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EFFECTIVENESS OF WASTE STABILIZATION PONDS IN REMOVAL OF LINEAR ALKYL BENZENE SALFONATE (LAS)

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Abstract: Detergents contain synthetic or organic surface active agents called surfactants, which are derived from petroleum product precursors. They have the common property of lowering the surface tensions of water thus allowing dirt or grease adhered to various articles to be washed off. Linear alkyl benzene sulfonate (LAS) is a most commonly used anionic surfactant. Discharge of raw or treated wastewater containing this chemical substance into the environment causes major public health and enviromental problems. In this study, samples were taken from raw wastewater and effluents of treatment ponds of Elzaraby waste stabilization ponds over a period of one year. The treated effluent is either discharged into surface waters or re-used in agricultural irrigation. The samples were analyzed according to the standard methods. The results obtained from the samples taken in different seasons showed that the highest overall removal efficiency of LAS was achieved in summer season (77%), and the least efficiency was observed in Winter season (55%), while the maximum overall efficiency of BOD5 was in summer (88%) and minimum efficiency was (73%) in winter season. The Dissolved oxygen concentrations along the pond series (DO) ranged from 0.18 to 4.8 mg/l.

Keywords: Waste stabilization ponds (WSPs), aniounic surfactant, Linear Alkyl Benzene Salfonate (LAS).

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INTRODUCTION

Waste stabilization ponds (WSP) are large shallow basins enclosed by earth embankments in which raw wastewater is treated by entirely natural processes involving both algae and bacteria (Mara. 2004), WSPs are usually the most appropriate method for domestic and municipal wastewater treatment in developing countries, where the climate is most favorable for their operation. WSPs are low-cost, low-maintenance and highly efficient. The only energy they use is direct solar energy, so they do not need any electromechanical equipment, saving expenditure on electricity and more skilled operation. WSPs can be classified with respect to the types of biological activity occurring in a pond. Three types are distinguished; anaerobic, facultative and maturation ponds. Usually WSPs system comprises a single series of the aforementioned three ponds types or several such series in parallel (H. Ramadan and Victor 2011).

Environment can be affected by wastewater pollutants, such as surfactants (surface-active agents), which enter domestic wastewater treatment plants (WWTPs) through discharge into municipal sewage systems, and cause major public health problems. Surfactants in sewage are found as a result of the use of consumer products like detergents, cleaning and dish washing agents, and personal care products. Surfactants consisted mainly of four types; anionic (negatively charged group), nonionic (uncharged group), cationic (positively charged group) and amphoteric (positive and negative charged group) (Tsz. K. K, 2011). According to the data reported by Comite´Europe´en des Agents de Surface et de leurs Intermediaries Organiques (CESIO) (2004) that 998,000 tons of anionics surfactants and 1,231,000 tons of non-ionics were manufactured during the year 2000 in the EU, these together account for about 90% of the total production of synthetic surfactants.

Linear Alkylbenzene Sulfonate (LAS) (Fig .1) is the most frequently employed synthetic anionics surfactants, whose production amounts to 1,040,000 t/year in the U.S.A., Japan and, Western Europe (Matthew and Malcolm, 2000). After use, LAS are discharged via WWTPs into aquatic environments, sewage sludges after treatment are incorporated into soil as soil fertilizers. Venhuis and Mehrvar (2004) have reported that 0.02–1.0 mg/l of LAS in aquatic environment can damage fish gills, cause excess mucus secretion, decrease respiration in the common goby, and damage swimming patterns in blue mussel larva and LAS concentration of 40~60 mg/kg dry wt. of sludge interfere with the reproduction and growth of soil invertebrates and earthworms. Surfactants are also responsible for causing foam in rivers and effluents of treatment plants and reduction of water quality.

LAS mainly show eye and skin irritation potentials and damage human skin (Eagel *et al.*, 1992). Under field conditions, LAS had acute effect on freshwater plankton and organisms including bacteria up to crustaceans (Venhuis and Mehrvar, 2004). Range of LAS concentration in sewage of 3~21 mg/L has been reported (Hol t and Bernstein, 1992), while McAvoy *et al.* (1993), in USA, monitoring at 50 wastewater treatment facilities in eleven states showed average LAS levels in raw sewage ranging from 4.0 to 5.7 mg /l. LAS levels in raw sewage from five European countries ranged from 4.0 to15.1 mg /1 (DiCorcia *et al.*, 1994; Feijtel *et al.*, (1995)).

Physical and biological methods of sewage treatment partially remove LAS and prevent them from reaching the natural environments. The removal efficiency of LAS depends on the method of treatment. Mungray and Kumar (2007) found that removal efficiency of LAS in two WSPs in India were 88% and 47%. A removal efficiency of LAS more than 99% has been reported by several researchers for activated sludge process ASP. In case of up-flow anaerobic sludge blanket (UASB), the removal efficiency of LAS was found to be 30%, while in trickling filter based STPs, total removals were found to be lower and more variable than ASP It was found in USA, average removals of 83% (Trehy *et al.*, 1996) and 77% (McAvoy *et al.*, 1993).

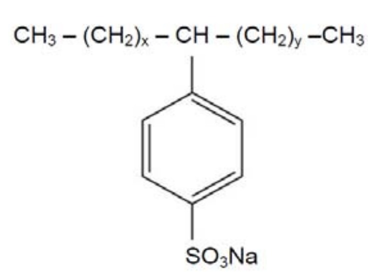

Fig. 1. General chemical structure of LAS, where x and y corresponds with the number of CH2 on each side of the benzene sulphonate group (7x+10y) (Liwarska-Bizukojc, Drews & Kraume, 2008)

Table. 1. Design basis for physical and operational characteristic of Elzaraby WSPs.

Ponds	Dimensions (m)of the water body				Design basis	
	Bottom/top Length (m)	Bottom/top Width (m)	Water Depth (m)	Water Volume (m^3)	Flow rate (m^3/day)	HRT (day)
A1-A2	146/163.6	45.4/63	4.4	37257	8250	4.5
F1-F2	277.8/288.8	154/164	2.5	112680	8250	14
M1-M2	158/164	104/110	1.5	25854	8250	3.0
M3-M4	158/164	104/110	1.5	25854	8250	3.0
M5-M6	158/164	104/110	1.5	25854	8250	3.0

The main objectives of this study are to evaluate the removal efficiency of LAS in an existing system of waste stabilization ponds (WSPs) in Elzaraby village, Abutig, Assiut governorate Egypt. Also some physical and biological characteristics of the waste water through the treatment plant are investigated.

MATERIAL AND METHODS

Description of wastewater treatment plant

A recent full-scale system of WSPs was constructed in 2009 in Elzaraby village in Upper Egypt. Elzaraby WSPs are designed to treat domestic waste water from Abutig city, with mean daily design flow rate of 16500 m^3 /day. The physical characteristics of the ponds are given in Table 1. The wastewater after screening is used to feed two parallel anaerobic ponds (A1~A2). Each anaerobic pond has a square with shape 10790 m^2 top water surface area and 4.4 m working depth. The two effluent of the anaerobic ponds is used to feed two facultative ponds (F1~F2) with top length of 292 m, 166 m top width at the water level and 2.5 m working depth. The effluent from the facultative ponds passes through two parallel lines of maturation ponds. Each line comprising a first, second and third maturation pond, (M1~M6). Each of the maturation ponds has 164 m length and 115 m width at the top water level of ponds and working depth 1.5 m. The treated effluent is either discharged into surface water or reused for agriculture irrigation.

Wastewater sampling

Wastewater samples were collected monthly from the plant through a period of one years, from Spt. 2011 to Aug. 2012 to study the seasonal removal efficiency of LAS in natural WSPs, Monthly-samples of raw wastewater after screening and effluents from each type of ponds were collected (S1to S5) as shown in (**Fig. 2**) of the sampling points. The samples were collected in plastic containers of 2 litre capacity. The following parameter were studied; water temperature (T), pH value, dissolved oxygen (DO), biochemical oxygen demand (BOD_5) and liner alkyl benzene salfonate (LAS). All analysis have been carried out according to standard methods for examination of water and waste water (APHA, 2005). LAS measurement in sampies of sewage as methylene blue active substance (MBAS) using the Spectrophotometer as prescribed in standard methods (APHA, 2005). pH value were measured using; multi meter with pH sensor. Determination of biochemical oxygen demand (BOD_5) by; electronic pressure sensor (Oxidirect) apparatus, determination of dissolved oxygen (DO); multi meter with DO sensor.

RESULTS AND DISCUSSIONS

In this study, a complete one-year monthly samples of wastewater were taken from WSPs of Elzaraby plant from locations S1~S5 totally 60 samples. The average seasonal values of T, pH, DO, BOD_5 and LAS through the ponds were calculated.

Wastewater temperatures in the ponds

The wastewater temperature for the four season of the year from (Spt. 2011 to Aug. 2012) through the water pass in WSPs are illustrated in (**Fig. 3**). Measured temperatures of wastewater through the ponds ranged from 18^0C and 35^0C. The maximum wastewater temperature in anaerobic ponds was 31.8^0C in summer season while the minimum was 22.1^0C in winter season. In facultative ponds, the temperature were ranged from 20.1 ^{0}C to 30.6 ^{0}C in winter and summer, respectively. In the last maturation ponds the minimum and maximum temperatures were 18 ^{0}C in winter and 27 ^{0}C in summer season. As shown in (**Fig. 3**), it is clear that the wastewater temperature decreases along the pass of the ponds and maximum temperature occurs in summer season . The decreasing rate was found to be much higher

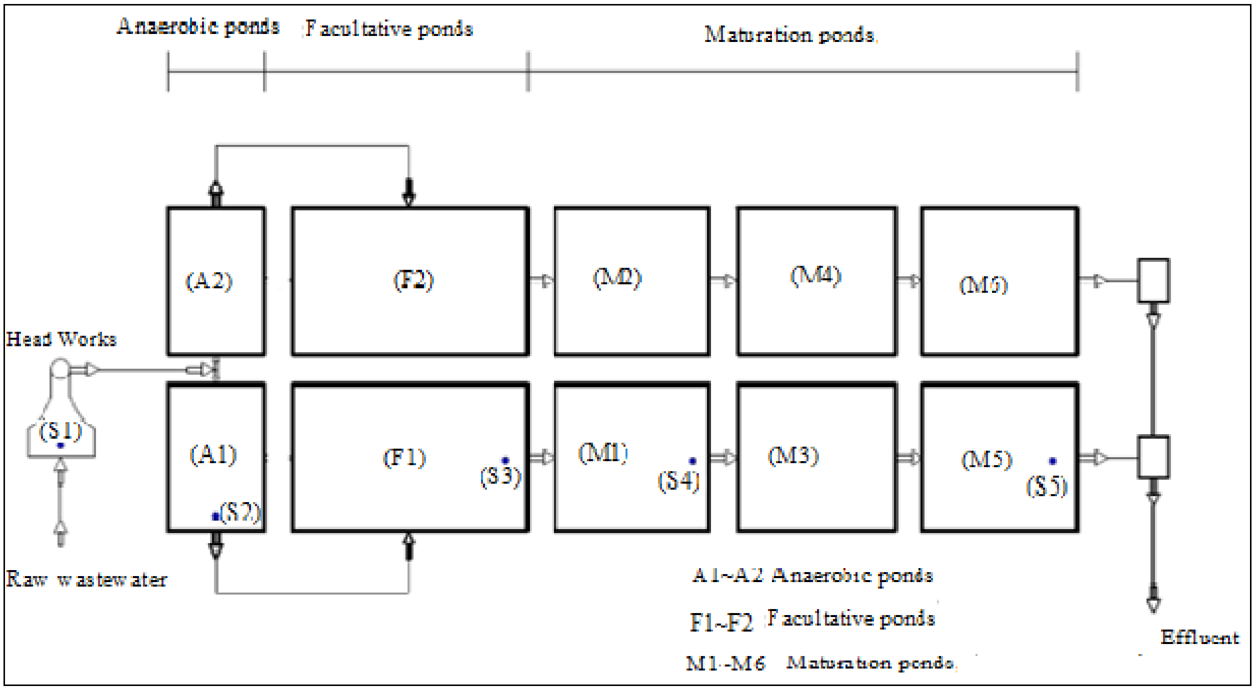

Fig. 2. The layout of Elzaraby WSPs

in the summer season (8^0C) than that in the winter season (4.4^0C), this due to the higher evaporation rate from the surface of the ponds which accomplished with higher latent heat in summer compared with that in winter season.

pH variations along the pond series

The average seasonal variation of the measured pH values for the raw sewage and effluent from each type of ponds in the period from Spt. 2011 to Aug. 2012 are presented in (Fig. 4). The average pH value of raw wastewater ranged between 6.63~7.4, while increased in anaerobic ponds to be 6.75 and 7.8 as minimum and maximum values in winter and summer seasons, respectively. In maturation ponds the measured pH recorded a maximum value in summer 8.8 and a minimum value in winter was 7.7. As shown in (Fig. 4), the pH values of the ponds' wastewater have their it's highest values in the summer season, and it increases along the wastewater pass with the highest values in the last maturation ponds. The increased pH value in maturation ponds is due to rapid photosynthesis by the pond algae, which consumes Carbon dioxide (CO_2)faster than it can be replaced by bacterial respiration; as a result carbonate and bicarbonate ions dissociate. Algae fix the resulting CO_2 from the dissociation while hydroxyl ions (OH^-) accumulate so raising the pH value. Similar results were found by Mahmod et al .(2010).

DO concentration along the ponds series

The seasonal concentrations of DO in raw wastewater were found to be between 0.11 to 0.25 mg/l as a minimum and maximum values in spring and summer seasons, respectively, while seasonal values of DO increased in facultative ponds and recorded a range 1.36~2.5 mg/l in winter and summer seasons, and the average values of DO in the effluent of maturation ponds recorded 3.8, 3.6, 4.93 and 5.8 mg/l in autumn, winter, spring and summer seasons, respectively, as shown in (Fig. 5). It is clear that the value of DO in the summer season increases relative to the winter season, because the rate of algae photosynthesis and the cellular metabolism of microorganisms in the ponds are enhanced by high temperatures and retarded by low temperatures. Algal oxygen production is directly related to photosynthesis, which depends on temperature variations. From the figure, it is clear that the average concentrations of DO along the ponds series ranged from 0.11 mg/l in anaerobic ponds to 5.7 mg/l in the last maturation ponds. Similar results were reported by Nasr *et al.* (2007).

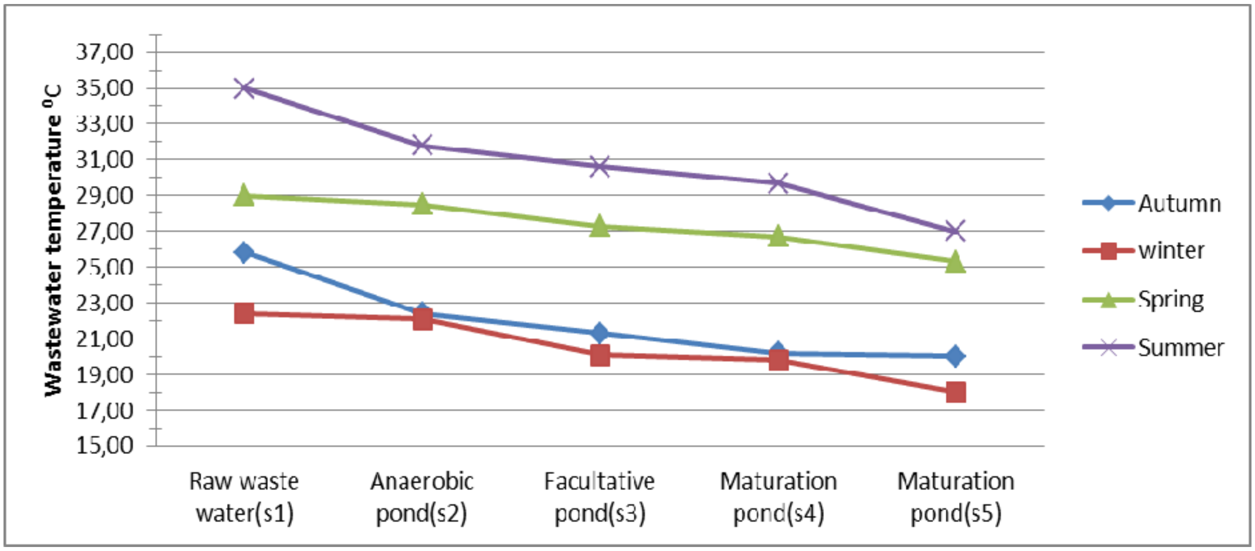

Fig. 3. Wastewater temperature for different season through the wastewater pass in Elzaraby WSPs.

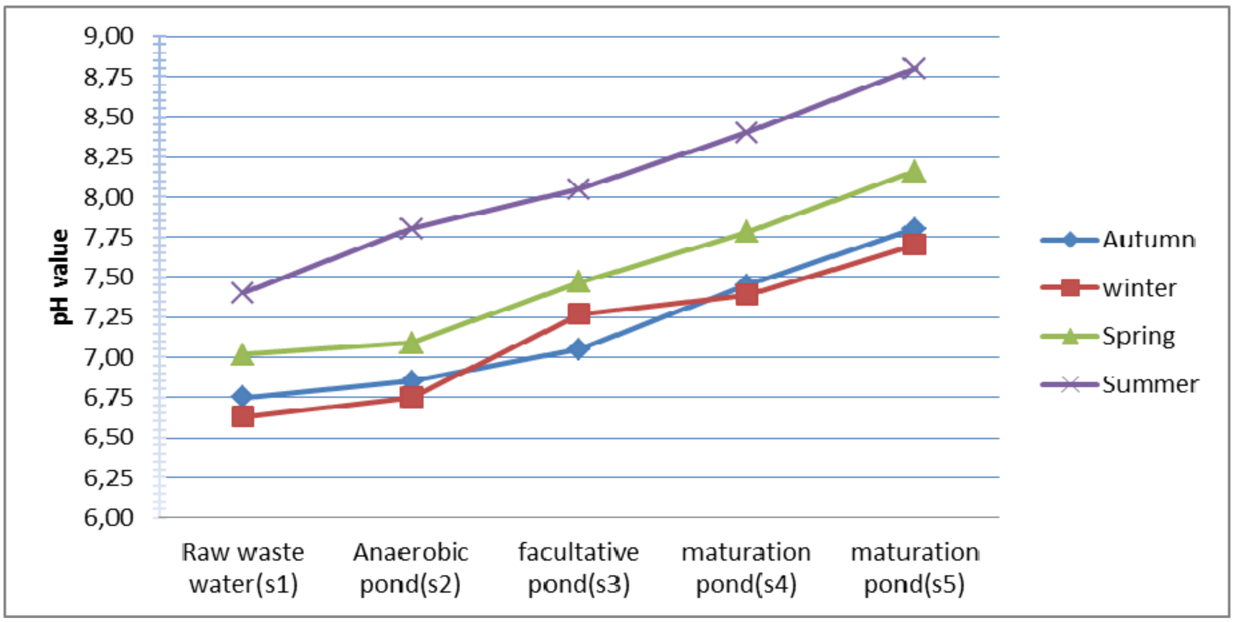

Fig. 4. Seasonal variation of pH value measured along Elzaraby WSPs.

BOD average seasonal concentration value

For comparison the mean values of the measured unfiltered BOD_5 in the different four seasons of the year are plotted as shown in (**Fig. 5**). The average concentration of BOD_5 values in raw wastewater ranged between 426.3 mg /l to 305 mg/l in summer and winter seasons respectively, while they recorded in anaerobic ponds 314~167.5 mg/l as a maximum and a minimum values. In facultative ponds BOD_5 concentrations were found to be ranged between 275~111 mg/l, while the effluent of the last maturation ponds has BOD_5 concentrations of 43.5, 51.5, 55 and 73.3 mg/l in autumn, winter, spring and summer seasons, respectively.

From (**Fig. 6**). It is clear that the maximum BOD_5 values occur in summer season, while the minimum BOD_5 values are in the winter season. The reason of this phenomenon is due to the high tempriture of air and and sun light intensity occurs in summer season relative to other seasons, which increased algal grow (Ali *et al.*, 2005).

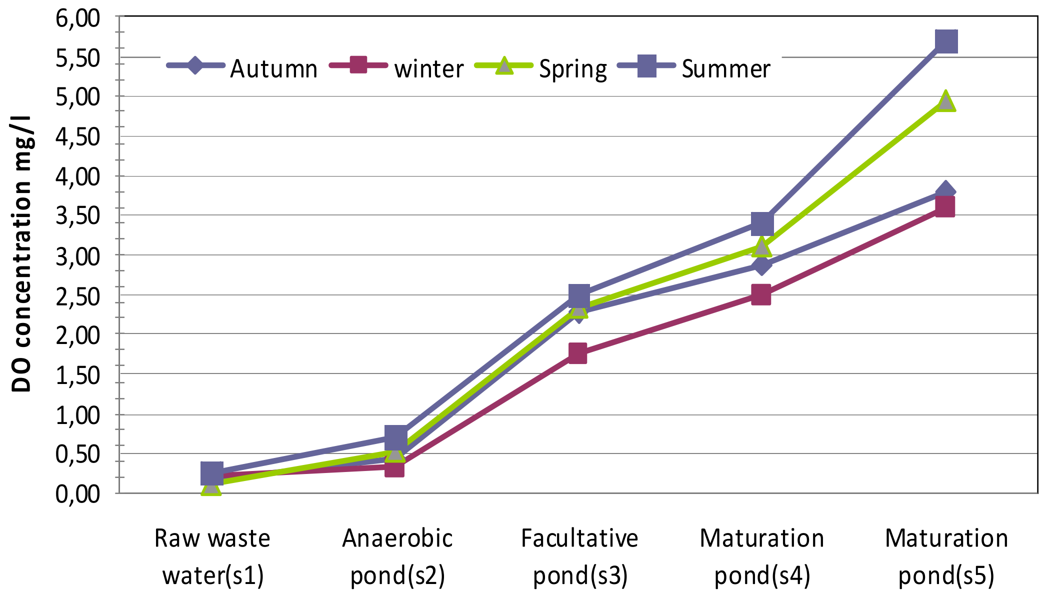

Fig. 5 Seasonal concentration value of DO measured along Elzaraby WSPs.

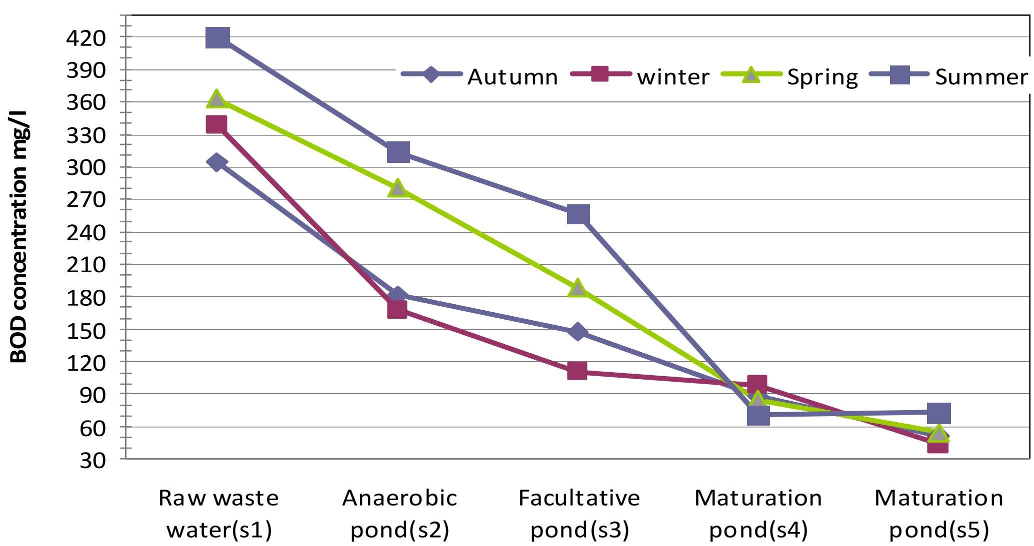

Fig. 6 Seasonal concentration value of BOD measured along Elzaraby WSPs.

LAS average seasonal concentration value

Linear Alkyl Benzene Salfonate (LAS) concentrations at the sampling points were monthly measured in the period from Spt. 2011 to Aug. 2012for Elzaraby WSPs. The average seasonal concentrations of LAS at the sampling locations are plotted as shown in (Fig. 7).

LAS concentrations in raw wastewater recorded an average seasonal values as 6.2, 6.7, 11.9 and 14.8 mg/l in autumn, spring, summer and winter season, respectively. Sewers contain microbial populations capable of initiating LAS biodegradation and concentration of LAS in wastewater treatment plant WWTP influents depends on the length of the sewer, travel time and the degree of the microbial activity present in sewers (Matthijs *et al.*, 1999). So the increased LAS concentration in the winter season influent of the plant compared with other seasons is due to low water temperature which causing a low microbial activity in sewers. In Contrast, LAS concentration in the summer season is higher than those in autumn and spring seasons which can be attributed to higher concentrations drained from source houses. From the figure, it is clear that LAS

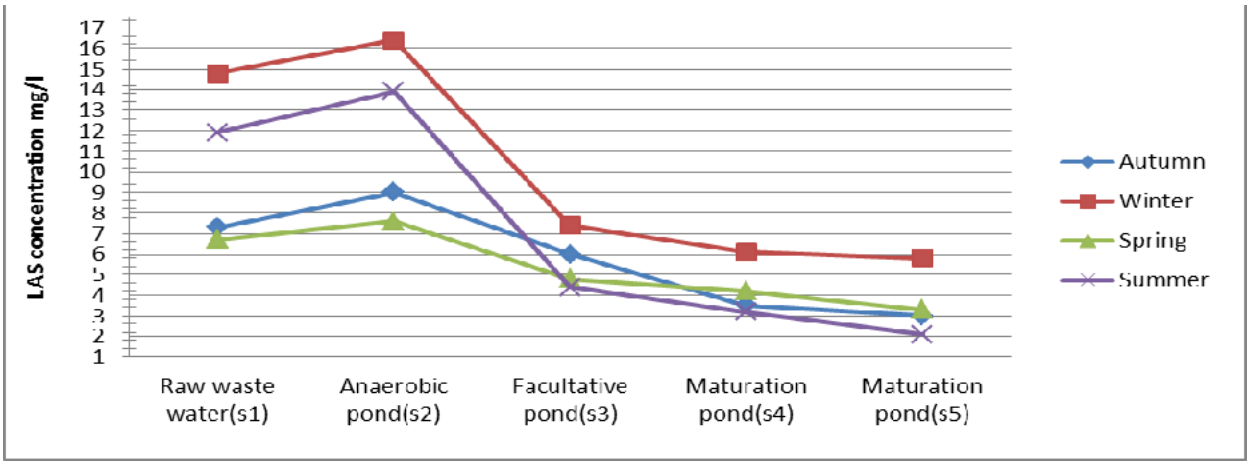

Fig. 7 LAS avareage seasonal concentration value in Elzaraby WSPs

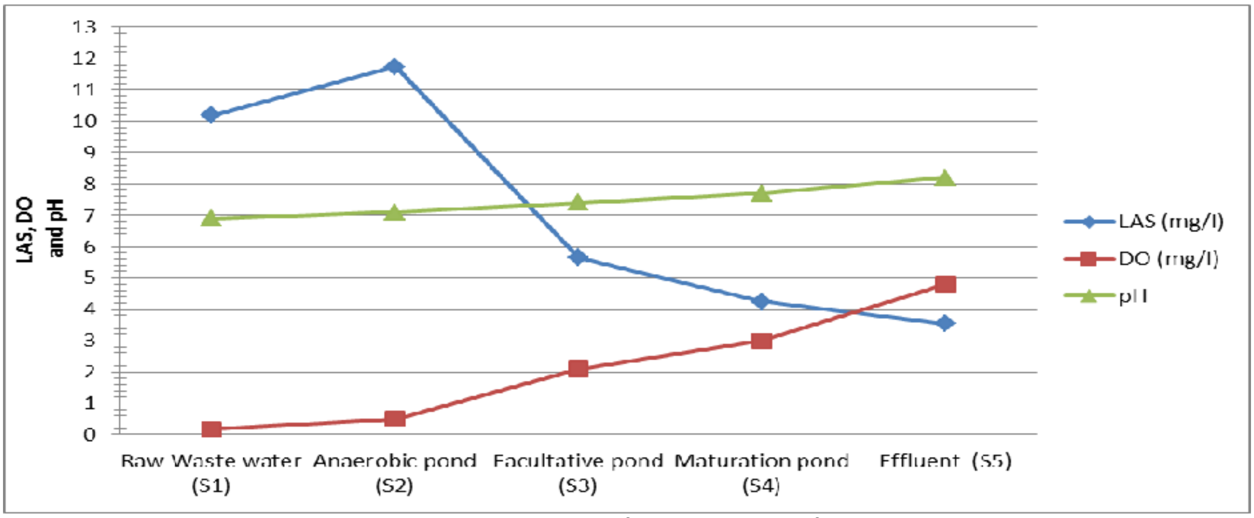

Fig. 8 The average annual variations of LAS, DO and pH for Elzaraby WSPs.

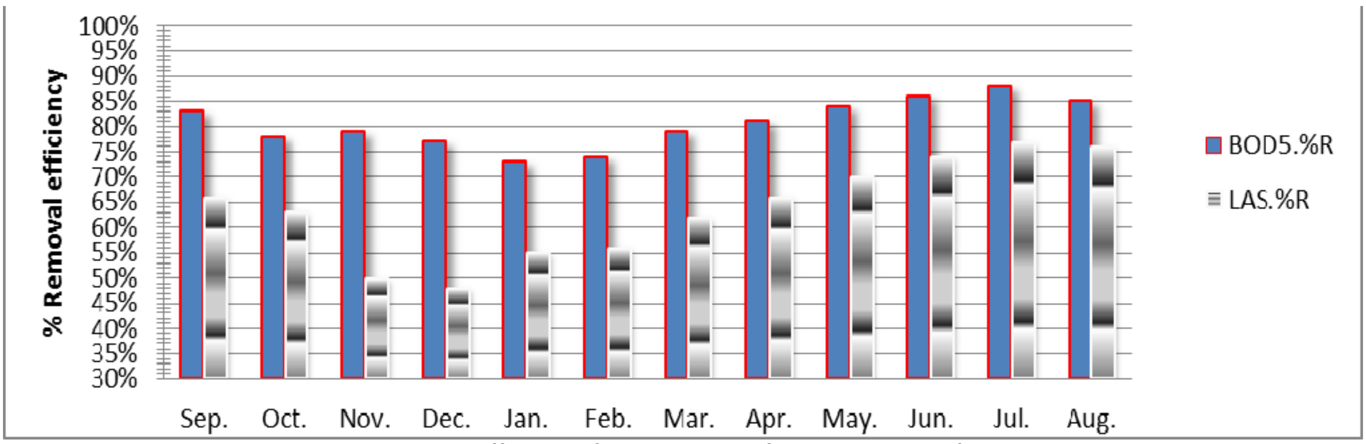

Fig. 9 The monthly overall removal efficiency of LAS and BOD_5 for Elzaraby WSPs from Spt. 2011 to Aug. 2012.

concentration values in the anaerobic ponds to recorded 7, 7.6, 13.9 and 16.4 mg/l in autumn, winter, spring and summer seasons, respectively. These values are higher than those of the concentration values of LAS in raw wastewater, similar increase of LAS concentrations values in anaerobic ponds was reported in Yazd WSPs in Iran (Asghr et al,. 2010). The reasons for this increase in LAS concentration can be attributed to the bad degradation of LAS in anaerobic condition (Guang Ying, 2004, John Jensen, 1999). the additional reason is that actual average daily flow rate of Elzaraby WSPs at measurement time was around 10000 m^3/ day, which leading to an actual HRT in the anaerobic ponds of 7.5 days causing high water losses by evaporation from the pond surface, therefore the water volume decreased and consequently the concentration of LAS increased.

The LAS concentration in maturation ponds (M1) recorded 6.1 mg/l as a maximum value in winter season, and recorded 3.2 mg/l as a minimum value in summer season. In effluent of maturation ponds (M6) LAS recorded 6.4 and 2.1 mg/l in winter and summer seasons, respectively. Similar results were reported by Asghr *et al.* (2010).

As presented in (fig. 8), it is clear that the concentration values of LAS, DO and pH along Elzaraby WSPs series were ranged between 10.18~3.15 mg/l, 0.18~4.8 mg/l and 6.9~8.2, respectively. From figure, it is clear that LAS concentrations in WSPs are multi-factorial, dependent on a synergistic interaction between pH, DO and sun Light. Because of good algal growth The high level of algal photosynthetic activity not only raises the pH of the ponds but also increases its DO content and biodegraded LAS. (Mungray & Kumar, 2008, Martin and Johannes, 1996).

As shown in (**Fig. 9**), the overall removal efficiency of LAS in comparison with removal efficiency of BOD_5 in Oct. 2011 were 63%, 78%, and decreased in Jan.2012 to be 55%, 73%, and increase in Jul. 2012 to be 77% , 88%, respectively. From the figure, it is clear that the overall removal efficiency of LAS and BOD in Elzaraby WSPs in hot months is higher than in cold months because of high air temperature and sun light intensity occurs in summer season relative to other seasons, which increased algal growth and increased biodegradation of LAS, similar result were reported by Asghr *et al.* (2010).

CONCLUSION

1. One year detaild fild investigation was completed to evaluated the removal efficiency of LAS in an existing system of waste stabilization ponds (WSPs) in Elzaraby WSPs, also some physical and biological characteristics of the waste water through the treatment plant are investigated.

2. From the raw wastewater to the anaerobic ponds effluent, pH value does not significantly change because the ponds are organically underloaded with along detinion time the pH values of the ponds' wastewater has it's higher values in the summer season, and it increases along the wastewater pass with the highest values in the last maturation ponds.

3. The avarege removal efficiency of the unfiltered BOD_5 of the plant were found to be as good as 80.5%.

4. The maximum over all removal efficiency of LAS occurs in warm monthes, while minimum removal in cold, and the mean over removal efficiency of LAS from the plant found to be around 63%.

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