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Algal Production in Al-Samra Waste Stabilization Ponds

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ABSTRACT. Al Samra Stabilization ponds is one of the largest waste water treatment plants in the world. this plant is formed of three parallel trains, each formed of two anaerobic, four facultative and four maturation ponds. It was designed to handle an average flow of 68000 M^3/day^{-1}. The main disadvantage to the operational capabilities of the stabilization ponds is the heavy populations of algae which freqently occur in the effluents; however, algal populations that develop in the ponds play an essential role in their efficient operation. The production of algae within the ponds represents the reverse of the process which is normally considered to be that of waste stabilization.

Algal production was studied both on a mass and on a count basis. The maximum algal count recorded was 3.0×10^{10} cells/l in pond M-3 at 250mm below the surface. Throughout the study period. *Chlamydomonas* was the most abundant algal genus in the ponds, *Euglena* appeared during November and December, while *Chlorella* appeared in low numbers during April and May. Hydrogen ion concentrations in the ponds ranged from 7.0 to 8.6, which is suitable for algal growth.

Dissolved oxygen in the ponds was very low to zero due to high oxygen demand in the system.

Old algae for yellow color, low chlorophyll content and low activity, appeared in the ponds due to increase in light intensity. Efficiency of treatment achieved in terms of BOD removal was as high as 97% for filtered samples and 87% for nonfiltered samples.

Due to various favourable factors, Jordan lately chose to treat the sewage of the greater Amman area by using stabilization ponds. Among such factors, one cannot overlook the fact that a waste area of desert land exists in the region. Such land is exposed most of the year to environmental factors which are very favourable for biological oxidation processes. As well as representing a most effective waste water treatment, this method is by far the cheapest and the simplest to operate.

The treatment plant is considered among the largest of its kind in the world and was erected on an area of 1000ha, near Hashmia village north of Zarqa City (Fig. 1). It constitutes three parallel trains, each of which includes 2 anaerobic, 4 facultative and 4 maturation ponds in succession (Fig. 2). Successively, pond depth is 5 and 3m for the anaerobic, 2.5, 2.0 and 1.5m for the facultative and 1.25m for the maturation ponds.

Total surface area of the various ponds is 19#87 and 75ha for the anaerobic, facultative and maturation ponds, respectively. Retention times in each train are: 8 days in the anaerobic: 20 days in the facultative and 14 days in the maturation ponds.

Algae play a key role in waste water treatment processes by altering a variety of chemical equilibria, increasing the dissolved oxygen concentration and increasing the supply of available caloric energy in the form of algal protoplasm.

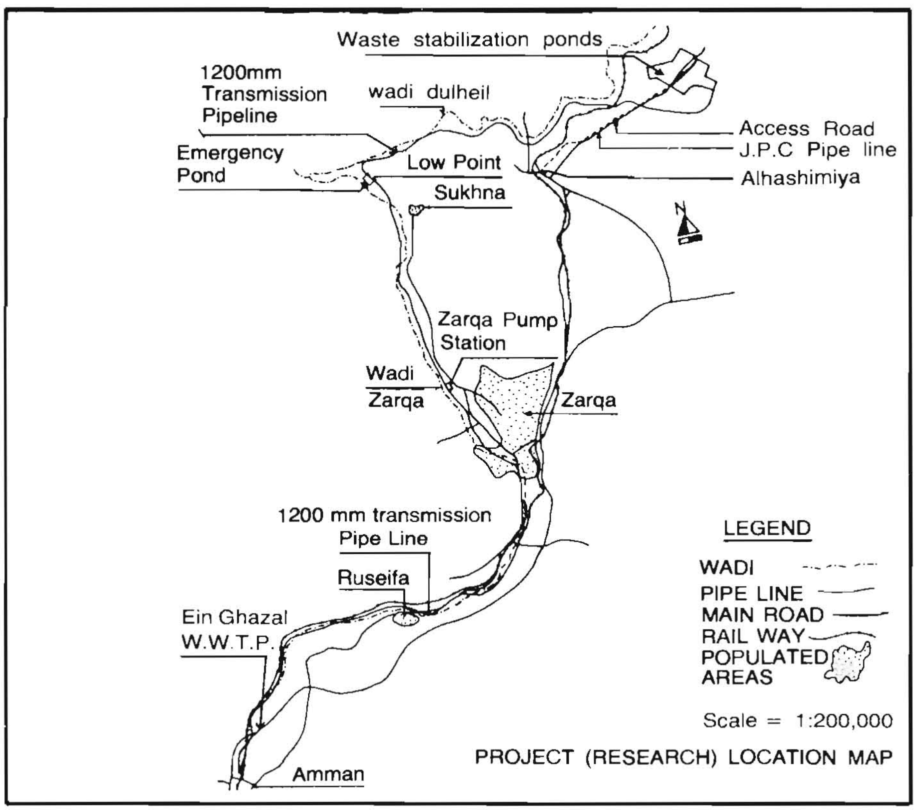

Fig. 1. Location Map of the Study.

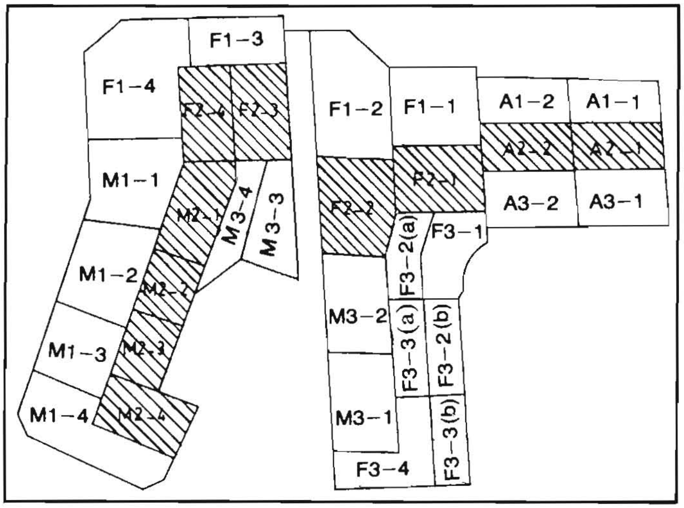

Fig. 2. Plan Lay Out of Al-Samra Treatment Plant.

Moreover, algae in the effluent can increase the BOD of the discharge by a factor of 4 to 6 or even higher (Ellis 1983). A schematic representation of a stabilization pond ecosystem is given in Fig. 3.

The present study was to evaluate the algal production in the facultative and maturation ponds of train II of the plant a few months after its commission and before utilization of train III, starting early November, 1985. Various chemical and physical parameters that affect biological treatment in this system were also considered.

Methodology

Three months after the plant commenced operation, 1000ml water samples were taken from all facultative and maturation ponds of train II, on weekly and sometimes bi-weekly intervals using an automatic depth sampler. The samples were taken at 250mm depths and its multiples, placed in wide-mouth jars and kept at 4°C, for as a short time as possible before analysis. Visual observations of pond colors were also noted.

Hydrogen ion concentrations, water temperatures, dissolved oxygen and relevant environmental conditions were determined on site.

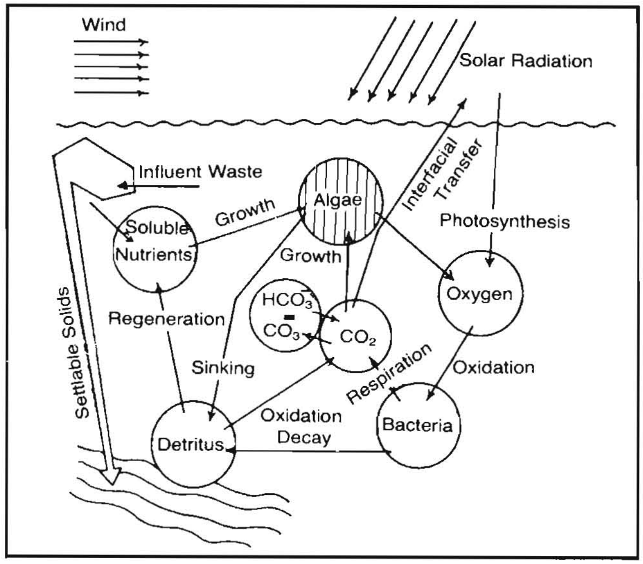

Fig. 3. Stabilixation Pond Ecosystem Scheme.

Total solids, suspended solids, dissolved solids and BOD were determined for each sample according to standard procedures (Standard Methods 1985).

Algal counts were by direct microscopic examinations, using a haemocytometer. Examination was made after treatment with formaldehyde (0.1N) to inactivate the algae.

Results and Discussion

Greneral observations

Though water color and microscopic examination did not reveal the presence of algae during May (first month of the train operation), algae started to show up during September. Water color in the last 3 maturation ponds (M-2, M-3 and M-4) became dark green by early November, whilst ponds M1, F-3 and F-4 were light green and ponds A-1, A-2, did not exhibit the green color indicative of algal growth.

Water color in the maturation ponds (M-2, M-3, M-4) changed from dark green in November to light green in December and continued to be so throughout january and February, A change to greenish-brown took place in March. This color turned into brownish-mud, starting end of March and early April, then turned into brownish-red by end of April and beginning of May.

As expected, no algae appeared in the anaerobic ponds. However, the anaerobic ponds achieved close to 90% removal of effluent suspended solids which ranged from 580 to 1200 mg/l, depending on the degree of its primary treatment. Figures 4&5 give suspended solids and algal counts in the four facultative ponds. No algae appeared in the facultative pond (F-1) until late March contrary to the other three ponds in which algal growth appeared as early as January.

Algal growth, as count or as suspended solids, attained successive increases in the facultative ponds on moving from F-1 to F-4. This increase is due to improved water quality and improved environmental conditions. During May, algal counts increased from 1 $\times$ 10^9 cell/l in F-1 to as high as 8# $\times$ #10^9 Cell/l in F-4. Such increase in algal count, corresponded to an increase in suspended solids (from 80 mg/l. in F-1 to 225 mg/l in F-4). Improved weather conditions and their effect on the algal growth in the ponds, was clearly demonstrated. Average monthly readings of indirect sunlight intensity, sunshine hours and air temperature during the study period are given in Fig. 6. Increase in algal populations (counts and

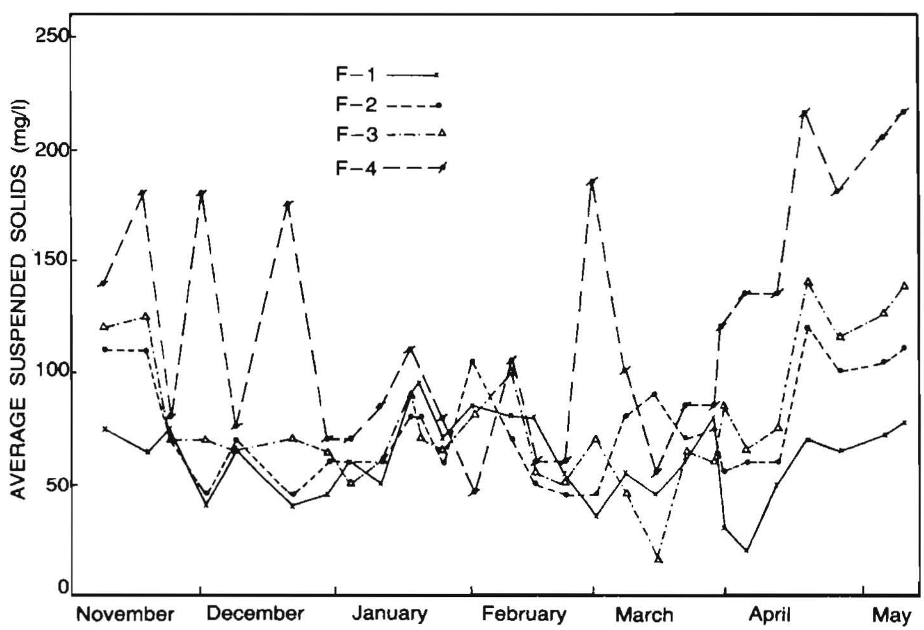

Fig. 4. Average Suspended Solids in The Four Facultative Ponds.

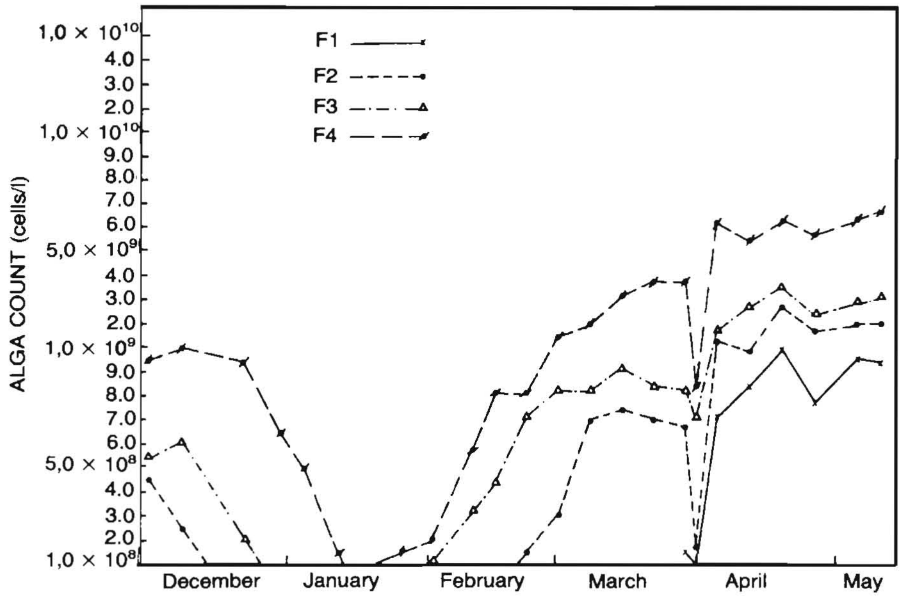

Fig. 5. Alga Count At 250mm Below The Surface In The Four Facultative Ponds.

suspend solids) across the facultative ponds clearly reflects the positive effects of these parameters. The high temperatures recorded in April and May, along with the increase in light intensity and sunshine hours, caused a rise in algal growth. Temperature was within the optimum range for maximum growth of mesophilic algae (Fritz et. al. 1979). The same can be said about the light intensity. Gloyna and Tischler (1979) reported optimum light intensity or saturation value for most algal species found in waste stabilization ponds to range between 4.0 to 6.0 Kcand/m^2 which is similar to the observations in Fig. 6.

Algal counts in the four maturation ponds was greater than that in the facultative ponds (Fig. 7). Increase in algal counts was exhibited throughout the system, reaching a peak (3×10^{10} cell/l) in M-3 while decreasing to as low as 3×10^9 cell/l in M-4. Drop in algal counts occurred during January and April. Decreases observed in January, can be attributed to adverse climatic and environmental conditions (Fig. 6). Low temperature (8°C), low light intensity and less sunshine hours during January could be responsible for lower algal counts.

The second drop in algal counts which occurred during April was probably due to senscence of algae. During this month, fat brownish yellow algal cells became common. Such algal cells moved downwards and caused increases in algal counts at depths of 250 and 1000mm (Fig. 8) Aging algal cells appeared more commonly in

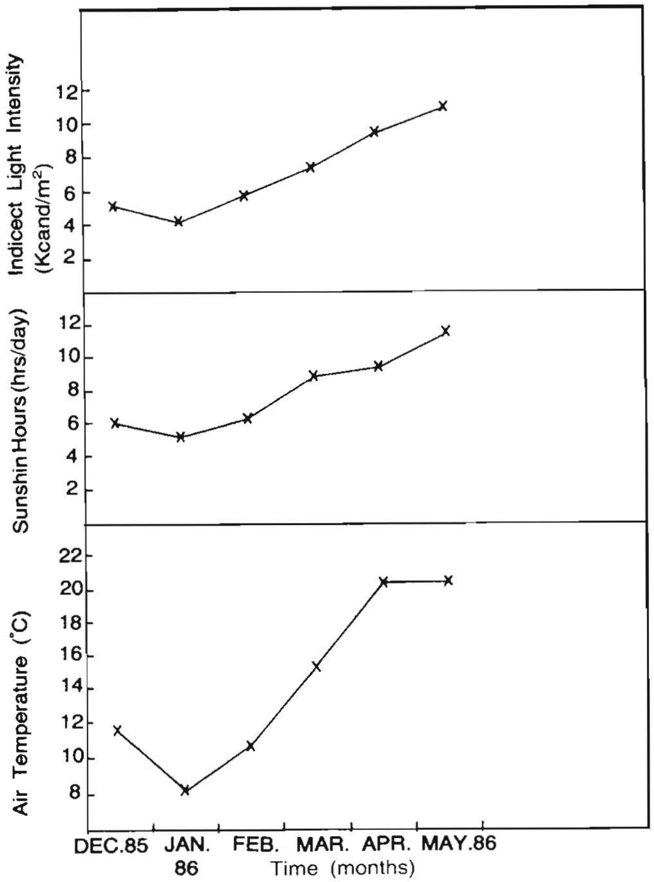

Fig. 6. Average Monthly Climatic Conditions During The Study Period.

the maturation ponds than in the facultative ponds. Maturation ponds, being shallower than the facultative ponds and containing higher algal concentrations are likely to be more susceptible to environmental changes. Such changes could cause algal cells to become yellowish, less active, larger and to move downward into the pond. Later they senesced and died.

Algal Movement Within a Pond

Diurnal studies of suspended solids, algal counts, pH and DO were made on the fourth mturation pond (M-4). Results obtained are given in Fig. 9. A sharp increase in suspended solids, at a depth of 250 mm, was obtained between 3:00 and 4:00 pm, followed by a gradual decrease, reaching its lowest at 4:00 am. Increases and decreases in algal counts, observed at 250 mm depth, were reversed at the 1000

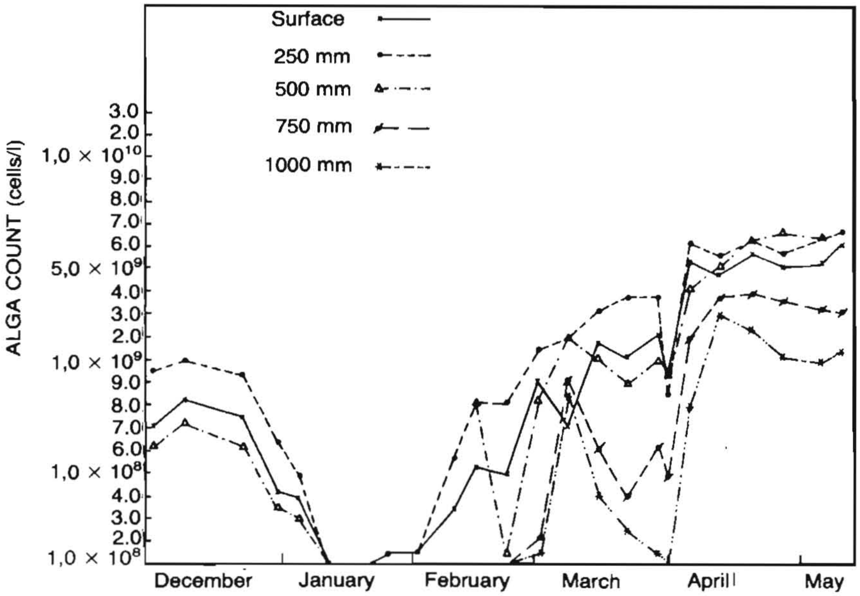

Fig. 7. Alga Count At Five Sampling Depths Of Pond F4.

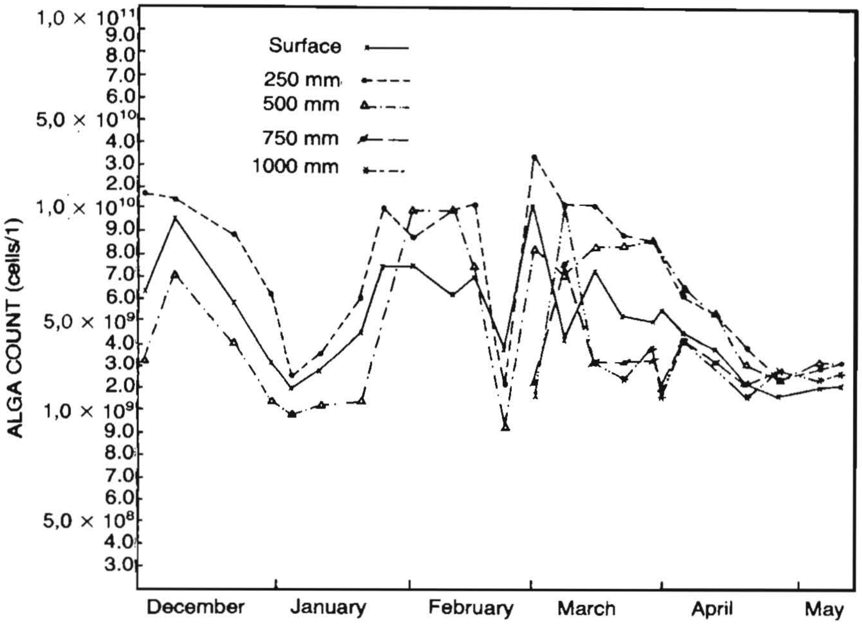

Fig. 8. Alga Count At Five Sampling Depths Of Pond M3.

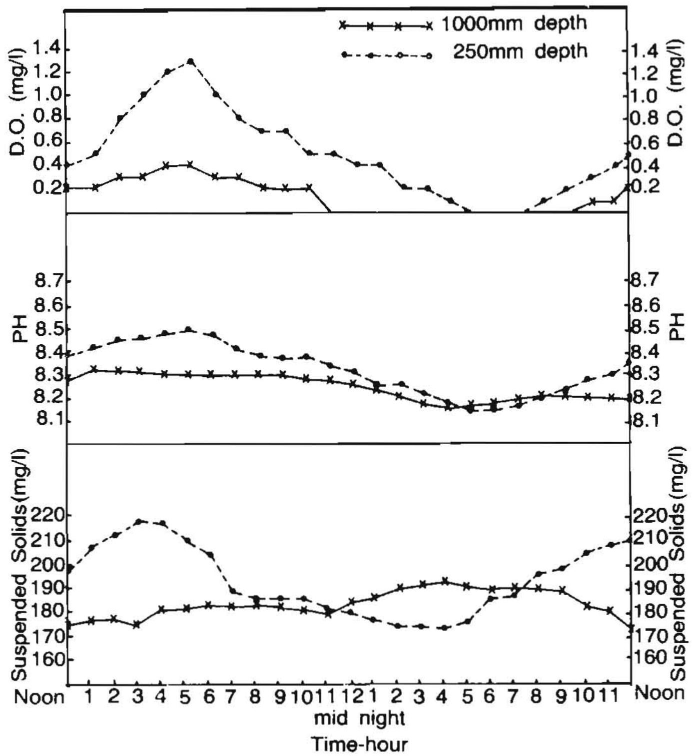

Fig. 9. Diurnal Variation Of Suspended Solids, PH & D.O. AT Two Depths Of Pond M4.

mm depth indicating a downward or upward movement of algae in response to prevailing light and temperature conditions. Direct and indirect light intensity during the day is illustrated in Fig. 10. Direct light intensity during the day reached its peak at 12:00 noon. However, the indirect light reached its maximum between 3:00 and 4:00 pm.

The rise in suspended solids corresponded with an increase in light intensity. Downward movement of algae during the dark hours, was due to the colder surface temperature forcing algae to migrate to warmer water. Morning light induced algae to start their vertical movement upward. This movement was a positive reflection of the DO and pH profiles during 24 hours of the study. Higher pH and DO were recorded during 3:00 – 4:00 pm at 250 mm depth and corresponded with the increase in suspended solids during this period. No great change occurred in either pH or DO at 1000 mm depth.

This phenomenon agrees with the suggestion that algae which stay at lower depths during daylight hours are the old algae with lower metabolic activity than

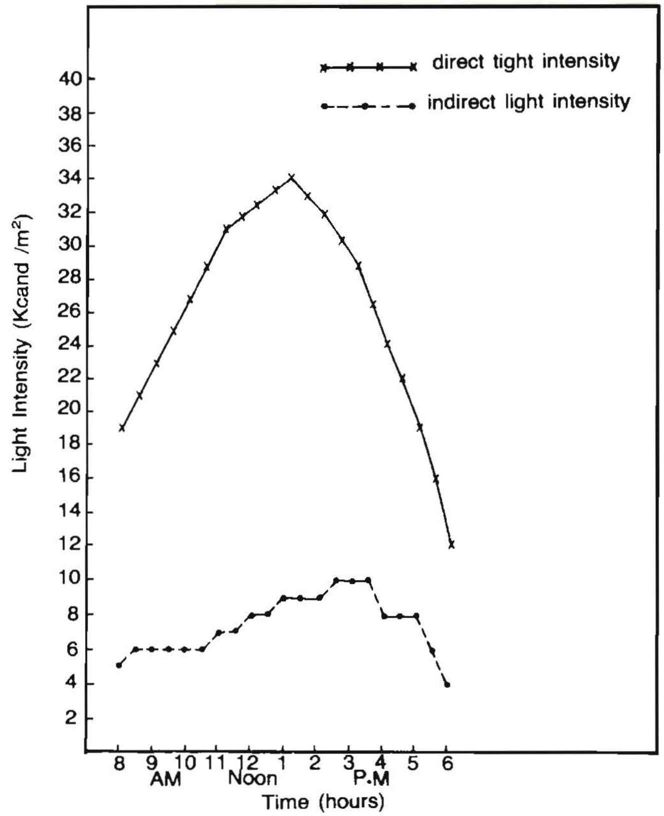

Fig. 10. Typical Light Intensify For A Sunny Day (May, 24th 1986)

those staying at lesser depths. Photosynthesis of these old algae is low as they have less chlorophyll. Thus, no major changes apppeared in pH and DO values during the twenty four hours at the 1000 mm depth. However, algae at 250 mm depth exhibited an increase in pH and DO values during day light hour, which can be related to their photosynthetic activity, for they were younger in age and had higher chlorophyll content.

Algal Species located in the Ponds

Microscopic analysis showed *Chlamydomonas* to be the most abundant algal genus in the ponds and agrees with other observations (Palmer 1975). *Euglena* also appeared during the first period of the study (November and December, 1985), but in lower amounts. These two genera are typical examples of flagellate algae present in waste stabilization ponds and are used in the field of sanitary biology. *Chlorella* also appeared in small numbers during April and may, when water temperature reached about 20°C.

As light intensity increased during April and May, algal cells tended to remain in a vigorous multiplying state at the expense of cell size. The percentage of cells which ceased to multiply also increased. They entered a phase of cell enlargement leading to senescence which ultimately led to death. Senescent algae, are usualy yellow in color, low in chlorophyll, multiply infrequently and may photosynthesize less oxygen than they consume in respiration (Oswald et. al. 1954). A similar pattern appeared in the ponds of this study.

Quality Changes Across the System

Water quality in terms of pH, BOD, algal count and suspended solids that occurred in the waste water from the intake structures up to the chlorination basin, for the period of the study, measured on monthly basis, are given in Figs. 11 and 12. Throughout this period, The anaerobic ponds achieved good reduction in the biodegradable material (BOD). The major initial BOD reduction that can be achieved in municipal waste water, is the result of removal of suspended solids (Gloyna 1971, Gloyna and Tischler 1979, Ellis 1983). It is worth noting that no major reduction in term of BOD, took place in the second anaerobic pond (A-2) suggesting that a parallel operation would have been more advantageous (Mara 1976). The pH of the two ponds stayed within the optimum range recommended for methane fermentation (Gloyna and Tischler 1979). Algal increase in the system led to a corresponding increase in suspended solids. The effluent suspended solids from the anaerobic ponds was in the range of 75-100 mg/l, while the effluent of the last maturation pond, contained up to 250 mg/l. Favourable prevailing environmental conditions led to high effeciency in waste water treatment and an increase in algal growth. Favourable climatic conditions had a progressively positive effect on algal counts and water quality (in terms of BOD reduction) in the facultative ponds. As time advanced, increase in algal counts among the facultative ponds was accompained by a decrease in the maturation ponds. This can be attributed to the appearance of new young algae in the facultative ponds and the aging of algae in the maturation ponds.

A Considerable BOD reduction was achieved throughout the system. Prevailing favourable climatic conditions caused an increase in BOD reaction rate, resulting in good removal of organic material. Gloyna and Tischler (1979) have previously demonstrated this phenomenon.

The increase in algal activity was well reflected in pH readings of the system. The pH increase went hand in hand with the increase in algal concentration leading to higher pH values between F-1 to M-4. The pH increase or decrease at a specific

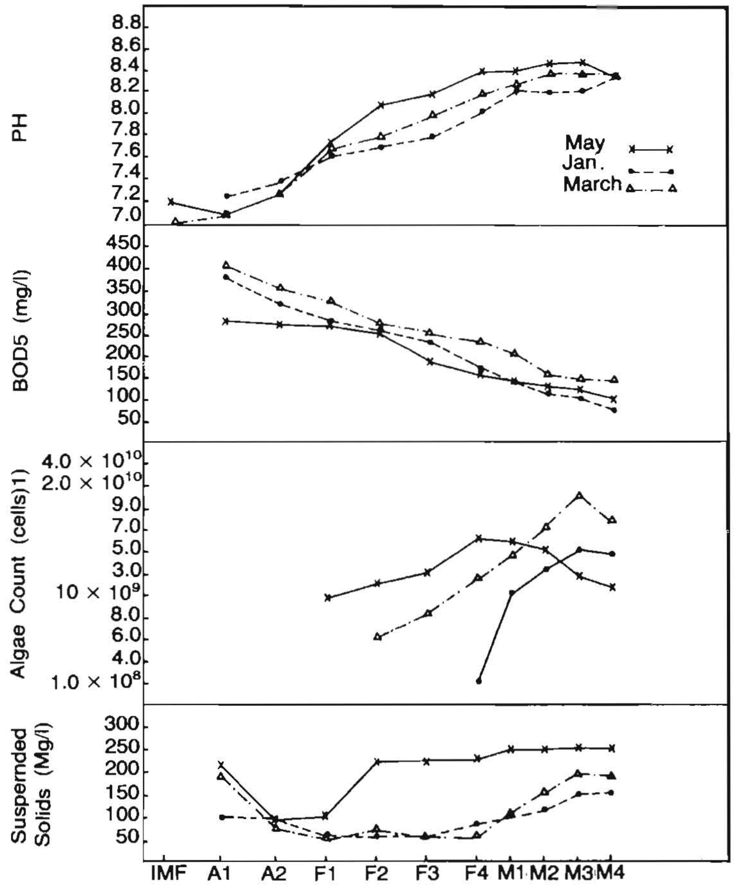

Fig. 11. Quality Changes Across The System For The Month Of January, March And May, 1986.

depth within the pond (Figs. 13 and 14) was in direct relation to maximum algal counts at that depth. This is in accordance with previous reports (Fritz 1979, Ellis 1983). Thus, pH measurement can be used as an indicator of algal presence at the various depths within the ponds (Hartley and Weiss 1970). The pH range in the system continued to be within the optimum range (7-8.6) for algal and bacterial growth. This agrees with previous reports (Bush *et al.* 1961).

Dissolved Oxygen

Algae present in the ponds, as a result of their photosynthetic activity, release oxygen into the water which becomes available for aerobic bacteria to decompose

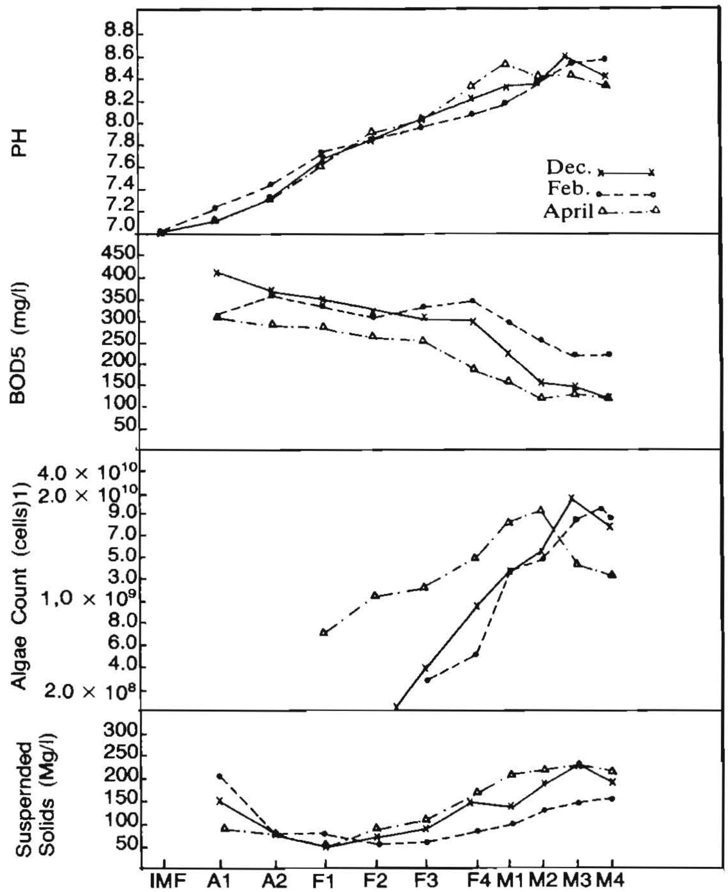

Fig. 12. Quality Changes Across The System For The Month Of December,February And April, 1986.

the organic wastes. Measurements of dissolved oxygen in the ponds of the train, showed it to be very low, even at the surface. In the facultative ponds, dissolved oxygen was not detected in the first two ponds (F-1 and F-2), even at the surface. Maximum DO in pond F-3 was about 0.3 mg/l, recorded in April 1986, at a depth of about 250 mm below the surface and near zero at the surface. This is due to higher algal counts at this depth. The maximum level of DO in F-4 (0.5 mg/l) was recorded at a depth of between 250 mm and 500 mm below the surface, during April 1986. Again, higher algal counts at this depth caused this condition.

Among the maturation ponds, M-1 was found to have its maximum amount of dissolved oxygen (1.2 mg/l) at 5:00 p.m., on 5th of April, at a depth between the

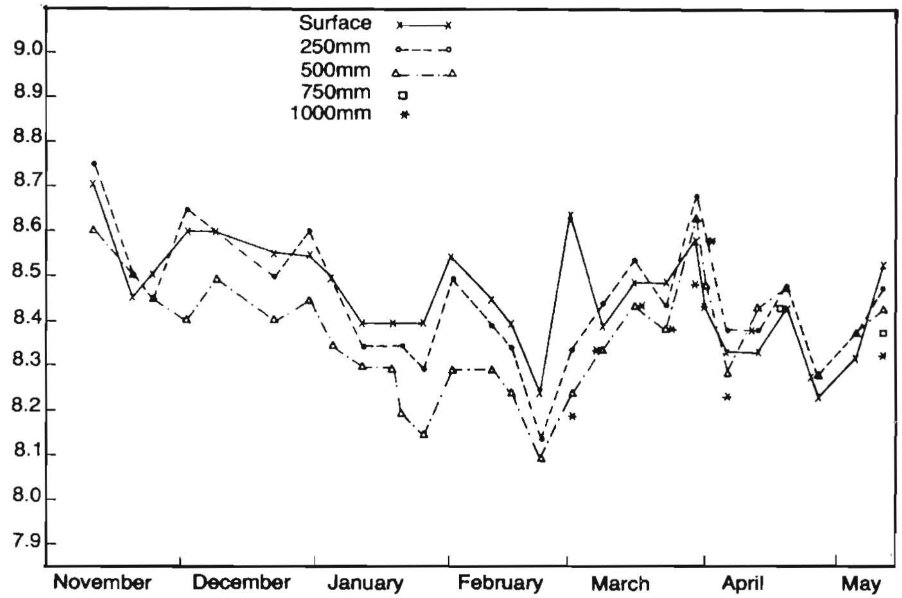

Fig. 13. pH At Five Sampling Depths Of Pond M3.

surface and 250 mm below the surface. Apart from anomalous in the afternoon, which recorded DO values of about 1.0 mg/l, other DO measurements at this Pond were between zero and 0.5 mg/l. Pond M-2 had its maximum dissolved oxygen reading (1.7 mg/l) at a depth of 250 mm below the surface, at 5:00 p.m., of the same day. Other dissolved oxygen measurements revealed small amounts of DO which ranged from zero to 0.5 mg/l.

A maximum DO value (4.5 mg/l) was recorded at pond M-3 (Fig. 14). This value was recorded at 5:00 P.m, on 5th of April, at 250 mm below the surface. Most measurements taken for this pond showed DO levels to range from zero to 0.5 mg/l.

Pond M-4 had dissolved oxygen levels almost equal to those of M-2. The maximum recorded amount of dissolved oxygen was 1.6 mg/l, but most DO values ranged from zero to 0.5 mg/l. Thus, due to high oxygen demand, the dissolved oxygen was very low in the ponds system.

Chlamydomonas was the most abundant algae in the ponds throughout the study period. *Euglena* appeared only during November and December, while *chlorella* appeared in small numbers during April and may.

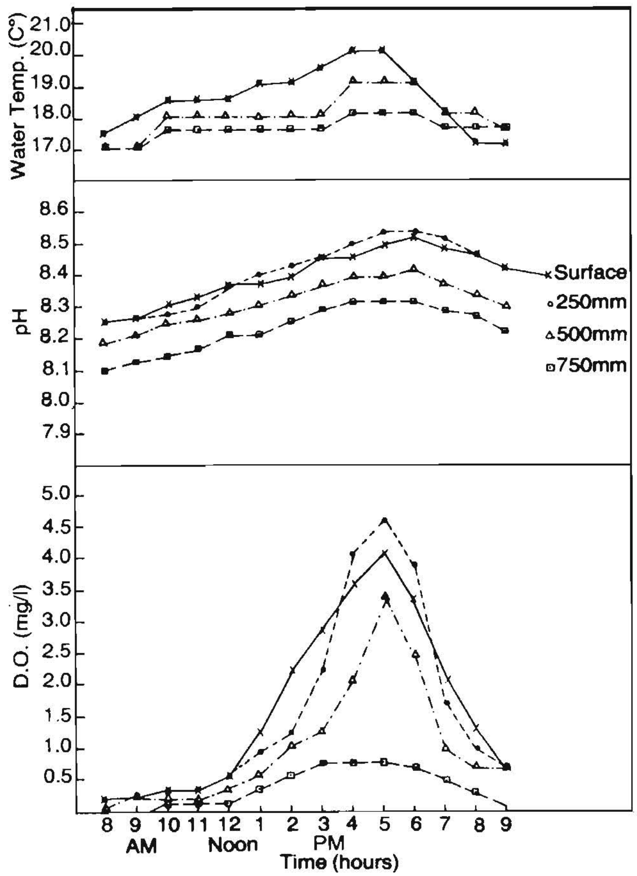

Fig. 14. D.O., pH And Water Temperature At Five Sampling Depths Of Pond M3 Over A Twelve – Hours Peried.

The maximum algal count (3×10^{10} cells/l) was recorded in M-3 at 250 mm below the surface. The average count across the system at that depth was 2.2×10^9 cells/l. An increase or decrease in algal counts coincided with a similar increase or decrease in suspended solids. Thus, measurements of suspended solids can be used as a good indicator of algal concentration in a pond.

Vertical migration of algae was mostly in the top 500 mm with less activity below this depth. Upward or downward movement of algae was a function of light intensity. Increase of light intensity and number of sunshine hours speeded aging of algae. Thermal stratification took place during day time, causing reduced mixing of the lagoons.

Variation of pH and DO were in direct response to algal movement. Older algae have lesser effect on changing pH and DO.

Due to high DO demand in the system, levels of DO recorded varied from very small to zero, even though algal counts were high.

In terms of BOD reduction, efficiency of the treatment plant was as high as 97% for filtered samples and 87% for the nonfiltered ones. This is mainly due to algal presence in the effluent.

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نمو الطحالب في محطة خربة السمراء للتنقية الطبيعية

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تعتبر محطة خربة السمراء للتنقية الطبيعية من أكبر محطات تنقية المياه العادمة التي تعتمد على مثل هذا النظام. وهي أكبر محطة لتنقية المياه العادمة في الأردن، فهي مصممة لتعالج مياه المجاري المنزلية من مدينتي عمان الكبرى والزرقاء وما حولها من مدن وقرى وتجمعات سكانية صغيرة. ويعتبر دور الطحالب الخضراء في عملية التنقية الطبيعية للمياه العادمة دوراً أساسياً، حيث تقوم هذه الطحالب بانتاج الأوكسجين الذي تستخدمه البكتيريا في تنفسها وتثبيتها للمواد العضوية.

هدفت هذه الدراسة إلى التعرف على ماهية الطحالب الموجودة في هذه المحطة من حيث النوع والكميات اضافة إلى دورها في انتاج الأوكسجين وتغيير درجة حموضة المياه العادمة وأثر ذلك في عملية تحليل المواد العضوية الموجودة في المياه العادمة.

لقد بينت هذه الدراسة أن الكلاميدوموناس هو النوع الغالب من الطحالب في أحواض هذه المحطة، في حين ظهرت أنوان أخرى من الطحالب الخضراء مثل الكوريلا و اليوجلينا لكن ظهورها كان خلال أوقات معينة من السنة وبكميات قليلة نسبياً.

بلغت أقصى أعداد هذه الطحالب خلال الدراسة ٣ × ١٠^١٠ طحلب/لتر على عمق ٢٥٠ ملم تحت سطح الماء. وقد تراوحت درجة الحموضة في هذه الأحواض ما بين ٧ × ٨,٦ وهي درجة مناسبة جداً لنمو الطحالب، في حين كانت كمية الأوكسجين المذاب في مياه الأحواض قليلة أو معدومة على

الرغم من توفر أعداد جيدة من الطحالب في مياهها. ويعود ذلك إلى نفاذ كميات الأوكسجين المنتج من قبل الطحالب في العمليات الحيوية التي تقوم بها البكتيريا في تحليل المواد العضوية عالية التركيز في المياه العادمة.

أدت زيادة شدة الاضاءة وإزدياد ساعات شروق الشمس إلى الإسراع في تدهور الطحالب في أحواض التنقية، حيث أصبح لونها مائلاً للأصفرار، اضافة إلى قلة إحتوائها على مادة الكلوروفيل وقلة نشاطها وميلها إلى الخمول والاستقرار على أعماق كبيرة في أحواض التنقية.

وصلت درجة تقنية المياه العادمة الخارجة من الاحواض كما سجلت خلال شهري نيسان وأيار إلى ٩٧ ٪ للعينات المرشحة حيث كانت درجة التنقية فقط ٨٧ ٪ للعينات غير المرشحة نظراً لتركيز الطحالب في المياه المنقاه الخارجة من المحطة.