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Correlating the Ganga River BOD and k, the BOD-Rate Constant

Devendra Swaroop Bhargava[*]

Department of Environmental Engineering and Pollution Control, Asian Institute of Technology, Roorkee University, UttaraKhand, India

[*]**Corresponding author:** Devendra Swaroop Bhargava, Department of Environmental Engineering and Pollution Control, Asian Institute of Technology, Roorkee University, UttaraKhand, India, Tel: +91-9412074331; E-mail: dsbhargava@yahoo.co.in

Abstract

Ganga River of India had an age-old reputation of being the most self-purified river whose waters neither putrefy despite long storages in air-tight containers nor cause any water-borne diseases despite its direct inhalation during huge religious gatherings at mass-bathing by millions at a time. These and many other aspects were investigated and the assimilation of biochemical oxygen demand (BOD), a parameter denoting the organic-related pollution status of waters, was comprehensively investigated and published in its varying forms/aspects, many for the first time, by the author. This presentation focuses, also for the first time, on correlating the river's initial BOD with the rate constant of BOD assimilation in the Ganga and Yamuna Rivers whose evaluations were no easy jobs.

Keywords: Ganga; Yamuna; Biochemical oxygen demand; Water-borne diseases

Introduction

The dissolved biochemical oxygen demand (BOD) in a river gets assimilated in an exponential manner such that at any time t, S (the BOD remaining after time t) equals the initial BOD (S_0) multiplied by e^{-kt}, where, k represents the BOD-rate constant which decides/controls the rate at which the river's BOD gets assimilated along the river course. The time is easily related to the distance along the river, if the average river velocity is known or determined. This kinetic coefficient 'k' depends on temperature, nature of BOD-causing material, presence of other oxygen-consuming material such as benthos, organisms, etc. in the river, river velocity and river configurations, amount of BOD-causing material, river's re-aeration abilities, presence of toxicants having adverse impact on the aerobes, and many other factors to a lesser or greater extent.

Streeter and Phelps [1] models, which do not take account of the settleable BOD which gets removed as the river flows downstream, have been in constant and universal use for predicting the BOD in streams. Theoretically rational and more scientifically valid models were evolved, for the first time by the author [2-8] which took account/cognition of the settleable as well as the non-settleable parts of the river BOD such that after a certain distance, when the settleable part of the river BOD is more or less removed, the model for BOD assimilation becomes similar to the stated Streeter-Phelps models. However, the author's evaluated/determined [2-8] values of the BOD rate-constant (k) in the Ganga and Yamuna Rivers of India were not only very widely and significantly different from those reported by Streeter-Phelps [1] in the Ohio River, but even varied in the various stretches of the stated Rivers. These already widely published data of the author is also used herein to establish some newer and more significant possible correlation(s).

Methodology

The author's data [2-8] is summarized below wherein k in day^{-1} and S_{0-y} mg/l, respectively represent the BOD rate-constant and the dissolved part of the initial river BOD (Table 1).

River	Location	Season	k	S_{0-y}
Ganga	Kanpur	Summer	3.5	12
Ganga	Kanpur	Winter	5.6	8
Yamuna	Delhi	Winter	1.4	25

Table 1: A Regression of the data yielded a relationship, k=9.8335e$^{-0.0788X}$, where X represents S_{0-y}.

Thus, manifesting that a lower S_{0-y} (initial BOD) means a higher k (meaning higher BOD assimilation rate), as also more of reaeration and thus more D

In other words, a less polluted river (lower S_{0-y}) would also have a higher BOD rate-constant or a faster assimilation of the river BOD. This relationship, however would have different constants/exponents/etc. for the different rivers, different stretches of the same river and in different seasons of the same river. This exponential form of the model also manifests that even for an extremely high initial river BOD, there will be some (though very small) value of 'k', that is, some assimilation of the river BOD, while for an extremely low initial river BOD, the BOD assimilation, as expected, would be at very high rate as also there will be big amounts of oxygen available for higher BOD assimilations.

Discussion

In continuation and context of the evolution of the above presented newer relationship for the 'k' value, in comparison to the Ohio River (for which 'k' was reported to be around 0.23), the extremely high, 10 to 25 times, increase in the self-purification abilities of the Ganga River (for which 'k' was reported to be around 2.5-5.6) is due to several reasons [2-8] including the following as their possible logics :

1. A very significant linear removal of the river's settleable BOD was discovered for the first time by the author, for the Ganga and Yamuna Rivers, and this phenomenon was included by the author in his BOD assimilation models [2-8] which obviously replace the age-old Streeter-Phelps [1] models used since 1925. Exocellular polymers excreted by the bacteria during their endogenous phase act as excellent coagulants [9] and with sufficient "mean velocity gradient" (G) available in the Ganga River, the colloidal part of the river BOD flocculates to also become settleable and removed from the river.

2. The rate-constant (k) for the exponential removal of the dissolved BOD was determined to be 10 to 25 times more in the Ganga River (compared to the Ohio and other Rivers) possibly due to the presence of better adapted microorganisms available in the Ganga River for the high rate BOD assimilation

3. The Ganga River was also observed to have a much higher rate of re-aeration than Ohio or other rivers mainly due to a very swift flow-rate, river-configurations, high width to depth ratio in the Ganga, etc., thus ability of the Ganga river in providing oxygen, the major BOD assimilation rate-limiting factor, at the needed rates which also prevents anoxic conditions in the Ganga River.

4. More favorable environmental factors and conditions in the Ganga River

5. The Ganga River water is well tested and established for its non-putrefying character despite its very long storage in air-tight containers, and for not causing any water-borne diseases despite mass-bathing in the River and also "aachman" (a religious rite to directly inhale the river waters despite the pollution status of the Ganga River) which are due to some volatile disinfecting [10] material's presence in the Ganga River's bed [11]. The water putrefying anaerobes, similar to pathogens in morphology, thus, also do not survive in the Ganga River waters. Hankin [10] too had reported non-survival of cholera 'vibrios' in the Ganga River and that the river looses this property after its waters are boiled [10], as also the Ganga river acquires [11] this property despite having run dry in-between Haridwar and Aligarh for several weeks when the downstream Ganga river regenerates with infiltration of ground waters and the inflows brought into the Ganga river from the small tributaries. The Ganga River thus, caused no water-borne epidemics due to its being anti-pathogenic and also due to acquired immunity in Indians right from their childhood.

Conclusion

The BOD rate constant of rivers are not very convenient to determine under the varying river conditions as also the numerous related parameters vary greatly from river to river, different stretches of the same river, time of the year, widely varying river configurations, environmental parameters, etc. Many such studies were carried out by the author and some aspects were already published for the first time. One of the many important aspects, the prediction of the river's BOD assimilation rate constant was not thus far correlated with the river's pollution status and this has been attempted herein for the first time and would be useful for other rivers too after some experimentation in the desired river.

Acknowledgement

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