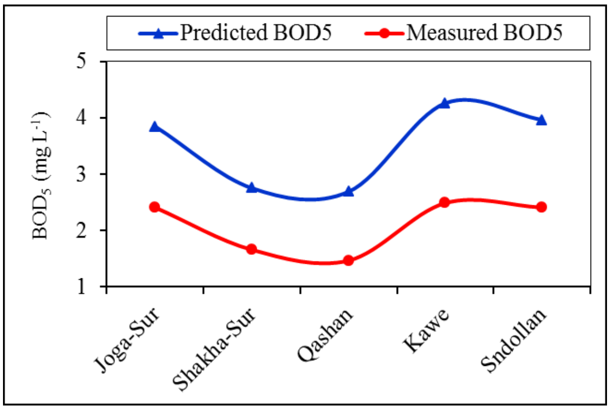

Fig. 9. Variation of BOD_5 with point sites in November.

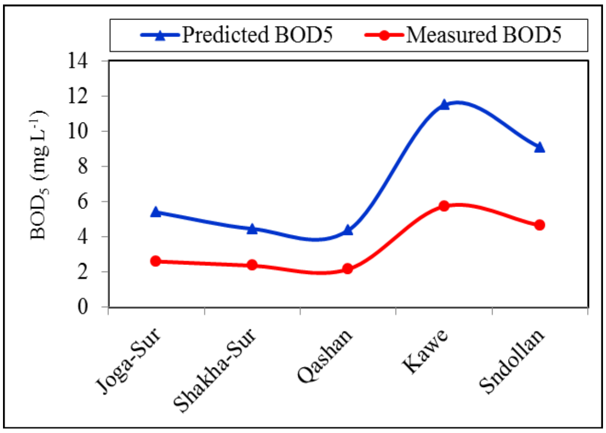

Fig. 10. Variation of BOD_5 with point sites in February.

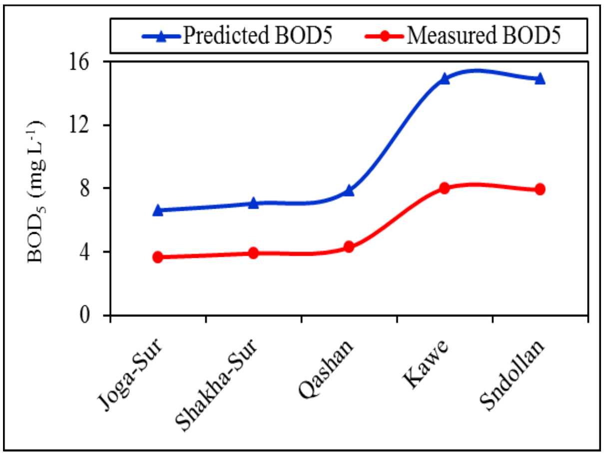

Fig. 11. Variation of BOD_5 with point sites in March.

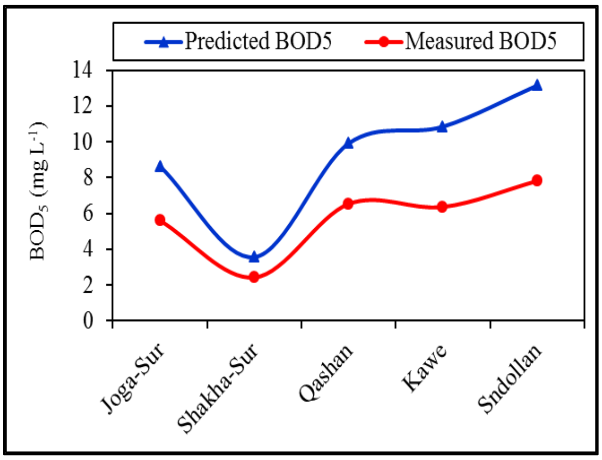

Fig. 12. Variation of BOD_5 with point sites in April.

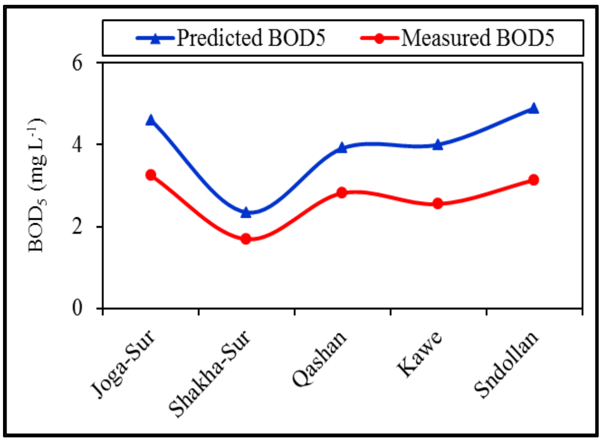

Fig. 13. Variation of BOD_5 with point sites in May.

Self-purification and fair ratio (f)

The values of re-aeration coefficients, de-oxygenation coefficients, time of travel and self-purification factors for different sites of Qalachwalan-Lesser Zab River were computed Table 3. The fair ratio (f), which is the ratio of the re-aeration coefficient ($k2$) to the de-oxygenation coefficient ($k1$), is the indices used in valuing the capacity of self-purification in this study.

The average values of (f) in all the studied months were lower than unity which means that de-aeration dominates, except November and May which fair ratio is greater than the unity which means re-aeration dominates across the studied river length (Chiejine *et al.*, 2014). The average of (f) for the months of November and May were found to be (1.50 and 2.82) respectively which higher than the other studied months. The reason for this could be related to fewer pollution activities (less DO reduction) in the month of November and May, which is suggested by the lower average BOD values generated in both studied months.

The month of April appears to be the most contaminated month since the entire calculated fair ratio values of the sampling sites were less than their unity. This result is similar to (Omole *et al.*, 2013 and Chiejine *et al.*, 2014) who discussed that when the de-oxygenation rate is greater than the re-oxygenation the fair ratio values could be less than unity. While the mean fair ratio of August (0.96) was higher than that of February (0.60) and March (0.87). This could be as a result of increases in waste disposal (high DO reduction) in these months of February and March and at some sampling sites like (Kawe and Sndollan) which have increases of the de-oxygenation rate and at last affecting the fair ratio.

Generally, the average fair ratio (f) of the studied rive areas were found to be greater than their unity during November and May which shows that, re-aeration is greater than de-oxygenation. After all, the obtained values were within the limits of self-purification capacity (0.5 to 5) according to (Garg, 2006) except those for April (0.14).

CONCLUSION

This study evaluates the self-purification for Qalachwalan-Lesser Zab River. The main results of this study are, (i) the measured DO decreased between (Joga-Sur to Shakha-Sur) and (Kawe to Sndollan), while at (Qashan) site was the values of DO increased, (ii) the strong correlation between predicted and measured DO at April was recorded, when the value of RMSE and PBIAS were low, while during the month of May the relationship was weak and the RMSE and PBIAS were high, (iii) the BOD values are varies spatially and temporary, and (iv) the average river (f) were observed to be less unity which means that the river has less self-purification ability for all months except May and November. To sum up, the river auto-purification processes are being disrupted at recurrent period by point and non-point source pollutants.

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قدرة التنقية الذاتية ومنحنى التدلى لنهر قلعة جوالان – الزاب الصغير، في محافظة السليمانية / العراق

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يستقبل نهر قلعة جولان-الزاب الصغيرأنواع مختلفة من المخلفات المنزلية والكيميائية من المناطق السكنية ومناطق الاستجمام والاراضي الزراعية الواقعة حول النهر. إن هذا احتمالية تؤثر على قدرة التنقيه الذاتية طبيعية. جمعت عينات المياه من خمس نقاط مختلفة بين مدينة قلعة جولان وقضاء قلعة دزة وقد تم تطبيق منحنى تدلى (Sag curve) لتحليل معايير جودة المياه للمدة بين آب ٢٠١٦ الى ايار ٢٠١٧. أظهرت النتائج بان قيمة الأوكسجين الذائب تراوحت بين ٤.٨١ ملغرام/لتر لشهر آب الى ١٠.٣٥ ملغرام/لتر لشهر شباط. اما قيمة الطلب الكيموحيوي للأوكسجين فتراوحت من ١.٤٧ ملغرام/لتر لشهر تشرين الثاني الى ٨ ملغرام/لتر لشهراذارعلى طول النهر. أظهرت نتائج التحليلات الاحصائية للقيم المتنبأة والقيم المقاسة لكل من الأوكسجين الذائب والطلب الكيموحيوي للأوكسجين بأن اقل قيمة لمتوسط مربع الجذر التربيعي للخطأ كانت ١.٠٩ ملغرام/لتر لشهر نيسان اما أعلى قيمة فكانت ٣.٩٢ ملغرام/لتر لشهر ايار للأوكسجين الذائب. بالنسبة لأقل قيمة للطلب الكيموحيوي للأوكسجين فكانت ٠.٧٧ ملغرام/لتر لشهر آب وأعلى قيمة كانت ٥.٠٨ ملغرام/لتر شهراذار. اما بالنسبة للقيم المتنباة المقاسة للأوكسجين الذائب بطريقة نسبة التحيز فكانت ١٢.٥ % لشهر نيسان و ٧٤.٩% لشهر أيار و بالنسبة لأقل قيمة للطلب الكيموحيوي للأوكسجين فكانت ٢٣.٤% لشهر آب و ٩٨.٩% لشهر شباط . يتراوح عامل التنقية من 0.03 الى 4.45 لجميع الفترات. أظهرت النتائج بأن النهر ملوث بصورة مؤقتة وله قابلية ضعيفة للتنقية الذاتية بالأخص خلال شهر نيسان حيث متوسط التنقية كان ٠.١٤.