EFFECT OF PLANTS, SHADING AND SOLAR RADIATION ON BIOAEROSOL IN WASTEWATER TREATMENT PLANTS

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ABSTRACT

The effect of planting covers, shading and solar radiation on the bioaerosol have been estimated for several wastewater treatment plants "WWTP", working by activated sludge processes "ASP". For each plant, the microorganisms has been estimated in air as colony forming units per cubic meter (CFU/M³) under different conditions of planting cover density, shading condition and solar radiation. In addition the secondary parameters such as boundary conditions, wind direction, temperature and measurement times have been considered. It was found that, there is a direct relationship between bioaerosol pollution in the air and both of planting density and shading ratio. Conversely, there is an inversely relationship between solar radiation and bioaerosol pollution. Despite the air quality improvements that take place by plants. They increase microorganisms account in the air. Also presence of shades in the WWTP and around it increase microorganisms account in air. Bioaerosol pollution has multiplied several times under plants from 1366 CFU/M³ to 14597 CFU/M³, also by shade from 4976 CFU/M³ to 19704 CFU/M³, but solar radiation decreased the pollution value from 13933 CFU/M³ to 796 CFU/M³.

Keywords: planting, bioaerosol, microorganisms, shading, solar radiation.

1 INTRODUCTION

In WWTPs working with ASP, the aeration tanks emit microorganisms from its surface into the atmosphere as fine air-bubbles, these air-bubbles are converted to form bio-aerosol, contains bacteria, virus and fungi (Vitězova et al., 2012). Fig. 1 illustrates the bioaerosol that is generated above aeration tanks.

Bio-aerosol is carried by wind to distances, according to several factors like temperature, solar radiation, wind direction, wind speed and relative humidity. The ability of microorganisms to survive in air depends on their vulnerability to drying out. Many of staphylococci are resistant to drying out, and die out very slowly in the air, other kinds of bacteria can survive on clothes even 130 days, and 7 days on paper, and salmonella-typhi survive 10 days in dust, 97 days on clothes and 90 - 119 on a tree (Z. Filipkowska, et al., 2000).

A great number of humans, animals, and plants illnesses are caused by microorganisms present in free air. Particular sources of microbiological air pollution are municipal facilities primarily wastewater treatment plants (Michel et al., 2001). Some bacteria are agents of hypersensitivity, infection, acute toxic effects, allergies and cancer, respiratory symptoms and lung function impairment are the most widely (P. Thorne et al., 2002). Microorganisms have been recognized as a health hazard and associated with asthma severity, the risk of illness from environmental bacteria increases when they enter buildings in inappropriate numbers or multiply indoors (Tsai& Macher, 2005).

The amount of CFU/M³ in air reflects the bioaerosol pollution strength. According to the commission of European communities "CEC" maximum amount for an average elevated contamination is 2500CFU/M³, more than 2500 less than 10000CFU/M³ is a high contamination and more than 10000CFU/M³ is a very high contamination (Marzenna R.Dudzinska, 2011). Also at distance of 250 m or at the nearest sensitive receptor "such as a dwelling or place of work", whichever
is closer, to protect public health, the acceptable level for total bacteria is 1000CFU/M$^3$ (Wheeler et al., 2001).

Generally several WWTPs are surrounded by plants, shaded areas or surrounded by buildings which minimize the solar radiation exposure. This research aims to measure bioaerosol pollution in WWTPs, also analyzing counted pollution values to find bioaerosol pollution relationships with planting cover density in the WWTP, shading ratio on surface area and the solar radiation strength on surface.

2 MATERIALS AND METHODS

The bioaerosol pollution has been estimated in various conditions, to find accurate scientific relationships between bioaerosol pollution and planting cover ratio, shading ratio, solar radiation conditions in Mansoura WWTP and Meet-Mazah as well.

Planting Cover Ratio "PCR" has been estimated to reflect the total planting volume above the area around every sample point; PCR was estimated by the equation:

$$PCR = \frac{V_p}{A}$$

Where $V_p$ is the total volume of plants above the surface area by cubic meters and $A$ is the area of the land by square meters.

Shading Ratio "SR" also has been estimated to reflect the shade density around sample points; SR was estimated by the equation:

$$SR = \frac{A_s}{A}$$

Where $A_s$ is the area of shaded land on surface, and $A$ is the total area around the sample point. The samples were taken at various conditions of shading.

Solar radiation was measured by LUX meter above the Petri dish in every sample point to measure the solar radiation strength. The bioaerosol pollution was evaluated under several conditions of PCR and SR and solar radiation for two WWTPs, Mansoura WWTP and Meet-Mazah WWTP, these WWTPs are in Mansoura government "located in the east of Egyptian delta".

The bioaerosol pollution was collected by gravity Petri dishes and estimated by colony counting method. The "gravity Petri dish" has been in common use for qualitative bioaerosol measurements, where a dish of sterile medium is left open at the sampling site for periods of 1 to 10 min to investigate the cultivable bacterial or mould flora of the atmosphere (Cox & Wathes, 1995). The samples were collected in July 2015. The testing Petri dishes have been pre-prepared in the laboratory of faculty of science Mansoura University. The Petri dishes were left on surface level in every point for 10 minutes then were covered, collected and sent to the laboratory. Fig. 2 illustrates the Petri dishes at sampling time. In the laboratory the Petri dishes were preserved according to standards (Feng et al., 2002). Then CFU/M$^3$ (Colonies-Forming Unit per air Cubic meter) number was calculated for every Petri dish.
2.1 Study area

Mansoura WWTP has a capacity of 270000 m³/day. It receives domestic sewage and treats it using ASP. It is nearby Mansoura city surrounded by an agricultural area and scattered buildings used for residential purposes, Fig. 3 illustrates Mansoura WWTP location.

Meet-Mazah WWTP is surrounded by an agricultural area, it is also working by ASP, and its capacity is 3000 M³, its treatment ability is 1500 M³/day. Fig. 4 illustrates Meet-Mazah WWTP location.

2.2 Sampling design

The Petri dishes were uniformly distributed inside several planting covers were estimated by PCR. Four samples have been taken for each estimated PCR. Table 1 illustrates PCR values and the numbers of samples.

Table 1. PCR values and the numbers of samples.

<table>
<thead>
<tr>
<th>point description</th>
<th>PCR</th>
<th>Number of samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>no Plants</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>area with little plants</td>
<td>1.1</td>
<td>4</td>
</tr>
<tr>
<td>moderated planting area</td>
<td>2.2</td>
<td>4</td>
</tr>
<tr>
<td>full planting area</td>
<td>3.25</td>
<td>4</td>
</tr>
</tbody>
</table>

Other Petri dishes were distributed in deferent shading conditions were estimated by SR. The shaded area were measured and divided on the total area to reflect the shading ratio. Table 2 illustrates SR value for each sample.

Table 2. SR value for each sample.

<table>
<thead>
<tr>
<th>point description</th>
<th>SR</th>
</tr>
</thead>
<tbody>
<tr>
<td>full shade</td>
<td>100%</td>
</tr>
<tr>
<td>moderated shade</td>
<td>70%</td>
</tr>
<tr>
<td>light shade</td>
<td>30%</td>
</tr>
<tr>
<td>no shade</td>
<td>0%</td>
</tr>
</tbody>
</table>

Petri dishes were distributed in several solar radiation exposure which measured by LUX above every sample point during sampling time. Table 3 illustrates solar radiation strength in sample points.

Table 3. Solar radiation strength in sample points.

<table>
<thead>
<tr>
<th>point description</th>
<th>LUX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Directs solar radeation exposure</td>
<td>32000</td>
</tr>
<tr>
<td>Moderate solar amount</td>
<td>19250</td>
</tr>
<tr>
<td>moderated cloudy</td>
<td>4250</td>
</tr>
<tr>
<td>cloudy</td>
<td>265</td>
</tr>
</tbody>
</table>

Petri dishes were distributed also inside and around the WWTPs to find the bioaerosol sources and the average of microoorganism's pollution in air; the samples were distributed above the aeration tanks, above the secondary settling tanks, beside the sludge drying basin, near chlorination tanks and beside fence for the pair of WWTPs. Fig. 5 illustrates Mansoura WWTP description and Fig. 6 illustrates
Meet-Mazah WWTP description. The Petri dishes also distributed in distances of 25,150 and 250 M outside both WWTPs.

3 RESULTS AND DISCUSSION

Most values refer to high bioaerosol pollution inside and around the WWTPs, which are more than 2500CFU/M³ according to CEC it is high contamination of bioaerosol.

The pollution values presented that: the lowest ratio was collected nearby the Chlorination tanks with 398CFU/M³ in Mansoura and 1858CFU/M³ in Meet-Mazah, according to the other pollution values it is a low ratio showing little bacterial hazard in this places. Inversely the highest pollution values were above the aeration tanks, with "uncounted value" in Mansoura WWTP; this value refers to much polluted environment in this place and 6170CFU/M³ in Meet-Mazah WWTP. The values prove that, in Mansoura WWTP and Met-mazah WWTP the aeration tanks are the main bacterial source.

After subtract the pollution values of aeration tanks from the both WWTPs, the average of other values in Meet mazah WWTP is more than the average in Mansoura WWTP. This refers to higher bioaerosol pollution in Meet-Mazah, this pollution may return to the agriculture area around Meet-Mazah WWTP. Fig. 7 illustrates the bioaerosol pollution distribution in Mansoura and Meet-Mazah WWTPs.

3.1 Planting cover effect

Without plants in PCR=0, the pollution values were from 796 to 1990 CFU/M³, with standard deviation 592CFU/M³, and average equal 1366 CFU/M³, it is the lowest average. And for the area of PCR = 1.1 the average of bioaerosol pollution increased to 2670CFU/M³. Thereby in the moderated planting area with PCR=2.2 the bioaerosol pollution average had a significant increase to reach 9765 CFU/M³. Also for the area of PCR=3.25 the bioaerosol pollution average increased to 14597CFU/M³, that is showing the cumulative effect of planting cover on the bioaerosol.

The average of bioaerosol pollution increases by the planting coverage ratio. The plants increase the ability of microorganisms to survive, and create good condition to grow up on the surface of the plant and on the earth surface. Fig. 8 illustrates planting cover effect on bioaerosol pollution.

3.2 Shading effect

The pollution values are showing that, in 100% shaded area the bioaerosol pollution was very high with result of 19904 CFU/M³, and the pollution was decreased by shading ratio. Otherwise in no shading area the result was decreased to the quarter "4972CFU/M³". In all samples bioaerosol pollution is increased by shading ratio. And there is a direct relationship between shading ratio and bioaerosol pollution. Fig. 9 illustrates shading effect on bioaerosol pollution.

3.3 Solar radiation effect

An inversely relationship between solar radiation and bioaerosol was found, especially under high radiation, at noon with 32000 LUX the result was 796CFU/M³, thereby the pollution values increased under less solar radiation, where at point with very low radiation with 265 LUX, the bioaerosol pollution was very high with 13933 CFU/M³. Figure.10 showing the solar radiation effect on bioaerosol pollution.
4 CONCLUSIONS

Planting covers, shading and solar radiation affect bioaerosol pollution in WWTPs, working by ASP. There is a direct relationship between bioaerosol pollution and planting density. Increasing of planting cover from PCR=0 to PCR=3.25 increases the bioaerosol pollution from 1366 CFU/M$^3$ to 14597 CFU/M$^3$. Also there is a direct relationship with shading ratio. Adding shades rise up the bioaerosol pollution from 4976 CFU/M$^3$ to 19704 CFU/M$^3$ in full shaded area. Conversely, there is an inversely relationship between solar radiation and bioaerosol pollution by absence of sun radiation, the bioaerosol pollution increased, under solar radiation of 32000LUX and 289LUX the pollution values were 796 CFU/M$^3$ to 13933 CFU/M$^3$ respectively.

Developing the design criteria and best practices for either new or working WWTPs to minimize the bioaerosol hazard inside and around the WWTPs. Increasing the solar radiation amount in WWTPs is nodded, especially around the aeration tanks. And more solar radiation amount must be provided for indoor areas inside buildings around the WWTPs.

Choosing a sunny place away from buildings or agriculture areas to implement new WWTPs, and aeration tanks should to be located away from any buildings or fixtures causing shades. Minimizing the planted areas, plants density and shade in WWTPs, especially in downwind direction and quit it near the aeration tanks.

ACKNOWLEDGMENTS

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ABBREVIATIONS

- ASP: Activated sludge processes
- CEC: Commission of European Communities
- CFU: Colony forming units per
- LUX: Luminous flux per unit area
- M$^3$: Cubic meter
- PCR: Planting cover ratio
- SR: Shading ratio
- WWTP: Waste water treatment plant

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Figure 1. The bioaerosol that is generated above aeration tanks.

Figure 2. Petri dishes at sampling time.
Figure 3. Mansoura WWTP Location

Figure 4. Meet-Mazah WWTP Location
Figure 5. Mansoura WWTP description

Figure 6. Meetmazah WWTP description
Figure 7. Bioaerosol pollution distribution in Mansorah and Meet-Mazah WWTPs

Figure 8. Planting cover effect on bioaerosol pollution
Figure 9. Shading effect on bioaerosol pollution

Figure 10. Solar radiation effect on bioaerosol pollution