Chapter

Assessment of Microbial Load Reduction Efficiency of Sewage Treatment Plants (STP's) in Mysore, Karnataka, India

Severeni Ashili, Harikaranahalli Puttaiah Shivaraju and George Jessen

Abstract

The present study mainly aims to determine the assessment of microbial load reduction efficiency of sewage treatment plants (STPs) in Mysore, Karnataka, India. The raw and treated wastewater samples were collected and tested for irrigation suitability using irrigation indices compared with the Food and Agriculture Organisation (FAO) standards. Seed germination study was carried and the vigour index was reported to be higher for raw sewage although the seedlings treated with this water had wilting shoot tips. The overall results of the present study observed that most of the parameters of both treated and untreated urban wastewaters have exceeded the FAO irrigation standard and continuous usage of such water may cause detrimental effects on the soil and crops. The sewage treatment plants have also shown very low efficiency in microbial load reduction, and this can have health risk implications to the farmers using this effluent.

Keywords: urban wastewater, sewage treatment plant, sewage effluent, vigour index

1. Introduction

Wastewater usage for irrigation is increasingly being practised in developing about 7% of the total irrigated land. Wastewater contains numerous potentially pathogenic microorganisms and a high content of organic matter; therefore, it poses a number of health risks [1–3].

Indirect use of untreated wastewater is one of the most common and extensive types of unintentional wastewater reuse [4–8]; this occurs when untreated wastewater is discharged into freshwater streams, gets diluted and subsequently used by farmers, households and industries. This is a common practice in low- and middle-income countries without or with limited collecting and treatment capacity. There are many pathogenic microorganisms which will always be present in partially treated or untreated wastewater and sewage sludge [9].

This work was primarily aimed to assess the efficiency of the STPs in Mysore in removal of pollutants and microbial pathogens with respect to coliform bacteria to the level set by the FAO, WHO, IBS and CPCB for agricultural and other uses. Secondly, the study tried to evaluate the effect the raw and treated wastewater on the germination and growth of seedlings.

2. Materials and method

2.1 Study area

The study area Mysore city has 887,446 people [10]. Mysore is located at 12° 18′N 76° 39′E 12.30° N 76.65° E and has an average altitude of 770 m (2,526 feet) [11]. The rainy season is from May to October with an average rainfall 782 (697–904) mm. The city has been provided with three wastewater treatment plants (Kesare, Vidarayanapuram and Rayankere). All the treatment plants have facultative aerated lagoons and sedimentation basins [12].

2.2 Sampling and analysis

Assessment of water parameters was carried out in March 2016 to May 2016. Water samples were collected from different stages, i.e., raw wastewater, after facultative pond and final effluent (after sedimentation) in cleaned/sterile 2-L polythene bottles as per the standard methods [13].

These samples were analysed for different physico-chemical, microbial and irrigation quality parameters and agricultural application. Analysis and collection of samples have been done according to standard methods prescribed by the American Public Health Association [13].

2.3 Physico-chemical parameters

Temperature, pH, electrical conductivity (EC), TDS, sodium (Na2+), potassium (K+), calcium (Ca2+), magnesium (Mg2+), total alkalinity (as CaCO3), total hardness (as CaCO3), dissolved oxygen (DO), chemical oxygen demand (COD), biochemical oxygen demand (BOD), etc.

2.4 Microbial parameters

The total coliform count was performed by multiple tube fermentation technique using a set of three tubes inoculated with 10 ml of lactose broth of different strength with samples of 10, 1 and 0.1 ml, respectively [2, 14].

2.5 Irrigation quality parameters

The parameters for irrigation of water quality were calculated based on the result obtained after determination/estimation of sodium (Na2+), potassium (K+), calcium (Ca2+), magnesium (Mg2+) and total alkalinity (as CaCO32−) in mg/l. These values of respected cation and anions were used in the following calculations of the respective parameter of irrigation quality for getting its index or ratios.

2.6 Agricultural application

All the samples were subjected to analysis of various physiochemical parameters with concentration on COD, alkalinity, hardness, K+, Na+, Mg+ and Ca+ followed by the methods of APHA [13].

Three different seeds green gram (*Vigna radiata*), Bengal gram (*Cicer arietinum*) and green peas (*Pisum sativum*) were used for the study. A seedling tray was filled with soil and prepared for seed sowing. The healthy and uniform seeds were cleaned with distilled water, and replicates of five seeds were sown for each of the four different, namely, raw wastewater, final effluent, activated charcoal/sand-filtered effluent and distilled water (control). The seedlings were treated with about 10 ml of sample for twice daily, and also the same was treated with distilled water that was set as control. The sampling study was carried out for a period of 7 days after which the seedlings were studied for different characteristics [15].

Percentage germination was calculated by dividing the number of seedlings germinated with the total number of seedling sown for each treatment set.

$$\%\,germination = \frac{N_G}{N_S} \times 100$$

where N_G is the number of geminated seeds and N_S is the total number of seeds sown.

a. Root length, shoot length, wet weight and dry weight: the root length and shoot length of the germinated seed were measured in centimetre scale. The initial weight of the seedling after 7 days was recorded, and the same was placed in hot air oven for drying at 65°C overnight and weighed. The weight after drying is recorded as dried weight and the weight before drying as the wet weight in grams (g).

b. Seedling vigour index (SVI): vigour index of the seedling was calculated using the formula suggested by Abdul Baki and Anderson in 1973.

$$\text{SVI} = \text{Germination (\%)} \times \text{Seedling Length (Mean Root Length + Shoot Length)}$$

3. Results and discussion

3.1 Physico-chemical parameters

Determination of the general efficiency depends on the overall performances of the different plants in terms of average removal of indicator parameters including TDS, COD, BOD_5, etc. Some of the parameters such as pH directly affect the performance of a secondary treatment process [16] because the existence of most biological life is dependent upon narrow and critical range of pH.

The amount of total dissolved solids (TDS) of inlet as indicated in **Figure 1** ranges from 717 mg/l as observed at Vidarayanapuram STP to 466 mg/l at Kesare STP and has shown little reduction over the stages of all three treatment plants. This proves that aerated lagooning treatment process is inefficient in the removal of TDS. Since the effluent of the three plants is being used for agricultural application or irrigation, the high TDS level may affect the porosity of the soil where this effluent is being used.

The plants have shown an overall biochemical oxygen demand (BOD) removal efficiency of 90, 87 and 97% at Kesare, Vidarayanapuram and Rayankere, respectively. The highest removal is associated with sedimentation tank with an average BOD removal 79% as compared to 54% average removal which was recorded in aerated tank for all plants. Similarly, the plants have an overall average chemical

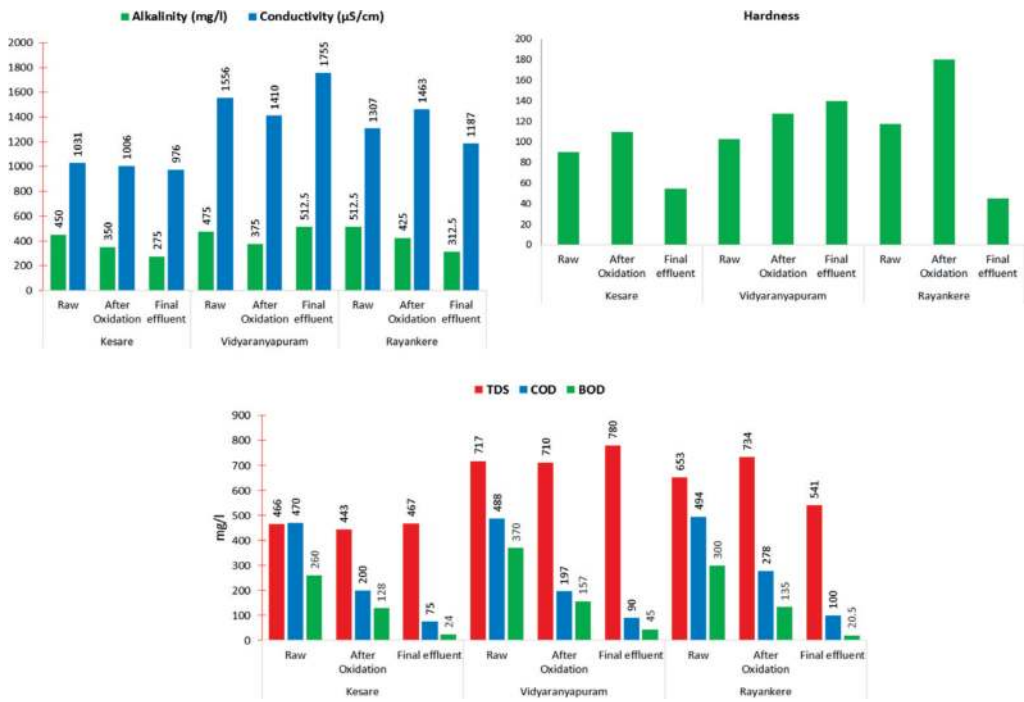

Figure 1.
Physico-chemical stage-wise efficiency of the STPs.

oxygen demand (COD) removal efficiency of 81%, and the high removal is still sedimentation tank with an average removal of 60% as opposed to 53% removal in aeration tank. This makes all the three sewage treatment plants efficient in terms of BOD and COD removal, and they are within the CPCB.

As observed in **Figure 1**, the conductivity of the water has shown no significant reduction over different stages in all the treatment plant. Conductivity increases with the increase of ions, and it is also effectively a surrogate for total dissolved solids and is important for irrigation because it is a measure of the salinity of the water. Salinity is known to restrict water available in the soil for plants to use and also impact crop's physiology and yield.

In the present study, EC of untreated UWW shows a range from 1031 µS/cm at Kesare STP to 1556 µS/cm at Vidyaranyapuram STP. EC of treated UWW showed a range from 976 µS/cm at Kesare STP to 1755 µS/cm at Vidyarayanapuram STP, and the values of untreated and treated UWW at all the three locations lie within the slight to moderate range of the FAO irrigation water quality standards. There was also no significant difference in the alkalinity at different treatment stages of all sewage treatment plants although the water at different location differs significantly in both parameters.

Hardness is usually reported as equivalents of calcium carbonate ($CaCO_3$) and is generally classified as soft, moderately hard, hard and very hard. It is commonly associated with two polyvalent cations, viz. calcium (Ca^{2+}) and magnesium (Mg^{2+}).

As from the results in **Figure 1**, the UWW in Mysore city falls between 75 and 150 mg/l which is classified as moderate hard with the exception of Kesare STP and Rayankere STP final effluent with 55 and 45 mg/l which is in the class of soft water. The effluent from the aerated lagoon in Rayankere STP is also an exception with a total hardness of 180 mg/l which is in the class of hard water as per the US Environmental Protection Agency (EPA). Hardness has no significant effect in the treatment system, but if this water mix with domestic or industrial water sources, it has a significant effect on the amount of detergent and soap required. It also has causes scaling in boiler and other industrial equipment when it is used and therefore reduce equipment overall efficiency.

3.2 Microbial efficiency

The Mysore city UWW system has shown a high number of coliform with Rayankere with the highest CFU of 8.42×10^5 per 100 ml in its raw water (**Figure 2**). All the sewage treatment plants have shown no significant efficiency in the removal of coliform with an overall removal of 5.1, 8.4 and 7.1% for of Kesare STP, Vidyaranyapuram STP and Rayankere STP, respectively. Sedimentation process has proven to be the stage where reduction is high compared to other stages with the highest reduction percentage of 8% at Vidyaranyapuram STP, while other treatment plants have recorded a reduction of less than 5%. This mean that the treatment process used in Mysore city is not effective in removing microbes and therefore the effluent possesses a health risk to farmers.

3.3 Agricultural applicability

3.3.1 Irrigation parameter

Although potassium is not an essential part of any plant component, it is known to be involved and physiological process such as plant water balance and protein synthesis which are important in plant growth. Potassium in UWW originates from human faeces and urine disposal, as human faeces has on average 1.6% and urine has 3.7% (dry weight) potassium. The concentration of potassium of untreated UWW was 18, 19 mg/l for the final effluent and 35 mg/l for the AC/sand column treated effluent as indicated in **Table 1**.

3.3.2 Sodium absorption ratio (SAR)

SAR indicates the effect of relative cation concentration on sodium accumulation in the soil. The present study shows SAR in UWW, final plant effluent and the activated charcoal/sand-filtered effluent to be 11.18, 6.1 and 13.08 respectively (**Table 1**).

SAR in the untreated and AC/sand-filtered water lies in the acute range with respect to sodium irrigation water hazard, while SAR of the treated effluent lies within the slight to moderate hazard. This means that farmers using the reclaimed water need to take extra care whenever they are using this water. Hence, to

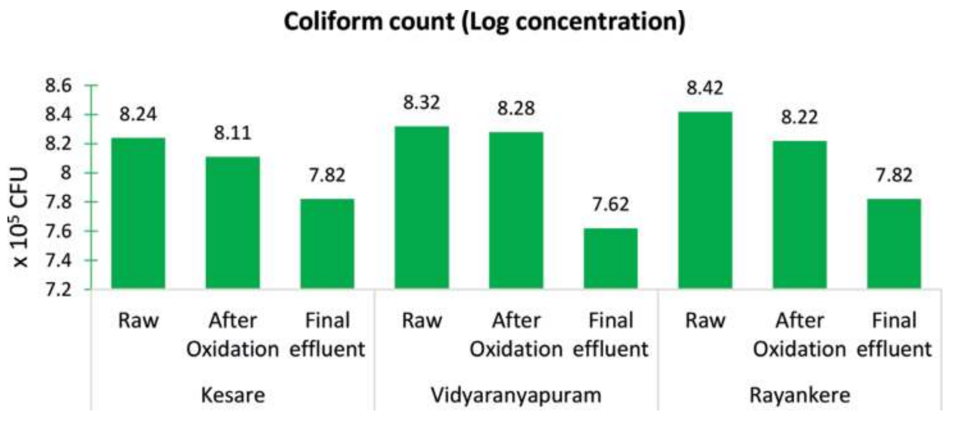

Figure 2.
Coliform count at different treatment stages.

Parameter	Raw	Final Effluent	AC/Sand filtered
Potassium (mg/l)	18	19	35
Sodium (mg/l)	80	51	97
Magnesium (mg/l)	41	56	44
Calcium (mg/l)	61.5	84	66
Carbonates (mg/l)	31.95	142.37	76.4
Bicarbonate (mg/l)	268.28	289.46	155.32
Sodium Absorption Ratio	11.18	6.1	13.08
Residual Sodium carbonate	4.6	3.11	0.54
Soluble Sodium Percentage	48.88	33.49	54.55
Kellys Ratio or Kellys Index	0.78	0.69	0.88

Table 1.
Irrigation parameters of water used in the germination test.

properly assess the suitability of a particular irrigation water supply, the apparent salt tolerance of the specific crop must also be taken into consideration.

3.3.3 Residual sodium carbonate (RSC)

It is another alternative measure of the sodium content in relation with Mg and Ca. Residual sodium carbonate (RSC) exists in irrigation water when the carbonate (CO_3) plus bicarbonate (HCO_3) content exceeds the calcium (Ca) plus magnesium (Mg) content of the water. Where the water RSC is high, extended use of that water for irrigation will lead to an accumulation of sodium (Na) in the soil. If the RSC < 1.25, water is considered safe, while if the RSC > 2.5, the water is not appropriate for irrigation. On this index, both untreated and treated wastewaters are unsafe or inappropriate for irrigation purposes with RSC of 4.6 and 3.11, respectively. The AC/sand-filtered water however lies in the safe range with RSC of 0.56 which is less than 1.25.

3.3.4 Soluble sodium percentage (SSP)

It is also used to evaluate sodium hazard. Water with SSP greater than 60% may result in sodium accumulations that will cause a breakdown of the soil's physical properties. The calculated values of SSP varied from 48.88, 33.49 and 54.55% for untreated UWW, final plant effluent and activated charcoal/sand-filtered effluent, respectively.

3.3.5 Kelly's ratio or Kelly's index

Suitability of water for irrigation purposes is also assessed on the bases of Kelly's ratio. Ratio of sodium versus calcium and of sodium versus magnesium is used as Kelly's ratios. Water having Kelly's ratio of more than one (>1) is considered not suitable for irrigation purposes. Kelly's ratio of the water samples tested was 0.78, 0.69 and 0.88, which implies that this criterion of the groundwater is suitable for irrigation purposes.

3.3.6 Effluent effect on seedling

The germination studies indicate that the percentage germination (**Figure 3**) of each of the three seedlings used for the study varies with different water treatment. The overall high germination rate was observed in raw sewage with 100% germination in both Bengal gram and green gram and 80% germination in green peas, while the least percentage germination was recorded with AC/sand-filtered effluent where a maximum of 80% was recorded for both Bengal gram and green gram and 60% germination in green peas.

This suggest that the percentage germination is not really depended on the concentration of the effluent as it was concluded by the previous study done in Mysore which concluded that the higher concentration of the effluent retards seed germination, whereas the lower concentration may enhance the growth [15]. Bengal gram has the highest germination percentage of 100% almost in all water treatment with only an exception of AC/sand-filtered effluent where only 80% germination was observed. Green peas on the other hand has the lowest overall percentage germination which recorded 80% germination for both control and raw sewage, while only 60% of the seeds germinated in the final effluent and AC/sand-filtered effluent (**Figure 3**).

Seed germination unlike general seedling growth and yield mainly depends on the basic factors such as light, moisture, air, temperature, etc. and therefore is not really affected by pollutant in water. Green gram was observed to have the highest overall growth of 8.65 cm on average under control treatment compared to 6.3 and 8.65 cm of green peas and Bengal gram, respectively; there is however no much difference in the average length of each seedling among treatment (**Figure 3**).

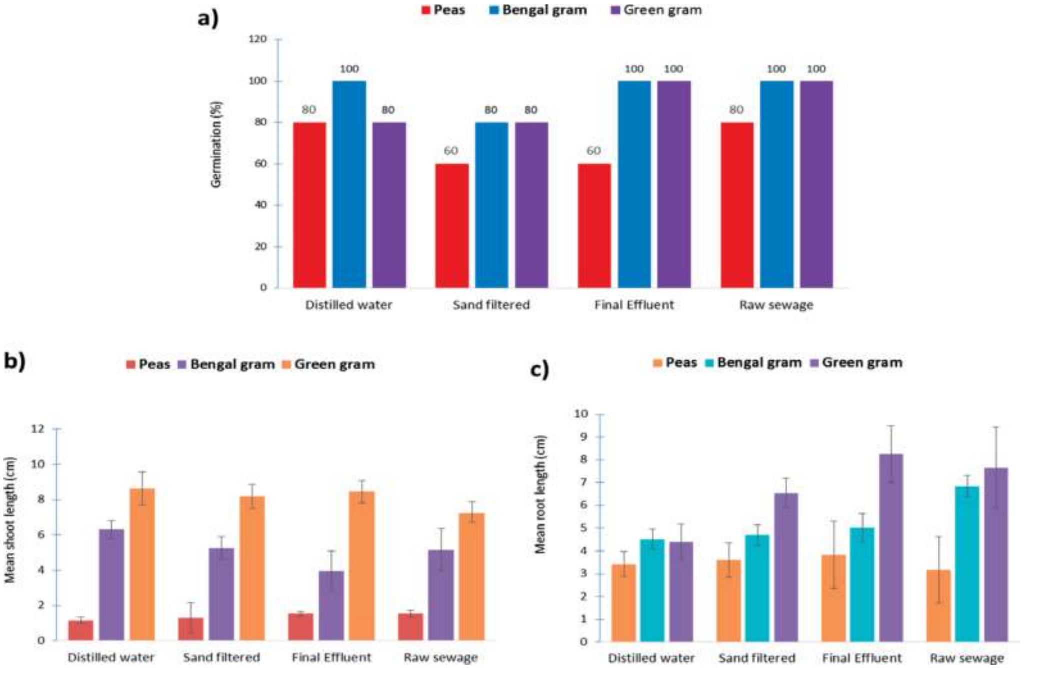

Figure 3.
(a) Percentage of different seeds under different water treatments; (b) mean shoot length of different seeds under different water treatments; and (c) mean root length of different seeds under different water treatments.

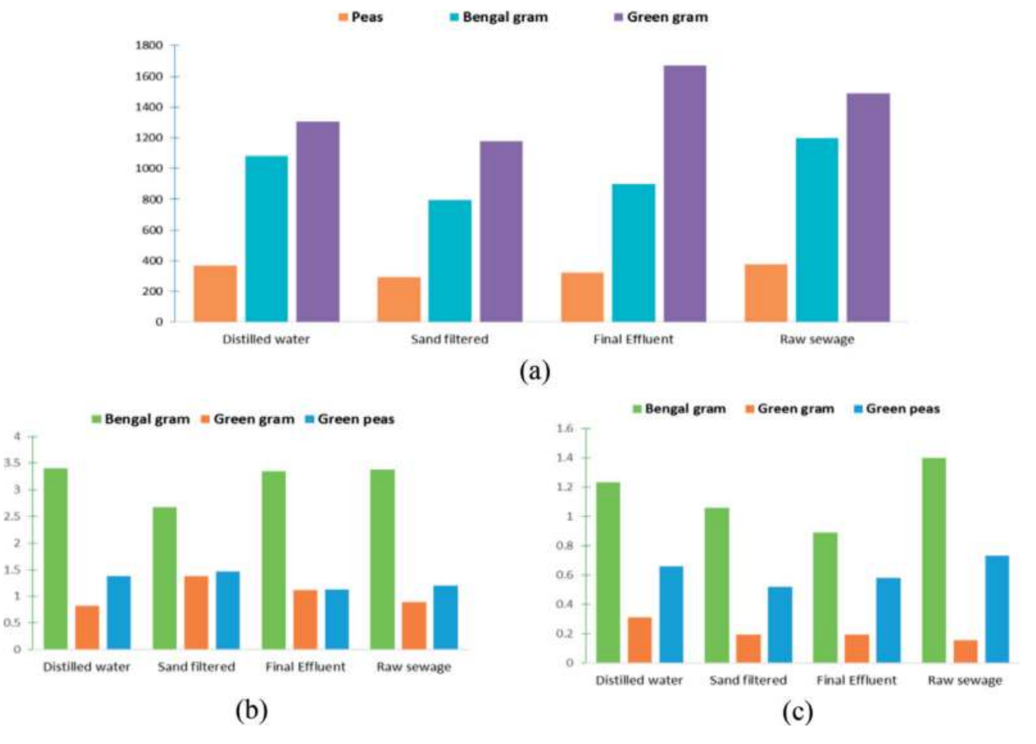

Figure 4.
(a) Vigour index of different seeds under different water treatment; (b) wet weight of different seeds under different water treatments; and (c) dry weight of different seeds under different water treatments.

The treated effluent have the highest average root length for the green peas and green gram seedling of 5.02 and 8.26 cm, respectively, while Bengal gram was high in raw sewage treatment 6.84 cm on average. This high root formation in reclaimed water as opposed to the control can be attributed to the presence of nutrients in it that can act as plant growth enhancer. Overall, green gram has shown a highest vigour, while green peas have the lowest vigour across all treatment. It is also important to note that among all the treatment the highest were recorded in the final effluent and raw sewage, and this can still be attributed to the nutrient and ion content that is associated with this water (**Figure 4(a)**).

Both wet weight and dry weight as indicated in **Figure 4(b)** and **(c)** have no relation with water treatment parameter. The highest weight recorded in both wet and dry was for Bengal gram, and green gram has recorded the lowest wet and dry weight.

4. Conclusion

The aerated lagooning treatment system used has proven to be effective in the reduction of some of the parameters and ineffective in some. Parameters like BOD and COD of treated effluent in UWW are within the CPCB permissible limit for disposing the UWW on land for irrigation. Continuous use of this effluent may however have a negative impact on the soil since some of the irrigation parameters like EC, TDS and SAR are over the average range of the FAO irrigation water quality standards.

The aerated lagooning treatment used in UWW has proven to be ineffective in the treatment or reduction of coliform bacterial which is used as a surrogate organism for microbial pathogens. This may be partially due to the chosen treatment system, but the operation and maintenance can also have an effect on the efficiency of the treatment.

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