Health Risk Assessment of Microbial Water Quality and Bioaerosols Emission from Byramangala Reservior, Karnataka, India

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Abstract: ***Bioaerosol emissions surrounding waste water treatment plants, polluted lakes and rivers are a health risk concern in humans. Dumping of human and animal wastes in the lake and river is the main reason for the bioaerosols emitted into the ambient air. The microorganisms in the air studied using an Anderson microbial air sampler. Microorganisms like E. coli and Fecal streptococci in water samples collected from Byramangala reservoir was estimated to be an average of 1,685 CFU/100ml and 1,648 CFU/100ml. Enterobacter allergens were estimated around 1,292 CFU/100ml and Staphylococcus aureus was 892CFU/100ml. Bioaerosols from outlet weir were enumerated and compared with upwind and downwind. The bioaerosols number was varied with distance of downwind. Intestinal pathogens like Fecal coliform aerosolized at outlet weir and population were ranged from 348 CFU/m^3 to 1372 CFU/m^3. Similarly, fecal streptococcus number ranged from 45 CFU/m^3 to 275 CFU/m^3. Salmonella sp., ranged from 95 CFU/m^3 to 322 CFU/m^3. Bacteriological analysis of a water samples reveals that Byramangala lake is polluted with E.coli and other coliform bacteria which has crossed the permissible limit prescribed by WHO, 1989 for wastewater irrigation and reuse. Microbial contamination beyond the permissible limit which is health risk for farmers who are irrigating the lake water for their farm. Bioaerosol studies around the lake indicates that the presence of bacterial pollution in the ambient air driven by Enterobacteriacae members such as E-coli, fecal streptococcus and salmonella sp in lake water which has got aerosolized with the influence of foam and gets transported by ground level turbulence. The formation of stable foams at outlet weir and irrigation canal proves that the water body receives phosphate and oil based pollutants from domestic sewage and industrial effluent. The continuous flow of raw sewage and industrial effluent worsening the lake water quality and deteriorate the air quality of settlements around the Byramangala reservoir.***

Keywords: Water pollution, air pollution, Enterobacteriaceae, *E.coli, Fecal coliform, Salmonella sp.,* Bioaerosols, meteorological parameters, health risk

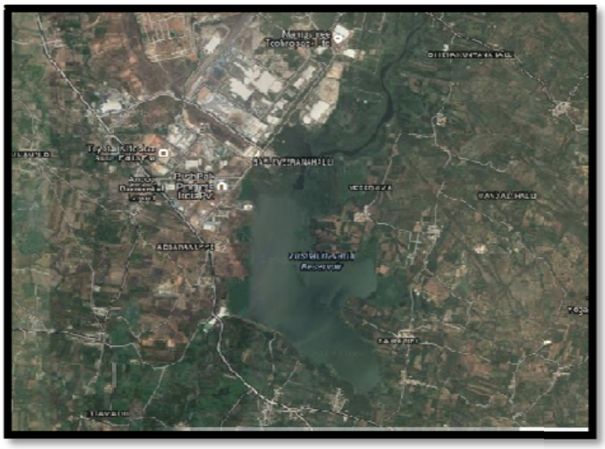
1. Introduction

The measurement of airborne microorganisms has gained importance as found in indoor and outdoor environments cause adverse health effects on humans. Bioaerosols can be formed from any process that involves biological materials and generates enough energy to separate small particles from the larger substance, such as wind, water, air, or mechanical movement [1]. Contamination of the air by microorganisms, including pathogenic ones, is generated from various sources, both natural, such as water, soil or rotting plants and animal remains, and anthropogenic, including municipal landfills and sewage treatment plants [2]. Pathogens, mainly found in excreta, and secretions of patients are transferred in general by sewage and municipal waste from households and hospitals, creating an unspecified health hazard in the surroundings of waste water treatment plant (WWTPs). The generation, treatment, and disposal of the human and animal waste contribute to the increase in the production of bioaerosols containing a wide variety of microbial pathogens and related pollutants [3].

Enterobacteriaceae bacteria, which are natural microbiota of the human gastrointestinal tract, represent a large part of the bacterial community of sewage[4][5]. These bacteria, including *Escherichia coli*, are important indicator organisms for evaluating the bacteriological safety of drinking water, recreational area, or food. The transfer of these microorganisms from waste water to the environment takes place primarily through the outflow of wastewater directly into surface water reservoirs which are the receivers of this sewage. They are emitted to the air mainly during the mechanical force of moving of waste water through outflow [6][7]. As bioaerosols might be a vehicle for the dissemination of human and animal pathogens from wastewater and inhabitants of their surroundings may be exposed to harmful influences of microorganisms from the air [8]. The aim of this study was to determine the effect of Vrishabhavathi Lake on the microbiological pollution of the surrounding environment with particular importance on the air in the overflow area and the lake water, which was the receiver of the industrial and sewage pollution. The present study gives the baseline information of water and air pollution of Byramangala reservoir to frame policy to mitigate environmental degradation.

2. Materials and Methods

2.1. Study Area



Byramangala reservoir is located at Byramangala village, Bidadi, Ramanagaram Taluk, Bangalore Rural district. It's positioned at latitude 12'47" N and longitude 77' 20" E. A number of villages surrounding the reservoir are Anchipure, Bannigere, Maregowdama, Doddi, Byramangala, Shanmangala, Kuntanalialli parasama palya, Thimmegowdama Doddi and Vrishbhavathipura.

2.2. Lake water sample collection

Air and Water samples were duly collected during the month of July 2013. Water samples collected from inlet and outlet using sterile carboy bottles, cap of the bottle tightly screwed and preserved for bacteriological analysis. Bacterial analysis of lake water samples were carried out by following standard method APHA, 2005. Eosin Methylene Blue Agar (Hi-Media M022) and MacConkey agar (Hi-Media M081B) were used for enumeration of Enterobacteriaceae members.

2.3. Bio aerosols sampling

Samples were collected near the emission source (outlet of weir) located in South West part of the reservior and four collection sites were selected according to predefined distances of 50m,100m,150m and 200m (with the exception of the waste dumping area), along the direction of the prevailing winds. Andersen single stage microbial sampler was used for collection of bioaerosols which have cutoff sizes of 0.65μm with impaction velocity of 28.3 L/m.

The sampled Petri dishes were incubated for 24 h at 35±2°C. Following incubation, bacterial colonies were counted based on the color change of the Eosin Methylene Blue Agar(Hi-Media M022) medium where they take on a celadon, purple, or blue color, and then, bacteria were analyzed for the production of cytochrome oxidase using 1 % tetramethyl-p-phenylenediamine solution. Oxidase-negative bacterial colonies are identified as members of Enterobacteriaceae.

3. Result and Discussion

3.1 Biological analysis of water sample

Micro-biological analyzed from 10 replicate samples from the study area. The results of microbial quality of lake water samples (Figure: 1) was found to have crossed the permissible limit for irrigation prescribed by World Health Organization (WHO), 1989. The water from outlet is diverted through the canal for irrigating agricultural lands.

Typical colonies of *E. coli* and *Feacal streptococci* isolated from water sample are direct evidence of the presence of fecal contamination from sewage and warm-blooded animals. The number of *E. coli* and *fecal streptococci* was recorded as an average of 1,685 CFU/100ml and 1,648 CFU/100ml which is crossed the permissible limit of treated waste water for irrigation and recreational purpose prescribed by WHO, 1989. The prescribed standard limit is less than 1000 CFU/100ml. The United States Environmental Protection Agency (USEPA) and the US Agency for International Development have recommended strict guidelines for wastewater use. According to USEPA, the permissible limit of Coliform bacteria is 4,200CFU/100ml in water used for cultivation of vegetable crops and fruits. For unrestricted irrigation of food crops these range from 10–1000 fecal coliform/100 ml for surface irrigation to 2.2–200 fecal coliform /100 ml for spray irrigation.

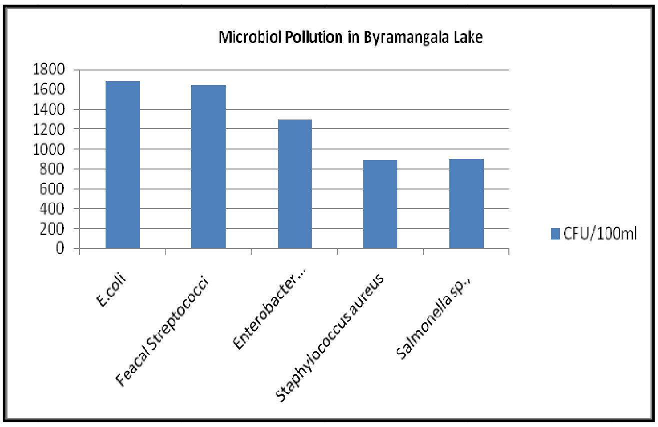


Figure 1: Microbial Pollution in Byramangala Lake water

Enterobacter allergens found to be 1,292 CFU/100ml which is nosocomial and pathogenic bacterium that causes opportunistic infections and *Staphylococcus aureus* around 892CFU/100ml. All the water used for irrigation, finally joins river Cauvery which flows across neighboring states. Microbial contamination beyond the permissible limit is health risk for agricultural labor including skin infections, such as pimples, impetigo, boils, cellulitis folliculitis, carbuncles, scalded skin syndrome, and abscesses, life-threatening diseases such as pneumonia, meningitis, osteomyelitis, endocarditis, toxic shock syndrome (TSS), bacteriemia, and sepsis [9].

3.2 Analysis of Bioaerosols near Byramangala reservoir weir

The bacterial member of Enterobacteriaceae was collected near the outflow weir using Anderson Petri sampler and simultaneously bacterial samples in air were collected at different downwind distance from the source. The obtained result indicates that bacterial densities are varied at different downwind distance (Figure: 2). Maximum number of intestinal pathogens *Fecal coliform* bacteria was ranged from 348 CFU/m^3 to 1,372 CFU/m^3 in air. *Fecal streptococcus* ranged from 45 CFU/m^3 to 275 CFU/m^3. *Salmonella sp.*, ranged from 95 CFU/m^3 to 322 CFU/m^3 and *Bacillus sp.*, ranged from 246 CFU/m^3 to 748 CFU/m^3. A considerable number of *Staphylococcus aureus* was ranged from 150 CFU/m^3 to 372 CFU/m^3. The common microbial flora *Aeromonas sp.*, was found to be around 72 CFU/m^3 to 75CFU/m^3. Maximum number of bioaerosols at outlet weir attributed by air moving over ground may create turbulence near the weir produce the potentially uncontrollable bioaerosols emission. Relative air movements near the weir enhanced the rapid dispersion of bioaerosols with wind velocity (Figure 4). The ground level air turbulence with a change of wind velocity precedes the mechanical force for generation aerosol emission. According to many studies, the bioaerosols emission from waste water treatment plant containing moving mechanical equipments for water aeration, are the steps with the highest emission of bioaerosols[6][7]. Maximum number of *Fecal coliform* and *Fecal streptococcus* bacteria in the air near the outlet indicates that the direct discharge of raw sewage into the Byramangala lake. Korzeniewska et al [5] and Filipkowska *et al.* [10] observed the highest numbers of Enterobacteriaceae bacteria reaching values up to 5.0×102 CFU/m3 near grit/grate chambers and 2.2×103 CFU/m3 near aeration chambers, respectively. Similar results were found by Heinonen-Tanski *et al*[7], who observed the highest microbiological air contamination in pretreatment and aerated grit separation stages of wastewater treatment. High density of foam generation at the outlet which is played as dispersion media for bioaerosols emission and transportation (Figure: 3).

Figure 3: Represents the ground level air turbulence generates the rapid bioaerosols emission from outlet weir

3.3 Comparitive study of Upwind and downwind airborne microorganisms

Bioaerosol concentration at upwind and downwind provides baseline information of bioaerosol emission contributed by the outlet weir. Concentrations of aerobic bacteria at upwind and downwind are plotted for comparison (Figure 2). The upwind concentration was measured at 100 meter and aerosol concentration in downwind were measured at 50m,100m,150m and 200m and its 95% confidence interval along with the downwind concentrations are plotted against downwind distance for comparison. The reason behind this plotting is that, based on air dispersion theory, the maximum downwind concentration decreases as the downwind distance increases. The concentration was elevated at outlet weir and rapidly decreased to the environment level at a distance between 150 m and 200 m. *Salmonella* sp., is closely related to the *Escherichia* genus were populated at downwind distance of 50m and 100m.whereas this pathogenic organisms were not isolated at upwind distance of 100m. These data directly prove that disease causing *Salmonella sp* emitted from out let weir.

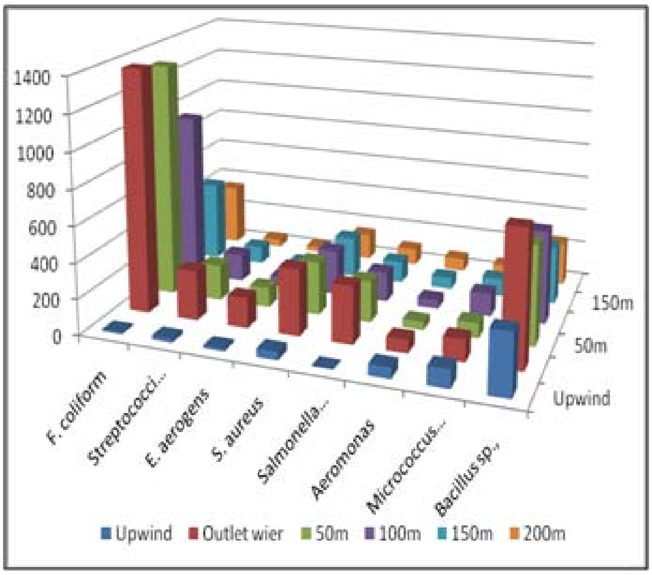


Figure 2: Bioaerosols distribution around the Byramangala Lake

4. Influence of Meteorological Parameters

The meteorological parameters like wind speed and direction data were collected from Bangalore University and used to predict the level of bioaerosols dispersion from the Byramangala Lake at different season (Table:2). The data are justified with the Indian meteorological center, Bangalore. The meteorological parameters of wind speed and wind direction provides the sign of the distribution pattern of bioaerosols at different seasons. Wind direction data during July to September reveal that the wind velocity from the west: west: north (WWN) direction carries the pathogenic aerosol from the Byramangala lake and dispersed to the East: East: North (EEN) direction. Bangalore urban city is located in East direction from point source which receives the maximum bioaerosols during the month of July to September with an average wind speed of 5.6km/hrs (Figure: 5). Similarly, the wind direction from the west: west: south (WWS) carries the bioaerosols and transported to Ramanagaram town during the month of October to December (Figure: 6). Wind direction from North East transport the bioaerosols to the neighboring town Kanakpura, Sathnur and Harohalli during the month of January to March (Figure: 5). Viable wastewater microorganisms can be aerosolized from flood irrigation sites during high-wind events. Gram-negative enteric microorganism concentrations increased markedly from the low- to the high-wind-speed regimen [11]. The ratio of heterotrophic plate counts of total cells was also higher in the high-wind-speed regimen and Aerosol concentrations varied by wind direction [12].

Table 2: Meteorological data by obtaining from Bangalore University

Seasons	*Temperature (^0C)*	*Relative Humidity (%)*	*Wind speed (Km/hrs)*	*Wind direction*
January to March	28 – 32	63	3.2	EES
April - June	32-36	70	4.5	WWS
July – September	34 - 28	75	5.6	WWN
October-December	27 - 25	72	3.8	NEE

Figure 4: Foam formation at outlet enhance the bioaerosols formation and transport by wind velocity

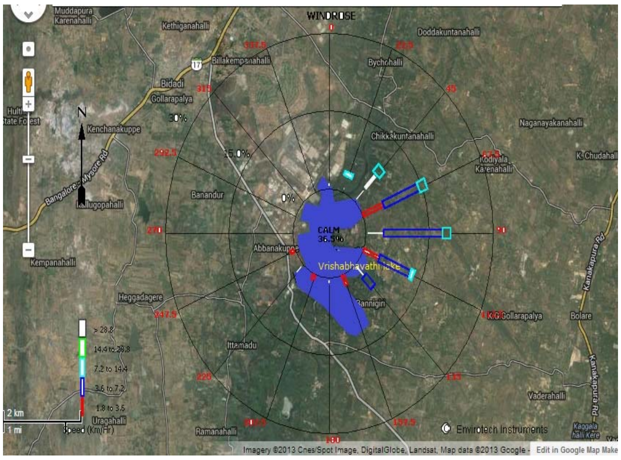


Figure 5: Wind speed and wind direction distribution between January to March (EES)

Figure 6: Wind speed and wind direction distribution between July to September (WWS)

5. Conclusion

Bacteriological analysis of a water sample reveals that Byramangala reservoir polluted by the Enterobacteriaceae family which indicates that the water bodies receives raw sewage from different sources. The lake water is not suitable for agricultural irrigation purpose for the reason that the presence of coliform bacterial number was crossed the permissible limit prescribed by WHO, 1989 for waste water irrigation and reuse. Bioaerosols studies around the lake indicates that the ambient air polluted by pathogenic bacteria. The majority of them are from Enterobacteriaceae family such as *E-coli*, *fecal streptococcus* and *salmonella Sp* aerosolized with influence of foam formation and transported by ground level turbulence. The formation of stable foams at outlet weir and irrigation canal proves that the water body receives phosphate and oil based pollutants from domestic sewage and industrial effluent. The continuous flow of raw sewage and industrial effluent worsening the lake water quality and deteriorate the air quality of settlements around the Byramangala reservoir.

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References

[1] Umesh B. Kakade (2012). Fungal bioaerosols: global diversity, distribution and its impact on human beings and agricultural crops.BIONANOFRONTIER,5(2).
Hurst, C.J, R.L. Crawford, G.R. Knudsen, M.J. McInerney, L.D. Stetzenbach: Manual of Environmental Microbiology, second Ed. Eds: *ASM Press*, Washington, DC (2002).
[2] Seurinck, S, T. Defoirdt, W. Verstraete, A.D. Siciliano, (2005). Detection and quantification of the human specific
[3] HF183 Bacteroides 16S rRNA genetic marker with real-time PCR for assessment of human faecal pollution in freshwaters. *Environ Microbiol* 7, 249–259.
[4] Wéry, N., Lhoutellier, C., Ducray, F., Delgenès, J. P., & Godon, J. J. (2008). Behavior of pathogenic and indicator bacteria during urban wastewater treatment and sludge composting, as revealed by quantitative PCR. Water Research, 42, 53–62.
[5] Korzeniewska, E. (2011). Emission of bacteria and fungi in the air from wastewater treatment plants—a review. Frontiers in Bioscience, S3, 393–407.
[6] Fracchia, L., Pietronave, S., Rinaldi, M., & Martinotti, M. G. (2006). Site-related airborne biological hazard and seasonal variations in two wastewater treatment plants. Water Research, 40, 1985–1994.
[7] Heinonen-Tanski, H., Reponen, T., & Koivunen, J. (2009).Airborne enteric coliphages and bacteria in sewage treatment plants. Water Research, 43, 2558–2566.
[8] Bünger, J., Schappler-Scheele, B., Hilgers, R., & Hallier, E.(2007). A 5-year follow-up study on

respiratory disorders and lung function in workers exposed to organic dust from composting plants. International Archives of Occupational and Environmental Health, 80, 306–312.
[9] Ryan KJ and Ray CG (2004). Sherris Medical Microbiology (4th Ed.). McGraw Hill. ISBN 0-8385-8529-9.
[10] Gallegos, E., A. Warren, E. Robles, E. Campoy, A. Calderon, Ma. G. Sainz, P. Bonilla, and O. Escolero. 1999. The effect of wastewater irrigation on groundwater quality in Mexico. Water Sci. Technol. 40:45-52.
[11] Tania Paez-Rubio, Emily Viau, and Jordan Peccia, (2005). Source Bioaerosol Concentration and rRNA Gene-Based Identification of Microorganisms Aerosolized at a Flood Irrigation Wastewater Reuse Site. Applied environmental microbiology, 71 (2): 804-810.
[12] US Environmental Protection Agency/US Agency for International Development. Guidelines for water reuse.Washington, DC, Environmental Protection Agency, Office of Wastewater Enforcement and Compliance, 1992 (technical report no. EPA/625/R-92/004).

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