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**Research Article**

# Water Quality Modelling of Major Drains of Patna, India by using Bioremediation to Attain Sustainable Goals for River Ganga

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**ABSTRACT**

Since 1990s, the major water polluting drains discharging to the River Ganga at Patna, Bihar, India have polluted and infected the river Ganga significantly. The possible addition of bioremediation and aeration at different reaches of wastewater drains is essential to attain sustainable goals (ASG) at the confluence of river Ganga with wastewater drains.

In order to evaluate the effects of possible bioremediation and aeration measures on DO, BOD, COD, Faecal coliform and total Coliform, a simple first-order faecal coliform decay model and chemical mass balance models have been added to the continuous-simulation flow-water quality model based on St. Vanant Equation. A modified concept of model parameter estimation based on natural drain discharge data has been used and applied to the model. The first order decay rate k was estimated for every reach of the of the major Rajapur drain. A total of 144 samples have been collected during April-June during the year 2022 at 15 days interval from Rajapur drain (a) at initial condition of wastewater without any prior treatment, (b) after use of aerators for reaeration, (c) after use of a biological product for bioremediation, and (d) after use of biological product for bioremediation and aerators for reaeration.

**Keywords:** Water Quality Modelling, Bioremediation, Sustainable Goals, River Ganga

## INTRODUCTION

In urban cities of India, a large amount of wastewater is produced and discharged to the rivers without prior treatment. Almost 80% of water supply goes back into the ecosystem as wastewater (Kramer et al., 2022). Due to concentric development of the cities like Patna in Bihar, India and increased floating populations, the magnitude of the pollutant concentration in wastewater is found to be very high in municipal drains (Kaur et al., 2012; Singh and Jha, 2021; Singh and Jha, 2022). Moreover, it is found that the sewage water is being discharged into the river Ganga at Patna, Bihar without proper prior treatment. The contaminated systems are causing impacts on human health, microorganisms, aquatic life, flora and fauna and health of ecosystem (Batayneh, 2012). It is to be noted that in the interest of public hygiene, public health and national economy, the municipal waste water, sewage water and industrial waste water are essentially required to be disposed-off properly only after treatment.

In general, the in-situ remediation techniques involve the treatment of sewage in the flowing drains by physio-chemical and biological treatment processes. In-situ remediation requires less space, low energy consumption and are easier to construct, work, and accomplish in comparison to conventional methods. As a result, it reduces BOD, TC and FC and increases DO concentration significantly.

In physical process screening, sedimentation, and aeration is done. In chemical process flocculation is done and in biological process (a) Green Bridge Technology (GBT), (b) Microbial Dosing (MD), (c) Soil

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Scape Filter Technology (SSFT), and (d)Floating Islands Technology (FIT) is done in recent years (U.S. EPA, 2000; Lopez et al., 2006; Joshi and Joshi, 2008; Joshi and Patil, 2018; Cyprowski et al., 2018; Su et al., 2019; Bi et al., 2019; Shahid et al., 2020a; Selvaraj and Velvizhi, 2021).

Microbial remediation of pollutants is one of the important in-situ methods of pollutant removal. It involves the use of microorganisms to (i) degrade pollutants completely into water and releases carbon dioxide in case of organic pollutants, or (ii) degrade into less toxic forms. (Tekere, M., 2019). The bioremediation is an option that offers the possibility to destroy or render harmless various contaminants using natural biological activity (Tomar et al., 2022). As such, it uses relatively low cost, low technology techniques which generally have a high public acceptance and can often be carried out at site (Vidali, 2001). Bioremediation stimulates the growth of certain microbes that use contaminants as a source of food and energy (EPA, 2012).

Kensa (2011) states that bioremediation may be any process that uses microorganisms, fungi, green plants or their enzymes to return the natural environment altered by contaminants to its original condition. By definition, bioremediation is the use of living organisms, primarily microorganisms, to degrade the environmental contaminants into less toxic forms, it uses naturally occurring bacteria and fungi or plants (Rani et al., 2007) to degrade or to detoxify substances hazardous to human health, aquatic and terrestrial life and/or environment.

In the bioremediation process, specific waste-treating microbes (bacteria, fungi etc.) are injected periodically or continuously to treat the wastewater in the drains (Jain et al., 2013). The efficiency of bioremediation depends on the characteristics of wastewater; the microorganisms and the products used, the rate of dosing, the time required for Colony formation, the amount and frequency of microbial dosing; retention time in the drain before its discharge to the river. Dosing is generally the process of feeding microbes or biomass in small amounts. In microbial bioremediation system, a natural consortium of microbes (group of microbes having different potential to remove different water quality variables) within the drain or an engineered treatment system are used (Coelho et al., 2015; Shan et al., 2009). Due to the inherently slow nature of the process, good performance will occur over a longer period of time. The slow process allows wastewater to come into maximum contact with attached and suspended microbes in the drain to degrade large amounts of organic matter. Interventions are sometimes necessary to slow down the flow rate in drains (Firmino et al., 2015; Karimi et al., 2015). For bioremediation treatment in the drain, bio-sludge generated over the time has to be removed periodically in order to avoid clogging of the drains (Sheng et al., 2012). The Bioremediation done with number of different technologies for the treatment of polluted water is as given below (Figure 3):

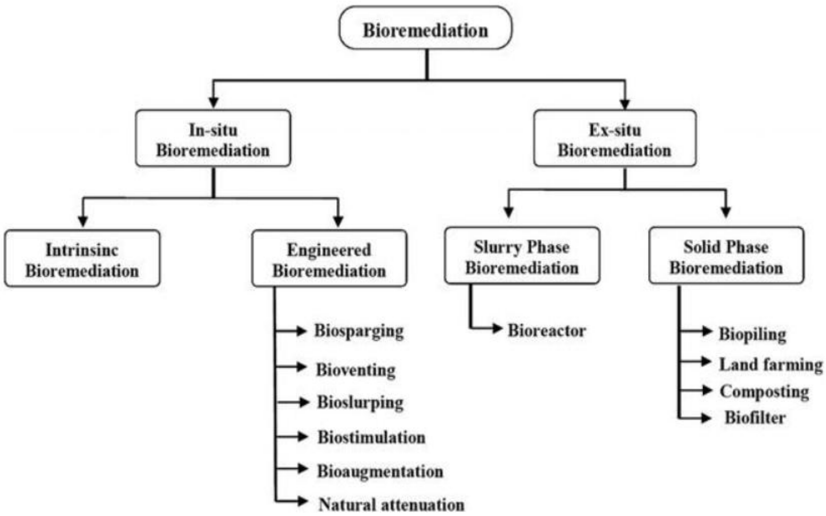


**Figure 3:** Methods used as bioremediation for pollution removal from wastewater

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In the literature, most of the works on Bioremediation is done in laboratory scale only (Monica et al., 2011), ETPs/STPs (Ahluwalia and Goyal, 2007; Jain, 2006; Singh et al., 2010), or land and ground water (Mani and Kumar, 2013; Chakraborty et al., 2012; Chatterjee et al., 2012; Achal et al., 2012b). Similar views are expressed in MoEF, Govt. of India Report (2011) and Mandal et al. (2012). Now, there is an urgent need to develop techno-economical solutions for revival of such dead rivers to meet growing demands of water and for the survival of mankind in future. Keeping this in view, one biological product for bioremediation has been tested for its applicability in water quality improvement in Rajapur drain, Mandiri drain and Badshahi Nala in Patna Bihar. In addition, the reaeration process is also applied using aerators with and without using biological products for bioremediation process.

## THE STUDY AREA AND DATA COLLECTION

Patna is an ancient city that sprawls along the south bank of the Ganges River in Bihar, northeast India (Figure 1). Patna, the "capital city of Bihar State" situated 15 km along the confluence of the River Ganges. It lies mid-way between the humid West Bengal in the east and the sub humid west which provides it with a transitional position in respect of climate, economy and culture. city is situated on the Ganga's south bank and serves as a key administrative and educational hub. The Ganga, Sone, and Punpun rivers covers the city on three sides, creating a lengthy river line. The river Gandak runs into the Ganga, making it a unique location to the north of Patna, with four large rivers in its area. The total area of Patna is 250 $km^2$ in which the municipal area constitutes 109.218 $km^2$ and the suburban area covers 140.782 $km^2$. Patna city is governed by Municipal Corporation which comes under Patna Metropolitan Region. The current estimate population of Patna city in 2023 is 2,321,000, while Patna metro population is estimated at 2,824,000. The process of reaeration and dosing of biological microbes for one drain is shown in Figure 2.

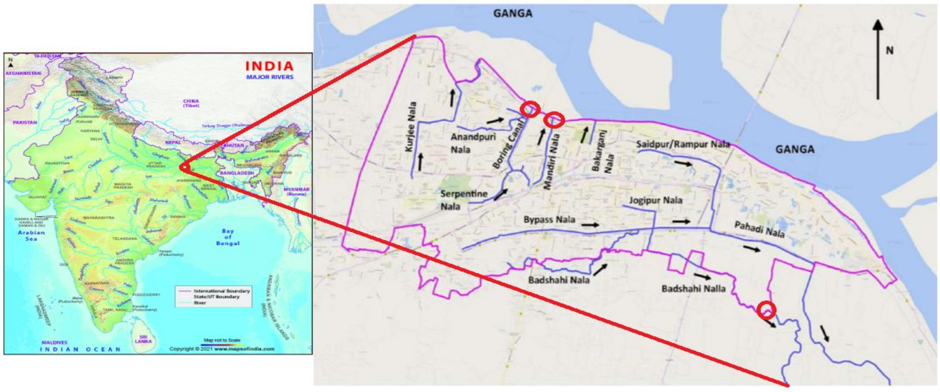


**Figure 1:** The study area and location of three drains considered in the present work


**Figure 2:** Reaeration and biological product dosing at initial point of Rajapur drain

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For the analysis and water quality modelling samples were collected from 6 locations of each drain at a distance of 100m, 250m, 500m, 1000m, 1500m and 2000m at an interval of 15 days during April, May and June months of the year 2022. A total of 432 samples have been collected from all the drains for (a) initial condition, (b) with reaeration, (c) with bioremediation, and (d) with bioremediation and reaeration both.

The following sampling procedure was adopted as per APHA ($24^{th}$ Edition, year 2022). The sampling was done on bi-monthly basis (15 days interval) from 6 locations of Rajapur drain. Grab sampling method was applied for collecting the samples. Samples were collected from each drain at a depth of ~0.5 m in Teflon bottles of 2L. The samples were transported and stored at 4 °C until analysis.

The samples for dissolved oxygen (DO) analysis were collected in BOD bottles and fixed onsite. The samples for metal analysis were preserved by acidifying with concentrated HNO3 to pH <2. Winkler-Azide method was used for Dissolved Oxygen analysis.To reduce the biogeochemical alterations as per standard procedure water samples were stored and preserved without delay inside acid-cleaned polypropylene bottles during frozen state using transportable ice box. While in-situ tests are by and large performed with a solitary or a joined meter brought down into the water for an estimation, the samples were taken for later investigation. The samples were taken from each sample station and placed in a labelled container. The samples were then blended to homogeneity after arriving at (Environmental Lab of NIT Patna), and aliquot part taken for laboratory analysis on the remaining physical and organic parameters.

## METHODOLOGY

### 3.1 Development of colonies of microbial consortium

The microbial consortium of the biological product PRIJOT has been used to reduce the concentrations of organic pollutants in water bodies. In the present work, the microbial consortium of the biological product PRIJOT was activated in 24 hrs retention time and dosing was done solutions to treat the domestic and industrial wastewater by microbial population. The dormant culture of biological product was opened and activated by taking 10 L of dormant culture, 50g of micro-nutrient and 1000 litre of filtered drain water in a PVC Drum. The rate of dosing was kept as 500 litres per day and it was done through an e-micro-acti-dozer (mechanical dosing), through PVC tanks (for gravity dosing) 24 hourly. The same process was repeated to take observations every day.

### 3.2 Mass Balance Model (MBM)

The concept of conservation of mass is useful for inorganic pollutant modelling in rivers such as Ca, Mg Fe, Ne, Cr, Zn, Pb etc. models The Mass Balance Model (MBM) is based on conservation of Mass and can be written as

$$Q_2C_2 = Q_1C_1 + \sum_{i=1}^{n} L_i \quad (1)$$

where $Q_1$ and $Q_2$ are upstream and downstream flow, $C_1$ and $C_2$ are upstream and downstream concentrations, and $\sum_{i=1}^{n} L_i$ is the sum of individual loading including effect of any loss or generation within the water body.

### 3.3 First-order Decay Model (FDM)

In many modelling cases, the use of a simple model such as First-order Decay Model (FDM) is justified by the fact that the uncertainty in the input loads is considerably high. The distributed models with detailed kinetic structure are found to be impractical for BOD-DO Modelling and Coliform Modelling. The governing equations used for FDM Model can be written as:

$$Q_{2n}C_{2n} = (Q_1C_1)e^{-kt_1} + Q_{npn}C_{npn} \quad (2)$$

In equation (2), the overall net loss rate *k (deoxygenation rate constant)* is used as a measure of DO, BO, and Coliform at any downstream location. Here $t_1$ is the travel time in days between two reaches.

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**Research Article**

The law of superposition will act if influx of pollution is from multiple sources. In the present case of major drains, it is not considered so. Equation (2) describes the local behaviour of the pollutant concentration reduction.

Now the global behaviour of the pollution in major drains cand be obtained by integral equation. The integral equations can be used to model the spread of pollutants in major drains, considering factors like flow velocity, dispersion, and decay. The generalised form of integral equation can be written as

$$Total\ Pollution\ load = \int_0^t \ [(C_1 Q_1)e^{-kt_n} + (C_{npx}\, Q_{npx})]e^{-kt_n} dt \tag{3}$$

By solving equation (3), we get

$$Total\ Pollution\ load = [-(C_1 Q_1)\frac{e^{-kt_n}}{k}]_0^t + [-(C_{npx}\, Q_{npx})\frac{e^{-kt_n}}{k}]_0^t + C \tag{4}$$

where C is to constant of integration. Now, by substituting values of t we get

$$Total\ Pollution\ load = \frac{1}{k} * [(C_1 Q_1) - (C_1 Q_1)e^{-kt_n}] +$$

$$\frac{1}{k} * [(C_{npx}\, Q_{npx}) - (C_{npx}\, Q_{npx})e^{-kt_n}] + C \tag{5}$$

For “k=1” Equation (2) and Equation (5) mare same. If value of “k” is less than 1.0, the integral effect (global effect) would be higher than the differential effect (local effect).

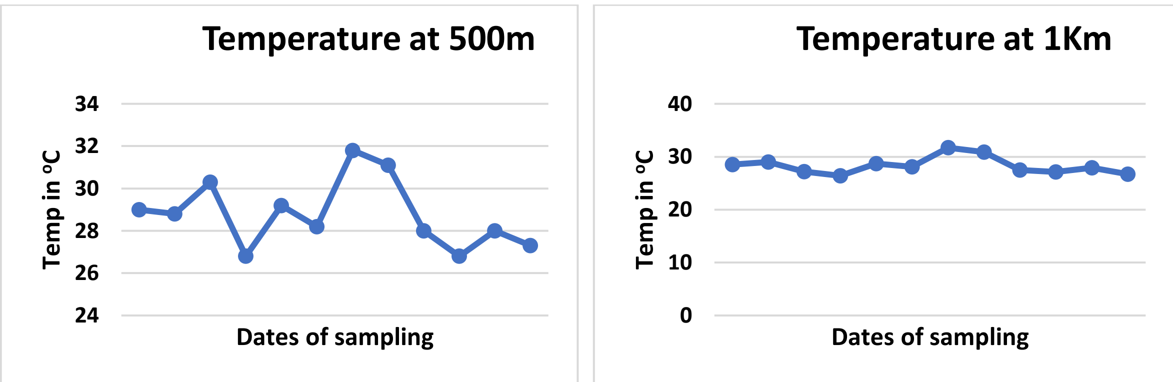
The travel time is the distance between two computational nodes divided by the mean of the velocities at these nodes. The travel time between every two consecutive locations is summed from intervening computational elements. A mean value of the deoxygenation decay rate “$k$” was computed

for every section by:

$$k = \frac{ln\,(\frac{(C_1}{(C_t})}{t} \tag{6}$$

## RESULTS AND DISCUSSION

The results obtained using equation (1) are given below (Figure 3).



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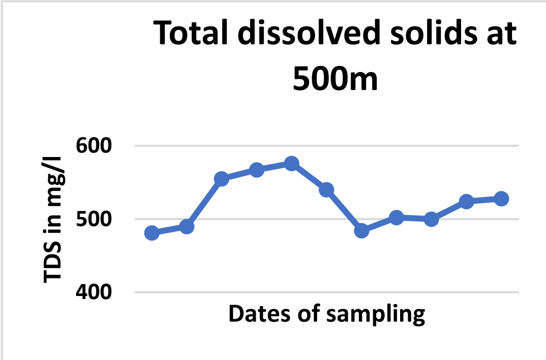


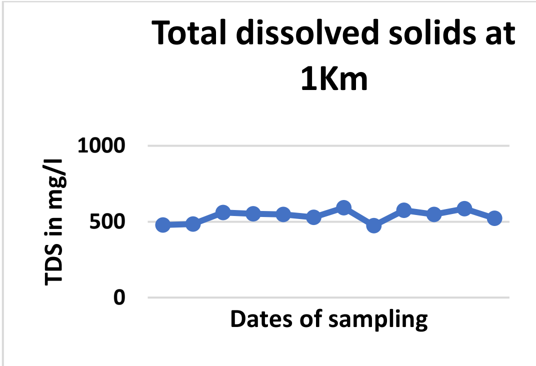


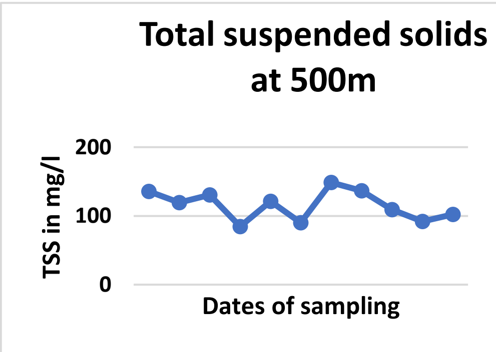


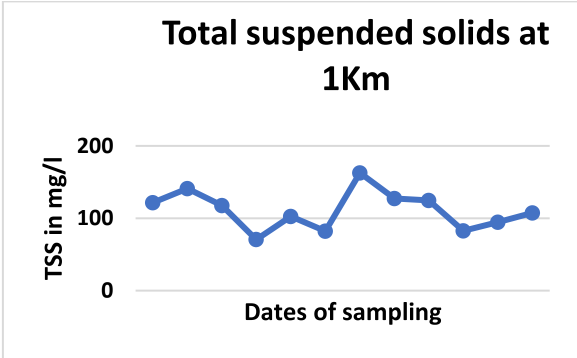


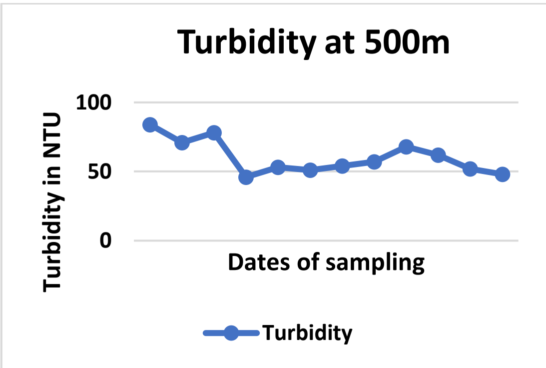


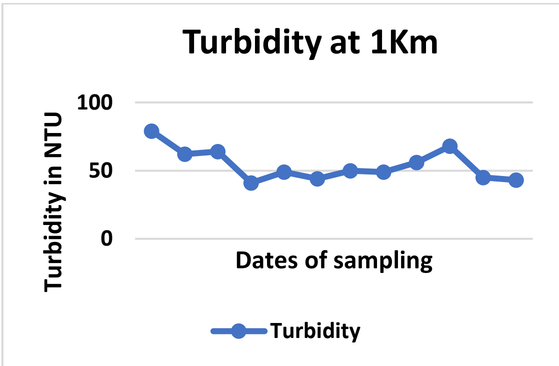


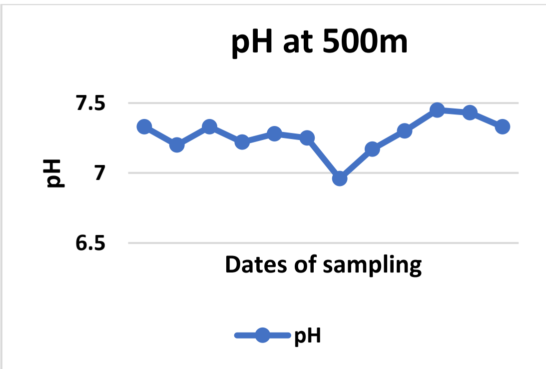


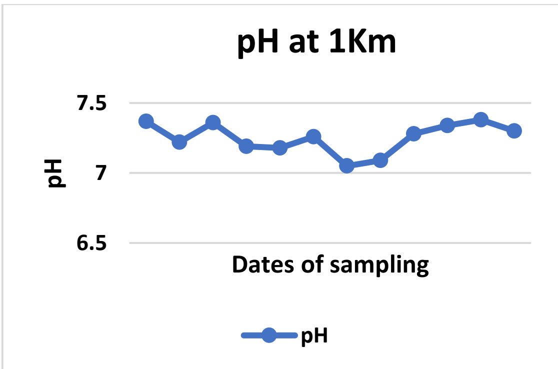

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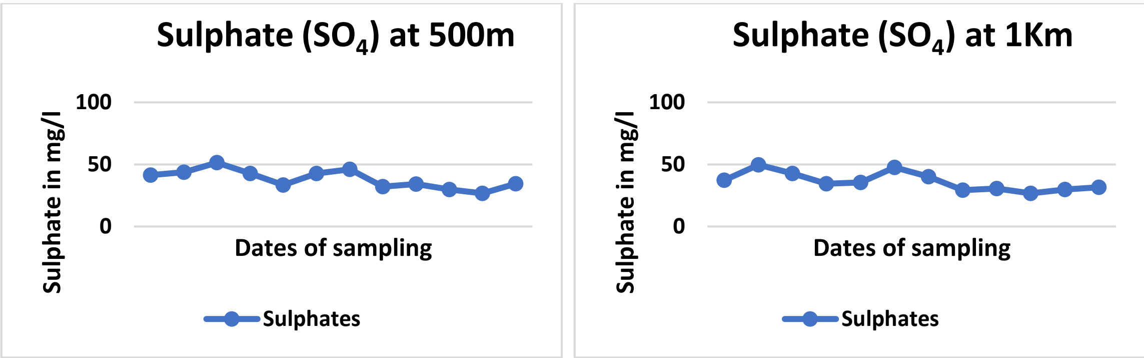



**Figure 3:** The results obtained using MBM

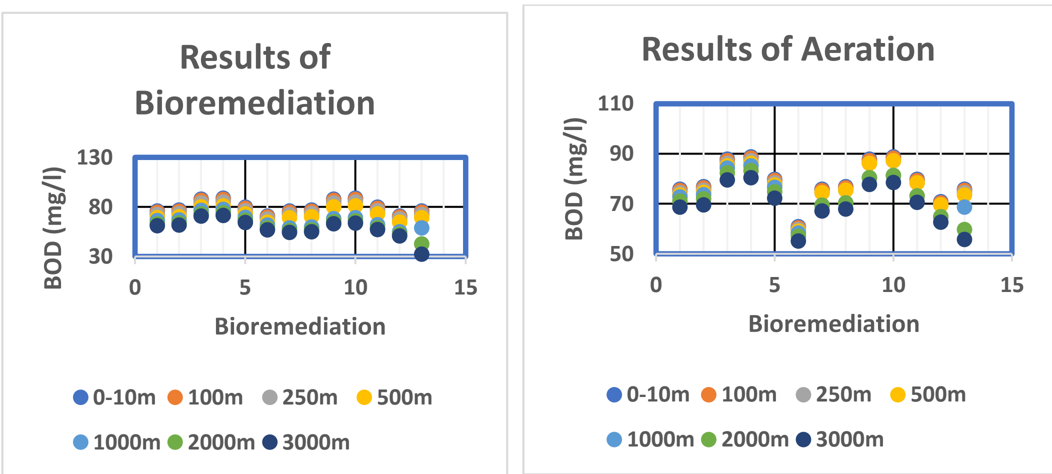
In general, it is observed that the inorganic matter follows conservation of mass. However, due to variation in boundary conditions, the influx of non-point pollution, the fluctuations are observed.

Equations (2) to (5) have been used to look for the impact of bioremediation, aeration and their different combinations. The values of "k" for different condition have been estimated using equation (6). It ranges between 0.5 to 11 at different locations of the Rajapur drain for different treatment conditions. The sludge formation, pathogens and its settlement help in improving "k" values.

Figure 4 shown the variation and improvement in BOD water quality of the Rajapur drain after 1000 m until 3000 m. The best results are obtained when aeration and bioremediation are done at 3 locations i.e. 0.0-10.0 m, 1000m, and 2000m.

Similarly DO plots show improvement when Aeration and Bioremediation are used with different combinations. It is found that the DO values do not improve significantly when bioremediation is done. IT is more prominent with aeration process to improve DO values. Figure 5 illustration DO values for different flow condition.

The Faecal Coliform and Total Coliform also follow the first order decay and "k" is similar to the results obtained for BOD values. Figure 6 and 7 shows the plots of Faecal and Total Coliform for different combinations of aeration and bioremediation.



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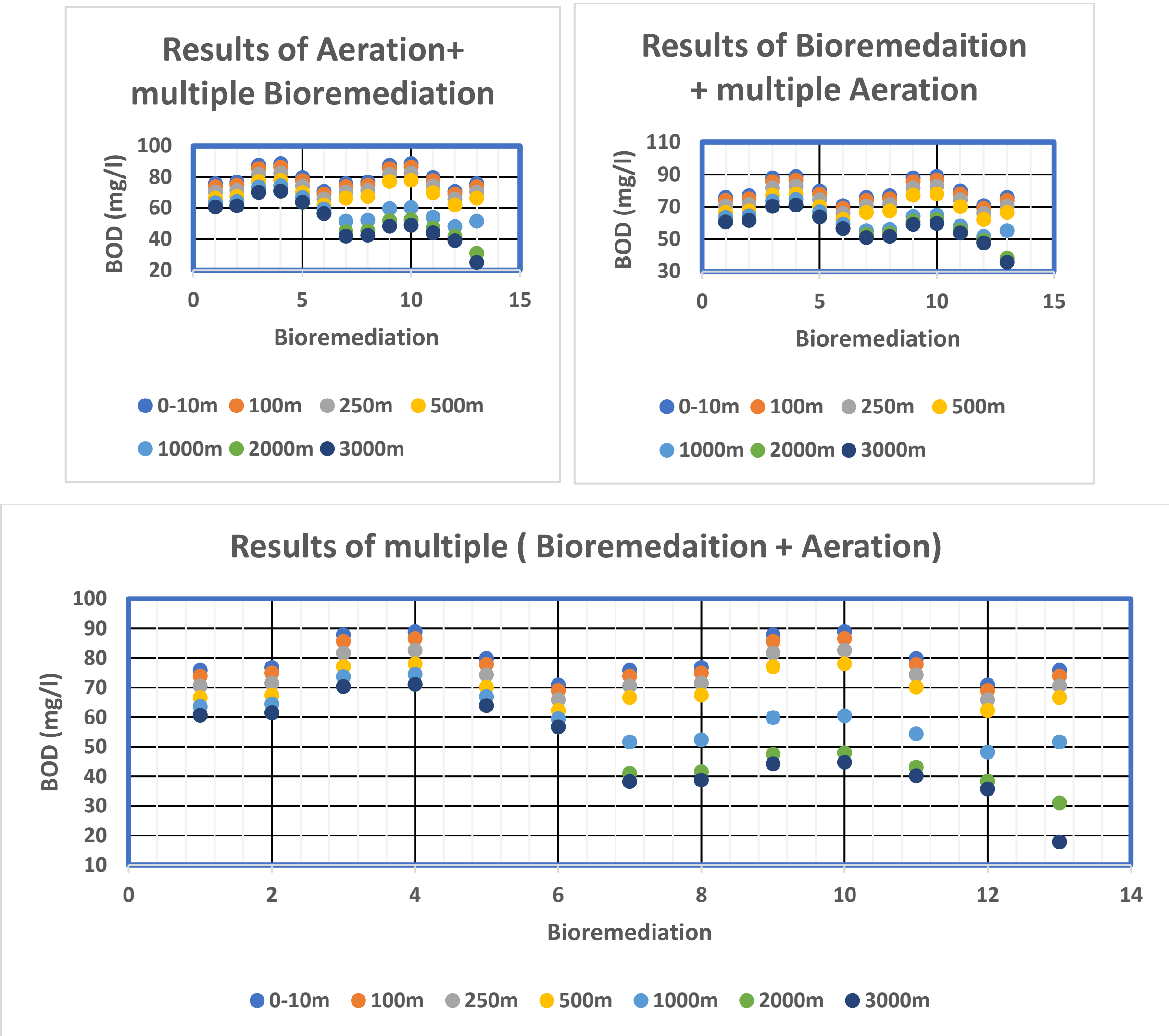
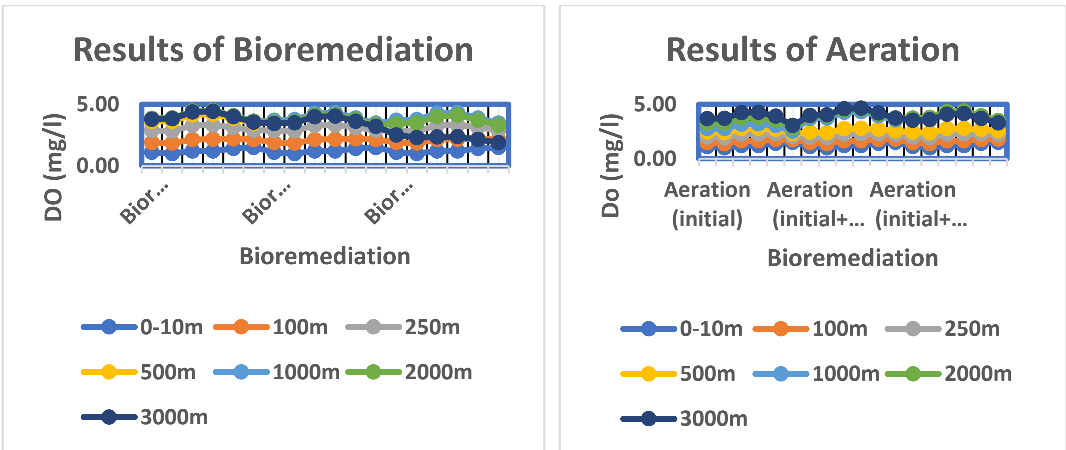



**Figure 4:** BOD Variation at different locations (up to down) for different combinations



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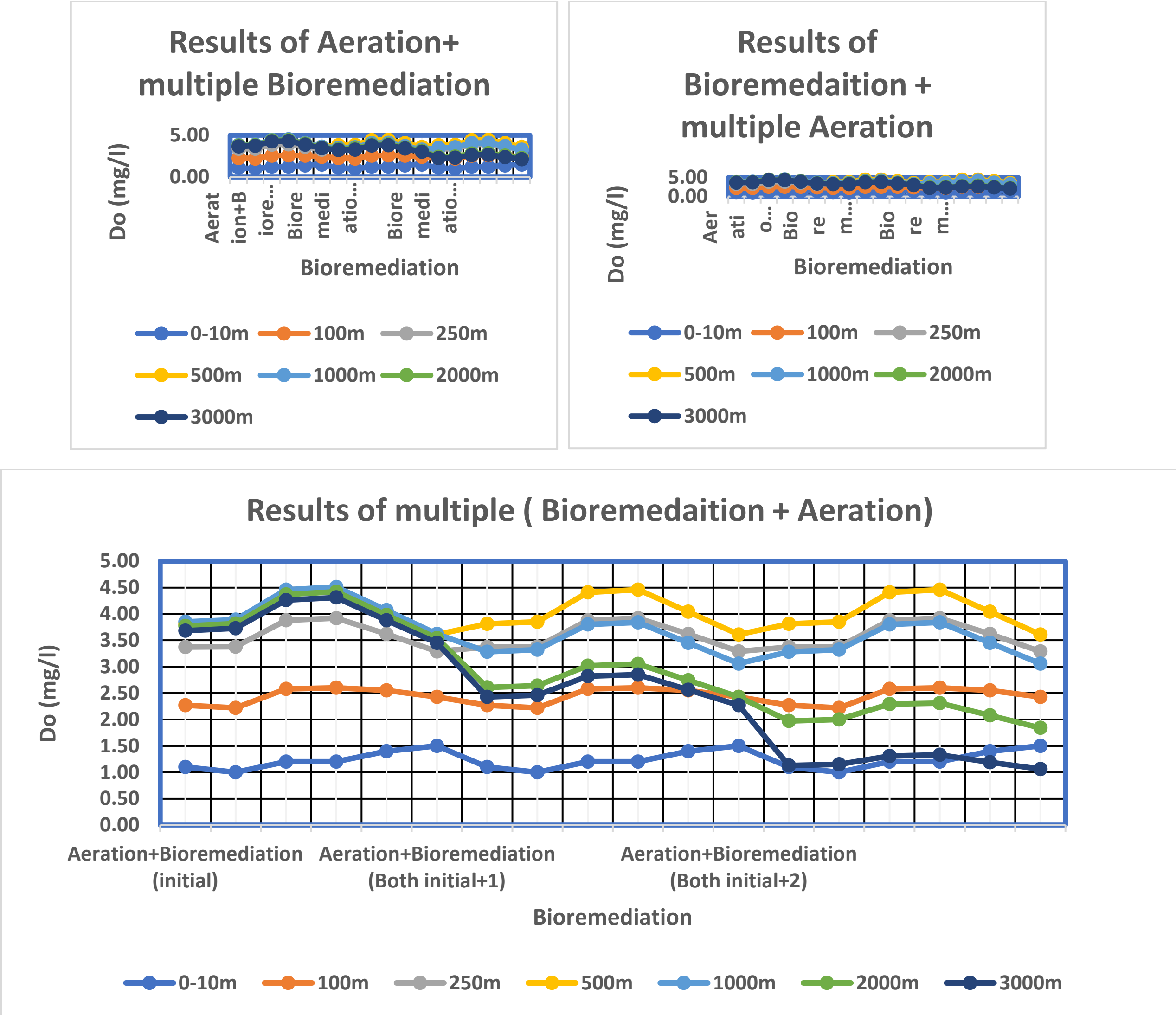
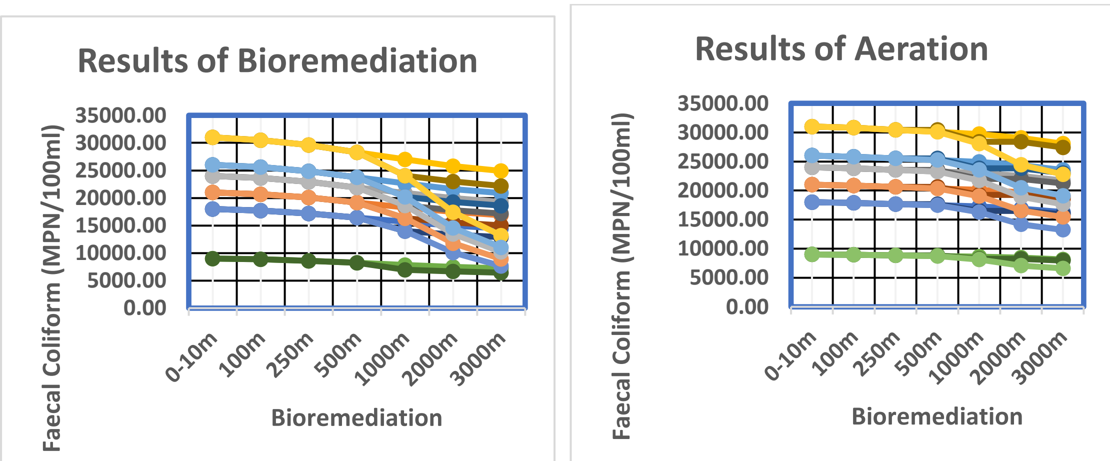



**Figure 5:** DO Variation at different locations (up to down) for different combinations



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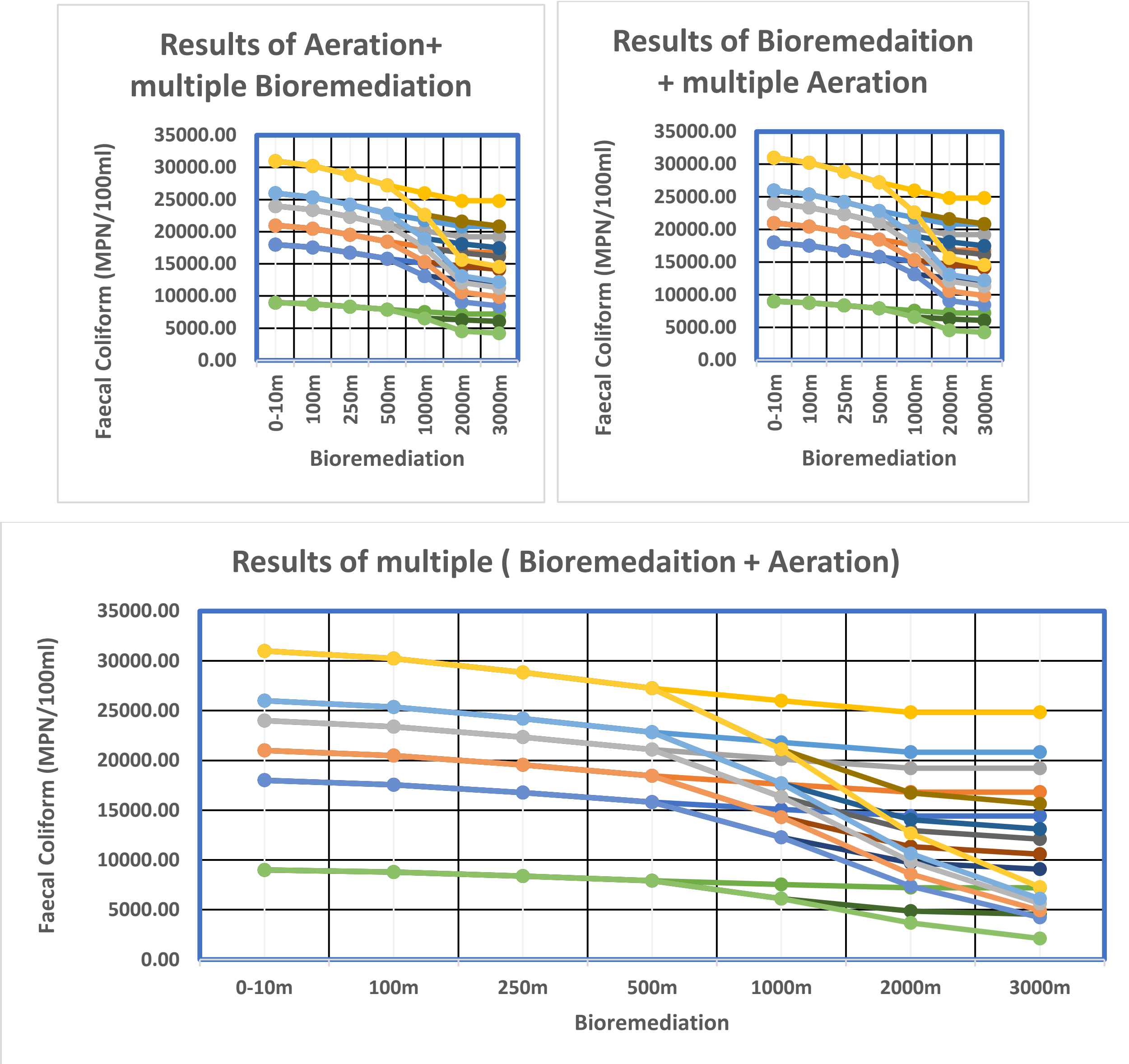
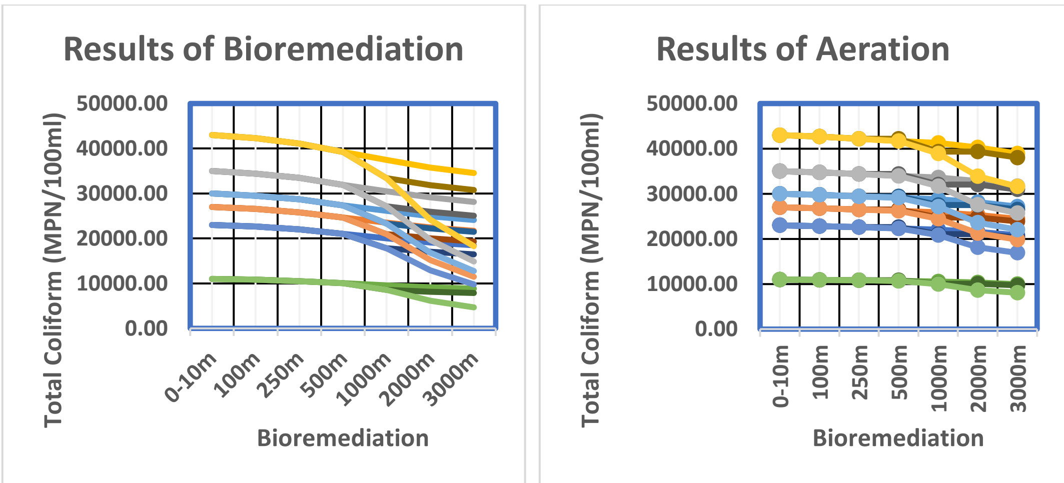



**Figure 6:** FC Variation at different locations (up to down) for different combinations



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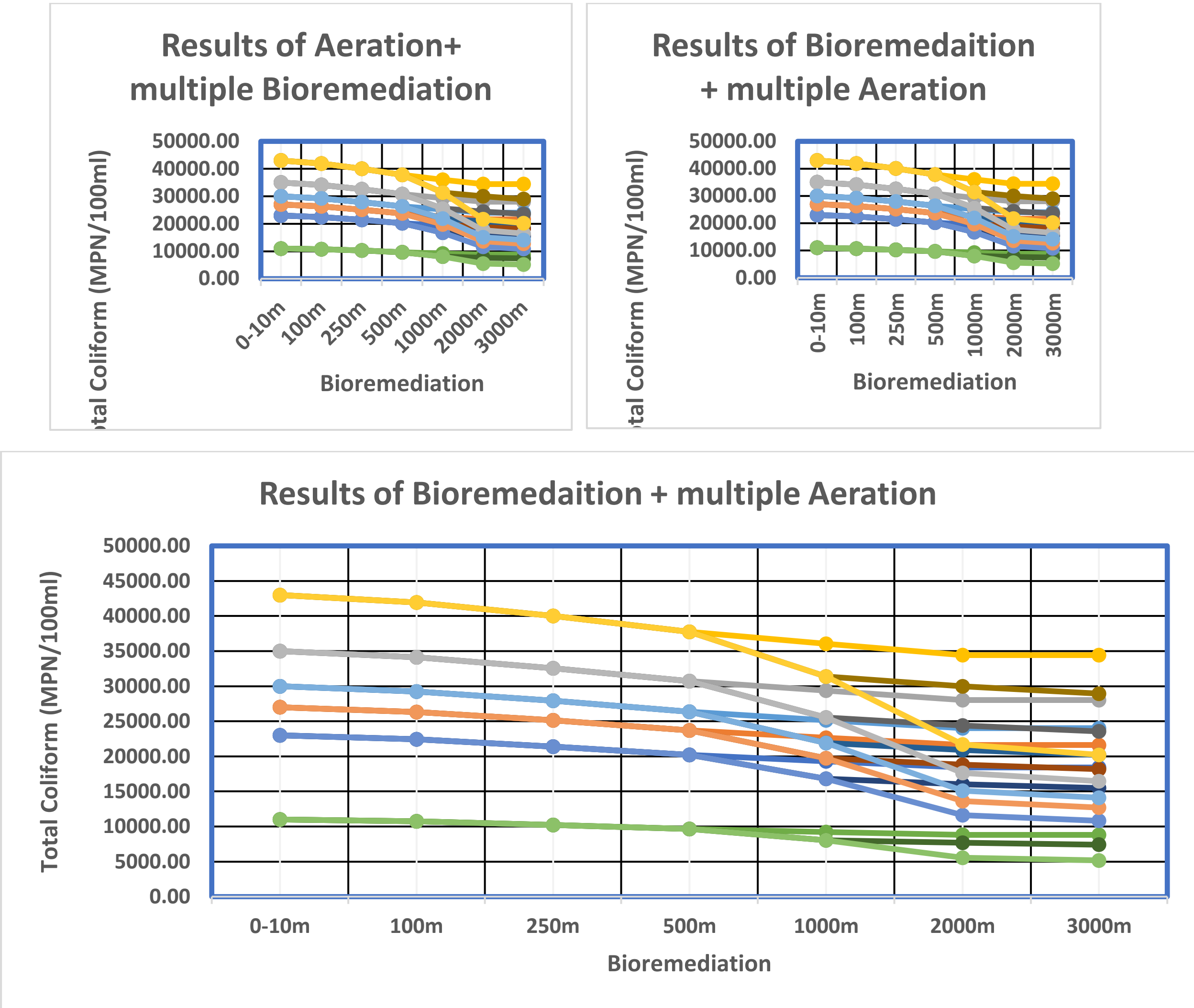


**Figure 7:** FT Variation at different locations (up to down) for different combinations

## CONCLUSIONS

The following conclusions are drawn:

1. BOD values, Fecal Coliform and Total Coliform can be reduced significantly with the used of Bioremediation, aeration and their different combinations.
2. The DO values are not significantly improving with addition of bioremediation at multiple points (1000m and 2000m).
3. The BOD values show significant improvement if waste treating microbes are used in bioremediation process at multiple locations. Moreover, if reaeration process is added, it improves the results and reduces BOD values.
4. Similarly, FC and TC values show significant improvement if waste treating microbes are used in bioremediation process at multiple locations. Moreover, if reaeration process is added, it improves the results and reduces BOD values.
5. It is recommended to use the bioremediation in similar studies to improve water quality of major drains before sending it to the STP or draining it to the rivers.

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