# Assessment Of The Waste Stabilization Pond Performance, New Borg El-Arab City

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## ABSTRACT

New Borg Al-Arab city includes 9 residential areas and 4 industrial zones. The four industrial zones are occupied by 266 running factories belonging to different industrial sectors. All the domestic sewage as well as the industrial wastewater is treated at an oxidation pond treatment plant and the plant effluent is used in irrigation of silviculture areas. The plant consists of 2 pond complexes. Each complex comprises 9 facultative ponds, arranged in 3 parallel series. Raw wastewater is pre-treated through screens and grit removal before entering the primary ponds. The study aims at assessment of the performance of the waste stabilization ponds. The results revealed that pre-treatment units were not functioning properly. The retention time was calculated to be 6 days in each pond of the first complex and 3 days in each pond of the second complex. The mean BOD surface loading rate was calculated to be 676 kg/ha/d for the first complex and 1584 kg/ha/d for the second. The plant was hydraulically and organically overloaded. The percentage removal of BOD, COD, SS, and $NH_3$-N had an annual mean of 57%, 56%, 44%, and 39%, respectively for the first complex and 21%, 42%, 39%, and 25%, respectively for the second. Faecal coliforms were reduced by about 1 $log_{10}$ unit in both complexes. The final pond effluent was not complying with the Egyptian law for reuse in irrigation. The study proposed some recommendations which can improve the efficiency of the plant as well as the effluent quality.

*Key words: Stabilization pond, New Borg El-Arab, Domestic sewage, Industrial Wastewater, Efficiency.*

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## INTRODUCTION

Wastewater may be domestic sewage, effluents from industrial and commercial activities, storm water, or a combination of all. They are often collected in combined sewers and are usually treated at a municipal wastewater treatment plant. Wastewater entering the treatment plant may contain organic pollutants, heavy metals, nutrients, pathogenic micro-organisms in addition to substances released by different industries. These components interfere with proper functioning of the municipal plant, or the plant may be unable to remove noxious pollutants and pass them into receiving waters. Also, municipalities often want to use biosolids for beneficial purposes; and the presence of certain industrial pollutants may make these applications impossible or more difficult.(1)

Waste stabilization ponds (WSPs) are one of the secondary treatments. They consist of man-made ponds or lagoons enclosed by earthen embankments, where wastewater is allowed to stand for a sufficiently long period of time under the influence of micro-organisms and the forces of nature so that it is converted to an effluent that meets the quality standards for final disposal or reuse.(2) There are many advantages associated with $WSP_5$ including no skilled labour is required; capital, operational, and maintenance costs are low; Biological Oxygen Demand ($BOD_5$) removal efficiency is high; can tolerate shock organic loads and toxicants; more efficient in the removal of bacteria, protozoa, and helminthes ova; a minimal sludge production; the effluent can be used in agriculture as well as in aquaculture; and the algal biomass can be harvested for animal feeding. The only disadvantages of $WSP_5$ are : the need of land at low cost and the plenty of sunshine.(3)

Ultimately, after appropriate treatment, the treated effluent is generally disposed off by either reuse or by discharge to surface waters.[4] In order to protect the environment and human health, there should be a comprehensive strategy for the application of reclaimed wastewater in irrigation. In such strategy, 4 groups of measures should be taken: reliable wastewater treatment, crop restriction, choice of method of application of the treated effluent to the soil, and control of the human exposure to the waste.[5]

The New Borg El-Arab city (NBA) is located 60 km from Alexandria. The prevailing climate of the area is arid, with a long dry fairly hot summer and a shorter cool to warm winter. The mean daily temperature is 21°C. The wind has an average speed of 9.56 km/h with a north east direction except in winter. The mean annual rain fall is 147 mm. The city includes nine residential areas and 4 industrial zones. A total number of 5,000,000 inhabitants are to be expected by the year 2010. Four industrial zones (I, II, III, and IV) are actually occupied by 510 factories.[6]

The wastewater of most of the residential and the industrial zones in NBA city are discharged to a WSP- treatment plant. The plant yet.[6] The study aims at assessing the performance of the waste stabilization pond.

## MATERIAL AND METHODS

This study was performed along one year. Evaluation of the WSP treatment plant performance was performed according to the following:

1. Determination of hydraulic mean retention time within each pond.
2. Estimation of the performance of the pre-treatment unit.
3. Determination of surface $BOD_5$ loading rate on the first facultative pond.
4. Determination of the efficiency of the pond complex

These steps were carried out through the following:

- Grab samples from the pond influent, all ponds content, and final effluent were collected and analyzed. Sampling was performed 3 times per season during the 4 seasons of the year for the first complex. Concerning the second pond complex, it was empty during autumn and summer seasons in addition to the end of spring season. Hence, sampling took place only 5 times from this complex. The samples were analyzed according to the Standard Methods for the Examination of Water and Wastewater.[7]

- Mean values and percent removals of some parameters were calculated.

- Since the final effluent of the pond series is being used for irrigation, additional parameters were measured in the final effluent. The results of the final effluent analyses were compared with the recommended standards[4] and by Egyptian Authorities[8] for reuse of treated wastewater in irrigation.

## RESULTS AND DISCUSSION

### 1. Evaluation of the Pre-treatment Units

Due to poor maintenance, the pre-treatment units are not frequently cleaned leading sometimes to an increase in the pollutional load of the wastewater reaching the ponds. This is presented in table (1) which shows the percentage increase or decrease in the measured parameters for complexes I and II.

The results for complex I showed that pH, TDS, total $PO_4^{3-}$ concentrations, and faecal coliform (FC) count showed no marked changes following screening and grit removal. As for $NO_3^-$, they were not detected in most of the samples. Ammonia-N, by its turn was always found to decrease by about 50%. Concerning the other parameters, they were fluctuating between high percentages of increase and decrease with an overall average of 11.7%, 41%, 20.7%, and 10.5% increase as regards SS, settleable solids, $BOD_5$ and COD, respectively. Oil and grease were reduced by approximately 29%.

Concerning $WSP_5$ complex II, no significant changes were detected for pH, TDS, $NH_3$-N, $NO_3^-$, $PO_4^{3-}$, and FC following pre-treatment. The variations of the other parameters showed a better performance than the pre-treatment unit of complex I. Suspended and settleable solids showed average decrease patterns of 38.8% and 10%, respectively. $BOD_5$ was oscillating between reduction and increase levels with an overall average decrease of 15%. Regarding COD, it was generally reduced with a mean of 17%. This was the same pattern for O&G except for one sample where the effluent from the screens and grit chamber was full of gazoline and hence higher levels of O&G were detected.

**Table (1): Percentage Increase (+) or Reduction (-) of some Parameters in the Raw Wastewater after Screening and Grit Removal in Complexes I and II of the Treatment Plant of NBA (1999-2000).**

| Parameter Samples | S.S. (mg/l) | | Settleable solids 30 min (ml/l) | | $NH_3$-N (mg/l) | | $BOD_5$ (mg/l) | | COD (mg/l) | | O&G (mg/l) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Complex | I | II | I | II | I | II | I | II | I | II | I | II |
| 1 | +73.8 | -28.4 | +100 | 0 | -50 | | -42 | +6.1 | -18.5 | 0 | -11.3 | +67.5 |
| 2 | -19.4 | -40.8 | 0 | +25 | -60 | | +37.5 | -43.8 | -25 | -29.6 | -24.5 | -25.3 |
| 3 | +65.5 | -65.3 | +300 | 0 | -33 | | +44 | 0 | -6.7 | -3.6 | -68 | -24.5 |
| 4 | -13.7 | +13.9 | -100 | -31 | -50 | | -70 | -53.9 | -27.7 | -38.9 | +8.2 | -23 |
| 5 | +33.3 | -7.33 | +100 | -44 | -57.1 | | -4 | +17.2 | -9.4 | -13.1 | +3.6 | -32.4 |
| 6 | -46.4 | | -6.25 | | -50 | | +13.6 | | +3.2 | | -8.7 | |
| 7 | +26.1 | | -100 | | -50 | | +82 | | -35.9 | | -90 | |
| 8 | +6.9 | | -100 | | -25 | | 0 | | -78 | | -98 | |
| 9 | -1.9 | | -100 | | -20 | | -42.9 | | -69.2 | | -87 | |
| 10 | -13.9 | | +600 | | -10 | | +87.5 | | +132 | | +18 | |
| 11 | +18.8 | | -100 | | -55.6 | | +87 | | +140 | | -1.3 | |
| 12 | +10.8 | | -100 | | -100 | | +55.6 | | +121.4 | | +12.9 | |
| Average | +11.7 | -38.8 | +41 | -10 | -46.7 | | +20.7 | -14.9 | +10.5 | -17.0 | -28.8 | -7.5 |

## 2. Hydraulic Retention Time (RT)

Calculation of the retention time (volume/flow) of the present study showed that concerning the first complex, it was approximately 6 days/pond with an overall of 18 days when the influent runs in the 3 ponds in series. As regards pond complex II, the RT was approximately 3 days/pond with a cumulative RT of 9 days for the whole pond series.

They are shorter than recommended by Environmental Protection Agency (EPA) who stated that a typical R.T. for facultative ponds would vary from 20 to 180 days especially in northern climates.(9) They are also shorter than what have been found in southern France (40 days)(10) and in north-east Brazil where the total R.T. is 60 days which provides an excellent effluent quality. Such effluent was thus suitable for unrestricted irrigation. In contrast, a R.T. varying from 9-19 days produced effluents of much lower bacteriological and parasitological quality and thus unsuitable for either irrigation or aquaculture.(11)

According to WHO standards, when facultative ponds are used as primary ponds in climates where the average air and water temperatures do not go below 10°C and 15°C, respectively, the minimum R.T. will be tens of days (10-50 days). This will achieve the required degree of treatment.(12)

From the previous discussion, it was evident that the ponds of the present study were hydraulically overloaded and consequently, the entire efficiency of such systems would be doubtful. It seems that they were designed for a lower flow.

## 3. Analytical Characterization of Both WSP Complexes

### *3.1 Influent characterization*

Tables (2) and (3) include the analytical characterizations of the influent for both $WSP_5$ complexes. As evident from the statistical analysis (t-test), there is a significant difference between the influent to both complexes as regards COD/BOD ratio. Therefore, the contribution of domestic wastewater with industrial stream was considered the main factor influencing the biodegradability of the influent.

Concerning total phosphate concentration, higher values were found to reach the pond complex II due to the large amounts of detergents used in cleansing purposes within the industrial plants. Similarly, higher concentrations of O&G were disposed off to the same complex. This probably might be generated from the industries deprived from oil trap in addition to the machinery lubricants escaping to the final effluents of the plants.

As for the FC count, these were expected to be higher in the first complex influent, which indeed was the case; but still high number of the pathogen existed in complex II influent. This was generally from the sanitary wastewater discharged from different plants with their waste stream.

Table (4) presents the surface and the volumetric loading rates ($\lambda s$ and $\lambda v$) for all facultative ponds of both complexes. It is clear that the loading rate decreases throughout the pond system.

The mean surface $BOD_5$ loading rates ($\lambda_s$) for both complexes (I&II) were calculated to be 676 and 1584 Kg/ha/d, respectively. They illustrate that the systems were really overloaded as they disagree with the recommendation of Mara (1997)[13] (100-400 Kg $BOD_5$/ha/d is essential for good performance of $WSP_5$).

In NBA oxidation pond treatment plant, anaerobic conditions were prevailing in the primary ponds of both complexes. So, when the organic loads applied to these ponds were calculated as volumetric $BOD_5$ loading rate ($\lambda v$) as is the case for anaerobic ponds, they revealed the following: For complexes I&II, the mean loads were calculated to be 57 and 132 $g/m^3.d$. Since the anaerobic ponds can tolerate 160-800 $g/m^3.d$ $BOD_5$ loading rate,[14] therefore, these primary ponds could accomplish some of the biological degradation of the organic matter present in the influent.

### *3.2. Evaluation of the pond performance*

Tables 2 and 3 present the analytical characterization of the raw influent, pond contents, and final effluent of the $WSP_5$ complexes during the different seasons. These results were computed as seasonal mean from the individual data.

#### *3.2.1. Physical and chemical characteristics*

It was found that pH values showed a gradual increase throughout the pond series and were usually oscillating between 6.2 and 8.4. Higher pH values were not encountered due to the short hydraulic R.T. in both complexes. This was supported by Mayo(1996)[15] who concluded that the pH of the final pond effluent increased with longer hydraulic R.T.

As for DO, although designed as facultative ponds, the first and second ponds in each series of both complexes appeared to be anaerobic as evidenced by the absence of DO. Exception of this case was during spring season where the first facultative pond in the first complex showed 0.8 mg/l DO and the second was of 2 mg/l concentration. This might be due to the less surface organic load applied to the pond system in spring.

**Table (2): Physico-chemical and Biological Parameters Determined for Evaluating the Performance of the Oxidation Pond Complex I Located in NBA City during the Different Seasons, 1999-2000.**

| Samples Parameter | Influent | | | | F.P 1 | | | | F.P2 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Season | Winter | Spring | Summer | Autumn | Winter | Spring | Summer | Autumn | Winter | Spring | Summer | Autumn |
| Temperature | 18 | 26 | 32 | 28 | 18 | 26 | 32 | 28 | 18 | 26 | 32 | 28 |
| PH | 7.1 | 7.2 | 7.8 | 6.2 | 7.2 | 7.7 | 7.9 | 6.6 | 7.5 | 7.8 | 8.0 | 7.2 |
| DO mg/L | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 | 0 | 0 | 2 | 0 | 0 |
| Settleable solids ml/L (10min) | 0.2 | 3.7 | 0 | 2 | 0 | 0.2 | 0 | 0 | 0 | 0.2 | 0 | 0 |
| Settleable solids ml/L (30min) | 0.5 | 3.2 | 0 | 2.3 | 0 | 0.2 | 0 | 0.1 | 0 | 0.2 | 0 | 0 |
| TDS mg/L | 1280 | 863 | 1567 | 683 | 1279 | 545 | 1412 | 526 | 1275 | 782 | 1311 | 786 |
| SS mg/L | 391 | 228 | 203 | 354 | 330 | 215 | 146 | 187 | 368 | 200 | 110 | 184 |
| $BOD_5$ mg/L | 313 | 240 | 380 | 387 | 300 | 144 | 120 | 120 | 287 | 108 | 120 | 113 |
| COD mg/L | 517 | 580 | 600 | 623 | 500 | 350 | 500 | 240 | 373 | 280 | 200 | 227 |
| O & G mg/L | 219 | 290 | 21 | 241 | 214 | 154 | 15 | 19 | 213 | 144 | 12 | 15 |
| $NH_3$ mg/L | 10 | 9.2 | 14 | 19 | 9 | 7.3 | 10 | 15 | 8 | 5.8 | 22 | 7.3 |
| $NO^-_3$ mg/L | 0.8 | 1.7 | 0 | 0 | 0.8 | 1.7 | 0 | 0 | 0.8 | 1.7 | 0 | 0 |
| $PO^{3-}_4$ mg/L | 7.5 | 6.8 | 5 | 5.1 | 20.5 | 7.7 | 0 | 4.3 | 9 | 8.3 | 0 | 1.5 |
| Faecal coliform/100ml | $9.1x10^8$ | $9.3x10^8$ | $3.5x10^9$ | $7.5x10^9$ | $7.2x10^8$ | $2.9x10^8$ | $3.5x10^9$ | $4.6x10^9$ | $7.2x10^8$ | $3.6x10^3$ | $3x10^9$ | $2.4x10^9$ |
| Total Algal count/L | | | | | $5x10^4$ | $98x10^3$ | $172x10^4$ | $48x10^3$ | $21x10^4$ | $234x10^3$ | $176x10^4$ | $56x10^3$ |
| Algal Genera | | | | | ***Oscillatoria*** | *Oscillatoria* | *Agmenellum* | *Oscillatoria* | *Oscillatoria Eudorina* | *Oscillatoria Eudorina* | *Oscillatoria Eudorina* | *Oscillatoria* |

**Table (2): Continued.**

| Samples Parameter | F.P3 | | | | Effluent | | | |
|---|---|---|---|---|---|---|---|---|
| Season | Winter | Spring | Summer | Autumn | Winter | Spring | Summer | Autumn |
| Temperature | 18 | 26 | 32 | 28 | 18 | 26 | 32 | 28 |
| pH | 8.2 | 8 | | | 7.7 | 8 | 8.0 | 7.5 |
| DO mg/L | 2.2 | 2.1 | | | 2.2 | 2.1 | 0 | 0 |
| Settleable solids ml/L (10min) | 0 | 0 | | | 0 | 0 | 0 | 0 |
| Settleable solids ml/L (30min) | 0 | 0 | | | 0 | 0 | 0 | 0 |
| TDS mg/L | 1744 | 822 | | | 1845 | 858 | 1244 | 790 |
| SS mg/L | 353 | 189 | | | 172 | 169 | 89 | 222 |
| $BOD_5$ mg/L | 247 | 97 | | | 247 | 80 | 120 | 107 |
| COD mg/L | 393 | 200 | | | 393 | 187 | 200 | 227 |
| O & G mg/L | 176 | 110 | | | 174 | 103 | 5 | 31 |
| $NH_3$ mg/L | 6.3 | 3.8 | | | 5 | 3.8 | 22 | 10 |
| $NO^-_3$ mg/L | 2.5 | 1.7 | | | 2.5 | 1.7 | 0 | 0 |
| $PO^{3-}_4$ mg/L | 13.5 | 8.8 | | | 8.2 | 8.8 | 0.5 | 1.5 |
| Faecal coliform/100ml | $2.3x10^8$ | $3.6x10^3$ | | | $2.3x10^8$ | $3.6x10^3$ | $2.7x10^9$ | $2.4x10^9$ |
| Total Algal count/L | $32x10^4$ | $1352x10^3$ | | | | | | |
| Algal Genera | *Oscillatoria* *Eudorina* | *Oscillatoria* | | | | | | |

*F.P = Facultative pond* *F.P3 in Summer and Autumn are by-passed*

**Table (3): Physico-chemical and Biological Parameters Determined for Evaluating the Performance of the Oxidation Pond Complex II Located in NBA City during Winter and Spring Seasons, 1999-2000.**

| Samples Parameter | Influent | | F.P 1 | | F.P 2 | | F.P 3 | | Effluents | |
|---|---|---|---|---|---|---|---|---|---|---|
| Season | Winter | Spring | Winter | Spring | Winter | Spring | Winter | Spring | Winter | Spring |
| Temperature | 16 | 24 | 16 | 24 | 16 | 24 | 16 | 24 | 16 | 24 |
| pH | 7 | 7 | 7.3 | 7.4 | 7.5 | 7.4 | 8.4 | 7.4 | 8.2 | 7.3 |
| DO mg/L | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 | 0.8 |
| Settleable solids ml/L (10min) | 3.7 | 90 | 0 | 3.5 | 0 | 0 | 0 | 0 | 0 | 0.3 |
| Settleable solids ml/L (30min) | 4 | 65 | 0 | 2.5 | 0 | 0.5 | 0 | 0 | 0 | 0.5 |
| TDS mg/L | 2667 | 2394 | 2029 | 2404 | 2886 | 2332 | 2316 | 2290 | 2211 | 2240 |
| SS mg/L | 630 | 408 | 569 | 349.5 | 480 | 216.5 | 394 | 223 | 392 | 242 |
| $BOD_5$ mg/L | 240 | 520 | 233 | 375 | 307 | 325 | 253 | 275 | 203 | 385 |
| COD mg/L | 713 | 1310 | 597 | 937.5 | 563 | 717.5 | 510 | 595 | 470 | 650 |
| O & G mg/L | 460 | 480 | 295 | 182.5 | 260 | 26.4 | 232 | 10 | 250 | 68 |
| $NH_3$ mg/L | 4.3 | 9.5 | 4.3 | 4.5 | 4.3 | 7.5 | 4.3 | 3.5 | 4 | 5.5 |
| $NO^-_3$ mg/L | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| $PO^{3-}_4$ mg/L | 20 | 21.5 | 22 | 16 | 12 | 13 | 13 | 9.5 | 15.7 | 9 |
| Faecal coliform/100 ml | $24 \times 10^3$ | $1.6 \times 10^4$ | $24 \times 10^3$ | $46 \times 10^2$ | $24 \times 10^3$ | 580 | $2.4 \times 10^3$ | 930 | $2.4 \times 10^3$ | $5.80 \times 10^2$ |
| Total Algal count/L | | | 4666 | $96 \times 10^2$ | $65 \times 10^3$ | $54 \times 10^3$ | $142 \times 10^3$ | $66 \times 10^3$ | | |
| Algal Genera | | | *Oscillatoria* | Agmenellum | Oscillatoria Eudorina | *Agmenellum* | *Oscillatoria Eudorina* | *Eudorina Diatoms* | | |

*F.P = Facultative pond*

Regarding SS, they were generally decreasing in the first complex. Their concentrations in the final effluents were ranging from 89 to 222 mg/l with an annual mean of 163 mg/l. On the other hand, for the second complex, they were not greatly reduced and varied from 242 to 392 mg/l. Suspended solids in the effluents might be attributed to the growth of microalgae *Spirulina* and other photosynthetic bacteria followed by their release in the effluents. Therefore the outlet design of the last pond should be deep enough in order to retain algae in the ponds. Retention of algae would not only reduce the SS, soluble $BOD_5$, and COD in the effluents, but would also improve the pond performance.[15]

Concerning $BOD_5$ and COD, they showed a decrease pattern throughout both pond complexes, but still, remained high at the outlets. This might be caused by the prevailing anaerobic conditions that reduce the rate of organic degradation within the ponds. So, after the 3 facultative ponds, an effluent was achieved with an unfiltered mean $BOD_5$ concentration of 139 mg/l for complex I. As regards the second complex, conditions were worst since the effluent $BOD_5$ mean concentration was 294 mg/l. Thus, both pond complexes failed to meet the maximum permissible effluent of $BOD_5$ and SS concentrations (<40 mg/l $BOD_5$ and <120 mg/l SS).[16]

These results of $BOD_5$ were contrary to those found by Mara et al (2001)[17] (an effluent of 10 mg/l unfiltered $BOD_5$ concentration). They attributed such appreciable effluent quality to the anaerobic pond preceding the facultative ones since 66% of the reduction in $BOD_5$ occurred in it.

Concerning the efficiency of complex I in removing $NH_3$-N, it was found to decrease by about 50% except in summer season where a 57% increase in its value was obvious. Ammonia volatilization being the mechanism of removal as the pH in the ponds is above 7.[18] The increase in summer could be contributed to the anaerobic conditions generating $NH_3$ within the ponds coupled with shorter RT resulting from by-passing the third pond to supply the forest with the sufficient amount of water necessary in that hot arid climate.

As regards P of complex I, it was fluctuating between high removal percentages of 71 and 90% for autumn and summer seasons, respectively and somewhat low percentages of increase in winter and spring (9% and 29%, respectively). Phosphorus removal occurs by assimilation into the biomass of algae and bacterial cells, in addition to precipitation as $Ca_3(PO_4)_2$ during daylight hours. Generally, the effluent phosphate concentration is less than half of the influent wastewater to the lagoon system.[19] Phosphorus increase could be attributed to the release of some of the phosphates captured in the sediment. In addition, the phosphorus content entering into the algal cell, still suspended in the effluent, could also explain the increase in its concentration in the final effluent. Nevertheless, the overall annual phosphate removal percentage was computed to be 22%.

As for nutrients removal by the second WSP complex, the study revealed that $NH_3$-N and total phosphates were gradually reduced to reach mean concentrations of 4mg/l and 5.5mg/l for the first and 15.7mg/l and 9mg/l for the latter for final effluent in winter and spring, respectively.

### 3.2.2. *Biological characteristics*

In NBA pond complexes the performance of both of them was very low as far as the faecal coliforms indicator were concerned. Their counts in the influents of both complexes (I&II) were varying between $7.5x10^9$ and 4600/100ml, respectively. In many times, these counts were the same in the final effluents. Therefore, the WHO guidelines (≤1 intestinal nematode egg/l and ≤1000 faecal coliform/100 ml to permit its reuse in unrestricted irrigation)[20] had never been achieved during the study. Nonetheless, they were obtained by Mara et al(2001) after an overall R.T. of only 11 days.[17] This confirmed the importance of the high algal-induced pH for the F.C. die-off in pond series. A correlation between pH and FC log count was developed by Curtis where the number of FC were ≤1000/100ml for pH values greater than 9.1 in the pond effluents. Curtis also suggested that FC removal was multi-factorial dependent.[21]

In contrast to FC, no helminth eggs were found in the effluents of any of the pond series. Their removal mechanism could be attributed to the sedimentation within the sludge layer. This was in agreement with Ayres et al.,(1995)[22] who found that a pond with a mean hydraulic RT of 5 days should remove 95.6% of parasitic ova.

As regards algae in the WSPs systems of NBA city, the blue-green algae were found to be the predominant genera replacing to a great extent the more efficient green algae. Blue-green algae were represented by *Oscillatoria (Cyanophyta)* and sometimes *Agmenellum*, while green algae were represented by *Eudorina (Chlorophyta)*. The reason for such predominance might be the high organic load applied since the primary ponds of both complexes were always containing *Oscillatoria* species that were gradually replaced in the second or third ponds by the green algae. Diatoms such as *Melosira* were also encountered in spring. Concerning the algal count, it was noticed that it was in continuous increase throughout the pond system as long as the organic load was decreased. This algal count was generally in the order of $10^4$-$10^6$cell/l where higher values were obtained in the hot summer season. In Brazil, the predominant photosynthetic genera was *Microcystis*.[11]

**Table (4): $BOD_5$ Concentration in mg/l, λs in kg/ha.d and λv in $g/m^3$.d for all Facultative Ponds of Complexes I & II in NBA Oxidation Pond Treatment Plant.**

| Sample | FP1 | | | | | | FP2 | | | | | | FP3 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Complex | I | II | I | II | I | II | I | II | I | II | I | II | I | II | I | II | I | II |
| Parameter | BOD | | λs | | λv | | BOD | | λs | | λv | | BOD | | λs | | λv | |
| Winter | 313 | 240 | 641 | 1000 | 54 | 83 | 300 | 233 | 615 | 971 | 51 | 81 | 287 | 307 | 588 | 1279 | 49 | 107 |
| Spring | 240 | 520 | 492 | 2167 | 41 | 181 | 144 | 375 | 295 | 1563 | 25 | 130 | 108 | 325 | 221 | 1354 | 18 | 113 |
| Summer | 380 | | 779 | | 65 | | 120 | | 246 | | 21 | | - | | - | | - | |
| Autumn | 387 | | 793 | | 66 | | 120 | | 246 | | 21 | | - | | - | | - | |
| Average | 330 | 380 | 676 | 1584 | 57 | 132 | 171 | 304 | 350 | 1267 | 30 | 106 | 198 | 316 | 405 | 1317 | 34 | 110 |

*λs = surface loading rates* *λv = volumetric loading rates*

BOD, COD, and SS, respectively, and poor $NH_3$ removal of only 13%.[25]

### *3.3. Pond performance:*

Table (5) shows the calculated removal percentages of $BOD_5$, COD, SS, $NH_3$–N, and $log_{10}$ unit reduction of FC count in both complexes. It is clear that the first complex was working reasonably well with 57%, 55.5%, 43.8%, and 39% removal for BOD, COD, SS, and $NH_3$, respectively, while FC count was reduced only by 1 $log_{10}$ unit. On the contrary, WSP complex II was not performing as it should be with respect to $BOD_5$ removal (21%) and $NH_3$-N removal (24.6%). This might be due to the higher organic load applied to this complex (1583 kg/ha/d) besides the shorter RT (3 days) within each pond, and the fewer number of bacteria present in the influent. Nevertheless, about 42% COD and 39% SS removals were achieved.

Similarly, in the WSP of Lorqui-ceuti in Spain, the annual mean reduction in $BOD_5$ and COD were 50% and 35%, respectively. However, the mean overall reduction of $NH_3$-N was 25% and FC count was reduced from $7x10^6$/100ml to $4x10^5$/100ml in the effluent. This reflected a poor performance of the lagoons in this respect.[23] This was not in accordance with Al-samra WSPs in Jordan which were overloaded hydraulically by a factor of 2.2. Nonetheless, their performance was remarkably good with 73-85% BOD removal and FC count in the final effluent of 1240/100 ml.[17] With respect to COD in France,[24] the mean removal percentages in the summer and winter were 66.6 and 60.6, respectively. That of SS, were 80.9 and 73.2, respectively.

In Egypt, evaluation of the performance of Adliya WSP system in Delta region showed that although the system was subjected to anoxic conditions due to overloading, it could remove 86, 77, and 62% for

**Table (5): Percentage Removal of $BOD_5$, COD, SS, $NH_3$-N and $log_{10}$ Unit Re
Located in NBA City during the Different Seasons of the Year (1999-2**

| Parameter | $BOD_5$ | | COD | | SS | |
|---|---|---|---|---|---|---|
| Complex | I | II | I | II | I | II |
| Winter | 21.1 | 15.4 | 24 | 34.1 | 56 | 37.8 |
| Spring | 66.7 | 26 | 67.8 | 50.4 | 25.9 | 40.7 |
| Summer | 68.4 | | 66.7 | | 56.2 | |
| Autumn | 72.4 | | 63.6 | | 37.3 | |
| Mean | 57 | 20.7 | 55.5 | 42.3 | 43.8 | 39.3 |

*FC = Faecal colifrom*

As for $NH_3$-N removal, the highest removals reported by Silva *et al.*,(1987)[26] were associated with very high hydraulic RT up to 227 days and depths of 1.2m in a series of ponds.

**4. Disposal of Final Effluent**

Table (6) shows the comparison of the physical, chemical, and biological constituents in the treated effluents of both complexes with the standards recommended by WHO for reuse of pond effluents in agriculture[4] as well as with those recommended by the Egyptian authorities.[8]

The table denoted that most parameters were violating the recommended limits except TDS out of the first complex and helminth eggs being absent from both effluents. With respect to $BOD_5$, the WHO had not specified any standard and this was based on that the pond effluent $BOD_5$ is composed of 60 to 90% algae that constitute a beneficial source of C, N, and P to the soil. Similarly, $NH_3$, $NO_3$, and $PO_4$ are beneficial for crop growing and hence have no limits in both regulations.[11]

In case of heavy metals, they showed extremely high values, table7. Comparison of their values with those stated in the Egyptian regulations[8] or FAO[5] for long-term use of reclaimed wastewater in irrigation, it was obviously concluded that none of them was in compliance with the recommended limits except lead and sometimes zinc.

Finally, as regards FC count, it was clear that the WHO quality guideline for unrestricted use (<1000 cfu/100ml) was not met. Therefore, crops were restricted to trees in a large forest with no access to the public.

**Table (6): Analytical Characterization of the Final Effluent of WSP Com Different Seasons (1999-2000).**

| | Winter | | Spring | | Summer | | Autum |
|---|---|---|---|---|---|---|---|
| **Complex** | I | II | I | II | I | | I |
| pH | 7.7 | 8.2 | 8 | 7.3 | 8 | | 7.5 |
| DO mg/L | 2.2 | ND | 2.1 | 0.8 | ND | | ND |
| TDS mg/L | 1845 | 2211 | 858 | 2240 | 1244 | | 790 |
| TSS mg/L | 172 | 392 | 169 | 242 | 89 | | 222 |
| $BOD_5$ mg/L | 247 | 203 | 80 | 385 | 120 | | 107 |
| COD mg/L | 393 | 470 | 187 | 650 | 200 | | 227 |
| O&G mg/L | 174 | 250 | 103 | 68 | 5 | | 34 |
| NH3-N mg/L | 5 | 4 | 3.8 | 5.5 | 22 | | 10 |
| $NO^{3-}N$ mg/L | 2.5 | ND | 1.7 | ND | ND | | ND |
| $PO_4^{3-}$ mg/L | 8.2 | 15.7 | 8.8 | 9 | 0.5 | | 1.5 |
| $Cl^-$ mg/L | 337 | 1350 | 410 | 970 | 420 | | 37.5 |
| Heavy metals mg/L | 18.696 | 24.23 | 13.859 | 25.63 | 12.486 | | 11.536 |
| FC/100ml | $2.3x10^8$ | $24x10^3$ | $3.6x10^3$ | $5.8x10^2$ | $2.7x10^9$ | | $2.4x10^9$ |
| Intestinal nematode Eggs | None | None | None | None | None | | None |

**Table (7): Determination of Heavy Metal Concentrations in mg/l in the Effluent of WSP Complexes I and II Located in NBA City (1999-2000).**

| | Samples | Mn | Cd | Fe | Zn | Cu | Ni | Pb | Cr |
|---|---|---|---|---|---|---|---|---|---|
| **Complex I** | Winter | 4.23 | 0.042 | 10.39 | 2 | 0.342 | 1.029 | 0.44 | 0.223 |
| | Spring | 2.08 | 0.045 | 8.49 | 0.917 | 0.306 | 1.295 | 0.52 | 0.206 |
| | Summer | 3.16 | 0.070 | 6.047 | 0.776 | 0.266 | 1.360 | 0.49 | 0.317 |
| | Autumn | 2.13 | 0.062 | 6.575 | 0.894 | 0.208 | 1.005 | 0.51 | 0.152 |
| **Complex II** | Winter | 3.17 | 0.038 | 16.12 | 2.24 | 0.715 | 1.049 | 0.61 | 0.288 |
| | Spring | 3.07 | 0.042 | 15.56 | 3.76 | 1.295 | 0.656 | 0.86 | 0.388 |
| **Egyptian guidelines** | | 0.2 | 0.01 | 5 | 2 | 0.2 | 0.2 | 5 | - |
| **FAO guidelines** | | 0.2 | 0.01 | 5 | 2 | 0.2 | 0.2 | 5 | 0.1 |

## CONCLUSION AND RECOMMENDATIONS

Based on the findings of the WSP evaluation, the following conclusions were obtained:

- The pre-treatment units of the oxidation pond treatment plant sometimes increase the pollutional load of the wastewater reaching the ponds.

- No marked changes or small percentage of removal have been noticed following screening and grit removal for most of the measured parameters.

- The hydraulic retention time in each pond was calculated to be 6 days in the first pond complex and 3 days in the second one. This proved that the oxidation pond treatment plant was hydraulically overloaded.

- The mean surface $BOD_5$ loading rate on the first facultative ponds was calculated to be 676 kg/ha/d for the first complex and 1584 kg/ha/d for the second one. This proved that the oxidation ponds were organically overloaded since the recommended $\lambda s$ is 100-400 kg/ha/d.

- Based on the calculated mean volumetric $BOD_5$ loading rate ($\lambda v$) of both complexes I&II (57 and 132 $g/m^3.d$, respectively), the primary ponds of the complexes could accomplish some of the biological degradation of the organic matter present in the influent.

- The percentage removal achieved by the first complex was found to be 57%, 56%, 44% and 39% for $BOD_5$, COD, SS, and $NH_3$-N, respectively. The $\log_{10}$ unit reduction of faecal colifom was 1.

- The percentage removal achieved by the second complex was found to be 21%, 42%, 39%, and 25% for BOD, COD, SS and $NH_3$-N respectively. The $log_{10}$ unit reduction of faecal coliform was 1.3.

- Final effluents from both pond complexes were used in irrigation despite being charged with TSS, COD, O&G, heavy metals, and faecal coliform levels much higher than the standards proposed by the WHO and the Egyptian regulations.

The following are some proposed recommendations to improve the efficiency of the ponds and the effluent quality:

1. Industrial plants are required to implement the possible reuse, recycle, and recovery techniques for pollution reduction in the industrial sectors, and to pre-treat the industrial wastewater violating the law 93/62 prior to its discharge into the sewerage system.

2. Regarding the oxidation pond treatment plant, the followings are recommended:

   a- Maintenance of the pre-treatment units.

   b- Increasing the aeration of the ponds mechanically or transforming the primary ponds to anaerobic ones.

   c- Adjusting the surface organic loads.

   d- Starting the operation of the post chlorination unit.

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