Impact Of Riverfront Development On Self-Purification Capacity: A Case Study Of Devika And Tawi River

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Riverfront development is a concept booming in India and other nations that aims to harness the river for beautification and increase tourism around the river. Rivers are the primary source of fresh water for living beings, which is already scarce. Rivers have a self-purification potential because of their flow, which protects the river's water quality and ecological health. Self-purification is based on the slope of the water surface, which affects the river's velocity, enhancing the turbulence and, hence, the oxygen level in the river. The general riverfront developments worldwide flatten the water surface slope, which leads to a reduction in the river's self-purification capacity.

The study here is based on water quality test findings from the Devika River flowing in the Udhampur district of Jammu and Kashmir, which has recently witnessed riverfront development. This research studies the variation of water quality parameters with respect to the water surface slope of the river and further projects its scope to predict the water quality of Tawi River. Tests were conducted on the Tawi River, located 50 kilometers from the Devika River, and the results indicated that its current capacity for self-purification is low. The DO (Dissolved Oxygen) levels in Tawi before the riverfront development range from 4 to 6 mg/l. However, after observing the Devika River's results, this research has concluded that the Tawi River's ability to purify itself is in jeopardy.

Index Terms— Dissolved Oxygen, Self-Purification, Waterfront, Water Quality.

I. INTRODUCTION

A. Devika and Tawi Rivers

Urban planning is seeing an increase in the trend of riverfront development, particularly in India and other nations. The main objective of these efforts is to develop the riverbank area to enhance the aesthetic attractiveness of rivers and promote tourism. The main aim of the riverfront development is to improve urban areas and offer tourism options for people, but it also raises significant environmental concerns, particularly concerning the river's ecological health and water quality. Riverfront development is also taking place along the Tawi River, one of the major rivers in the Jammu region. Tawi River is the tributary of the Chenab River and passes through many areas of the Jammu division. Tawi River is the primary source of water for the entire city. The "Waddi Tawi Barrage" and the "Nikki Tawi Barrage" are being built to obstruct the river's flow while generating pondage to form the artificial Lake Tawi. This study aims to forecast how riverfront development may affect the water quality of the Tawi River in the future. Arguments are being made only after examining the effects of riverfront development on the Devika River's water quality. Devika River holds significant religious importance as it is also called the sister of The Ganga. Devika originates from Suddha Mahadev Temple in the Udhampur district of Jammu and Kashmir. It flows to Pakistan, where it merges with the Ravi River. As it flows in both base flow and surface runoff, it is also known as Gupt Ganga.

Fig. 1: - Tawi Barrage Plan [Source: Jammu Smart City Project]

Fig. 1 shows the plan for the first phase of the riverfront development, which is happening on the Tawi River. The plan shows the formation of a pond, which will be created due to the barrages that are being constructed.

B. Hydraulics of Self-Purification:

As per the Manning's formula,

$$v = \frac{1.49}{n} R^{\frac{2}{3}} S^{\frac{1}{2}} \qquad (1)$$

Where, R is the Hydraulic Radius of the channel, n is Manning's coefficient, S denotes the slope of the water surface, and v denotes the velocity of the flow (Holland, 1998).

From this, it is evident that the relationship between S and v is directly proportional. Therefore, a decline in the channel's slope results in a drop in velocity. Also, the velocity and turbulence are related. The relation between velocity and turbulence is given by the Reynolds number, which is given as

$$R_e = \frac{\rho v D}{\mu} \qquad (2)$$

Where Re is Reynolds number, ρ is the density of the fluid, v is the flow velocity, D is the depth of the channel, and μ is the fluid's Dynamic Viscosity. (Rott, 1990). Higher the Reynolds number, more is the turbulence. Theoretically, based on (eq 2), it is clear that Reynolds number (Re) is directly proportional to velocity (v).
i.e.

$$R_e \propto v \qquad (3)$$

Further studies quote that the turbulent velocity diffusion coefficient is directly proportional to the Reynolds number, as shown in Fig. 2.

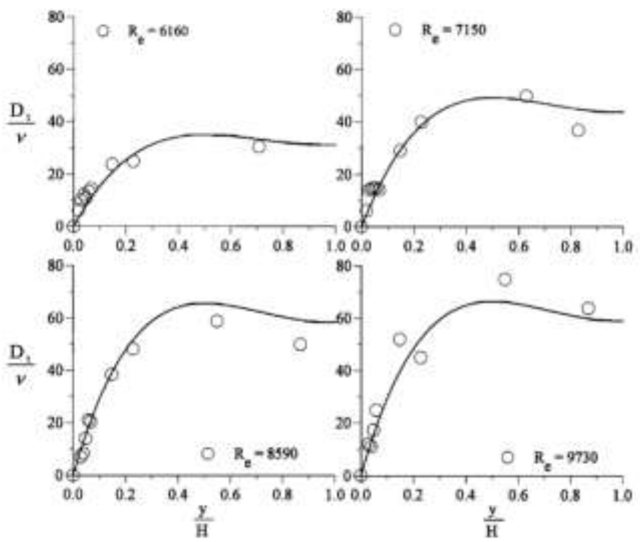

Fig. 2: Relation between Dt/v and Reynolds Number (Hondzo, 1998)

Fig. 2 shows four graphs between Dt/v and y/H for different values of Re. For a constant value of y/H, there is an increase in Dt/v with the increase in the value of Reynolds number. It is also evident that the value of Dt/v varies directly with the value of the Reynolds number for a constant value of y/H.

Therefore,

$$\frac{Dt}{v} \propto Re \qquad (4)$$

From (3) & (4),

$$\frac{D_t}{v} \propto v \qquad (5)$$

Hence,

$$D_t \propto v^2 \qquad (6)$$

Here, D_t is the Turbulent Diffusion Coefficient, defined as the amount of air diffused in water across a unit area in turbulent

conditions, which signifies the transfer of DO.

From (6), it is evident that with an increase in velocity, Dt also increases. Also, from (eq 1), it is observed that velocity varies directly with the square root of the slope of the water surface; hence, it can be said that Dt also increases with an increase in the water surface slope.

So, theoretically, the natural slope of the water surface is reduced due to riverfront development, which lowers flow velocity. This reduces the turbulence in the water, and the aeration is reduced, lowering the water body's ability to purify itself. This theory, in this paper, is supported by measuring the channel's natural slope (considered equal to the water surface slope assuming uniform flow in the natural channel), located about two kilometers upstream of the riverfront development and comparing the results to water quality measures. The unaltered natural site's slope and water quality are determined to be significantly better than those at the riverfront development location.

This study also looks at the Tawi River's current purifying ability. It was discovered that the river was underpowered, meaning that it could not restore its dissolved oxygen levels between two consecutive sewage outlets. This suggests that the river's ability to purify itself was inadequate even before the development of barrages and that it will likely continue to decline even after the completion of the riverfront development project.

II. METHODOLOGY

The tests were conducted on two rivers viz. Devika and Tawi. Two parameters were considered: "Longitudinal Slope" and "Water quality." A relation between the two is developed to show the impact of change in slope on water quality.

A. River 1: Devika river

Three samples were taken from the location of the riverfront development, which is around 200m long, and one sample was taken from a location 2 km upstream of the riverfront development, which has an undisturbed natural slope. The coordinates of the locations are as follows:

Table 1: Coordinates of sample collection from Devika River

Sample No.	Coordinates
Sample 1 (Near Riverfront)	32°55'31"N, 75°07'55"E
Sample 2 (Near Riverfront)	32°55'31"N, 75°07'52"E
Sample 3 (Near Riverfront)	32°55'30"N, 75°07'49"E
Sample 4 (Undisturbed natural slope)	32°56'32"N, 75°08'26"E

The water samples were then tested for Dissolved Oxygen (DO) levels, and their 5-day BODs were also measured. Subsequently, the water surface slopes of the given locations were measured using Auto Level and Measuring Tape.
At the location of sample 4, which depicts the undisturbed natural slope of the river, the river was completely dry, and thus, the bed slope of the river was measured.

Fig 3: Location of samples collected near Riverfront development

Fig 4: Location of samples collected near undisturbed slope

Here, the flow is assumed to be uniform; hence, the bed slope would be the same as the surface slope. The water sample collected for this point was from a well adjacent to the river bed, 4.1 m away. The Devika River flows in the base flow for most of its length, so the water collected from the well just adjacent to the river bed shows the relatable water quality of the river at the location. The test results of this sample will give the same results that would have been obtained from the river when it would have flown as surface flow in the river at the time of flood.

B. River 2: Tawi river

The self-purification capacity of the river was to be analyzed to understand the impact of riverfront development on the present water quality of the river (Mekonnen, 2024). Five water samples were collected between two consecutive sewer lines with drainage outlets in the river Tawi at a distance of about 350 m to understand the DO sag curve, and one was collected just upstream of the first sewer outlet to understand the river's natural state before discharge of waste. The location of these points is as follows:

Table 2: Coordinates of sample collection from Tawi River

Sample No.	Coordinates
Sample 1	32°46′07″N, 74°54′44″E
Sample 2	32°46′10″N, 74°54′30″E
Sample 3	32°46′18″N, 74°54′13″E
Sample 4	32°46′21″N, 74°53′59″E
Sample 5	32°46′27″N, 74°53′49″E
Sample 6	32°46′28″N, 74°53′39″E

Fig 5: Location of samples collected from Tawi River

Similar to samples collected from Devika River, the samples collected from Tawi were tested for Dissolved oxygen (DO) levels and 5-day BOD.

III. RESULTS AND DISCUSSION

A. Results from Devika River

For Devika River, three samples were collected from each of the four locations at an interval of one week, and these samples were tested for their DO (Dissolved Oxygen) and BOD5 (Biochemical oxygen demand). The water surface slopes for these locations were also measured. The mean of the test results of all four locations are as follows:

Table 3: Test results of Devika River water samples

Sample No.	DO_0 (mg/l)	DO_5 (mg/l)	BOD_5 (mg/l)	Slope
1.	5.70	3.55	2.15	1/103 or 0.97%
2.	5.65	3.75	1.90	1/130 or 0.77%
3.	5.60	3.60	2.00	1/130 or 0.77%
4.	7.80	6.95	0.85	1/9 or 11.25%

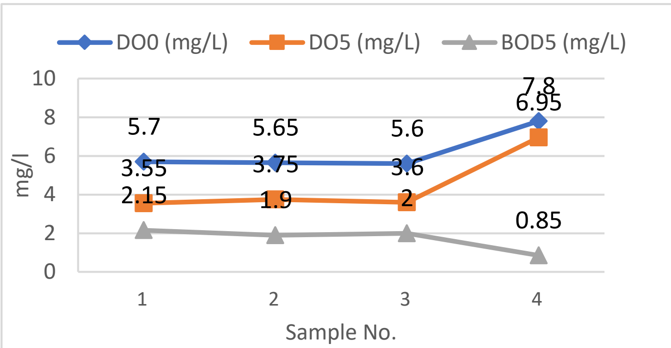

Fig 6: Graph showing Devika River's water quality parameters

From the above results, it is evident that for the sample collected from the undisturbed section of the river having a higher slope, the DO value is much higher than the DO levels of samples collected from locations near the riverfront development having a much-flattened slope. Also, the BOD for the water sample from the undisturbed section is lower than that of the samples collected near the riverfront development. From this, it can be concluded that the steeper the slope, the better are the water quality parameters.

B. Results from Tawi River

Tawi River was inspected for DO (Dissolved oxygen) and BOD5 (Biochemical oxygen demand), and the water surface

slope was also measured. DO levels were taken between two consecutive sewer outlets from six locations at an interval of one week, and for each location, three samples were collected, the mean of which is shown in the table below:

Table 4: Test Results of Tawi River water samples

Sample No.	DO_0 (mg/l)	DO_5 (mg/l)	BOD_5 (mg/l)	Slope
1.	5.55	4.50	1.05	1/150 or 0.66%
2.	5.05	3.85	1.20	1/200 or 0.50%
3.	4.75	3.10	1.65	1/150 or 0.66%
4.	4.65	2.95	1.70	1/100 or 1%
5.	4.80	3.20	1.60	1/120 or 0.83%
6.	4.90	3.35	1.55	1/350 or 0.28%

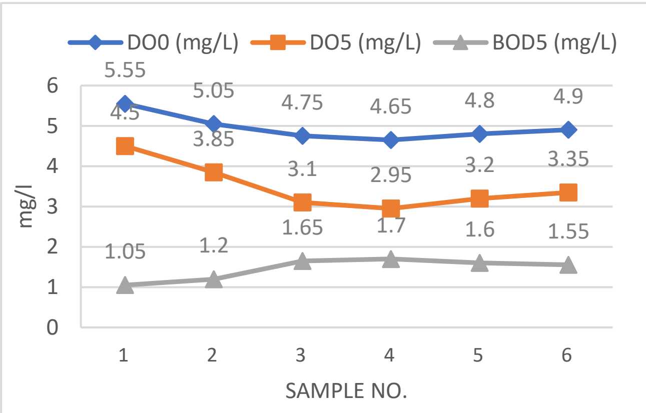

Fig 7: Graph showing Tawi River's water quality parameters

From the above graph, it is clear that the river is unable to replenish its Dissolved oxygen levels between the two outlets even in natural conditions, which tells us that the current condition of the river is not good, having lower self-purification capacity than required due to insufficient slope of the river which once the riverfront is completed is expected to be worsened due to the backwater curve.

IV. CONCLUSION

This research has concluded that slope plays a significant role in the self-purification capacity of the river. The steeper the slope, the better the water quality parameters are and vice versa. In this research, two rivers, Devika and Tawi were studied.

Devika River was studied to learn about the after-effects of riverfront development on the water quality parameters, and the results obtained were compared with the water quality of natural conditions. The results concluded that due to an alteration in slope near the riverfront development, the river's velocity is significantly reduced, which in turn reduces the river's water quality and self-purification capacity.

Tawi River was studied for its current self-purification capacity under natural/undisturbed conditions, which was found to be poor as the water surface slope is insufficient. After studying the effects of slope flattening of Devika, it is expected that if a barrage is developed on the Tawi River, it will flatten the water surface slope due to the backwater curve that may

extend throughout the Jammu region. This will affect the water quality of the river as it would further reduce the self-purification capacity and DO of the river, and if the DO of the river falls below 4mg/l, the aquatic life within the river would not have sufficient oxygen for survival.
Also, the primary purpose of a riverfront development is to beautify the river by creating pondage and increasing its aesthetic appeal, but on a river like Tawi, whose slope and DO levels are already not sufficient, doing so in the form of a barrage would result in the stagnation of water which would result in degradation of water quality and the pondage created would not be beautiful but unappealing defeating the primary purpose for which the barrage is being developed.

V. RECOMMENDATIONS

The Devika River requires slope correction. The slope must be increased, or the artificial turbulence must be generated.

In the Tawi River, since the condition of the river is expected to deteriorate, some remedial measures should be adopted. A few measures could be the installation of artificial aerators and fountains throughout the backwater curve of the reservoir. These systems can be solar-powered to make the technology more sustainable. Also, Jammu city lacks sewage treatment plants. The construction of sewage treatment plants is also recommended.

Adapting these measures would not only result in the betterment of water quality but would also increase the aesthetic appeal of the riverfront.

VI. REFERENCES

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