# S E C T I O N "D"

## " THE SEVEN CELL OXIDATION POND "

## INTRODUCTION

Raw sewage of Ahmedabad has been utilised directly for irrigation since 1894, after screening and removal of detritus in the two pumping stations. The total quantity of sewage and industrial wastes at present is about 50 mgd. of which about 10 mgd. consists of treated textile mill wastes. Owing to the limited available area of about 2856 acres in the farm, most of the sewage finds its way into the river Sabarmati throughout the year excepting the monsoon season, when the entire sewage is diverted into it. So, inadequacy of the farm area, application of a heavy dosage of raw sewage on land and the resultant odour and mosquito nuisance have all created problems for an immediate solution.

One of the remedial measures taken by Mr. M.J. Kakkad, the city Engineer, was the construction of a series of stabilization lagoons in the Pirana Sewage Farm beginning from four cells in April 1961 to seven cells in 1963. The results of examination of the bio-chemical changes taking place in each of the seven cells or ponds working in series during the year 1963 are discussed in this paper.

## 2. STRUCTURAL FEATURES OF THE PONDS.

(a) Location: The ponds have been constructed at the junction of the farthest end of the auxilliary sewage

## TABLE NO. I

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MORPHOMETRIC DATA ABOUT THE SEVEN PONDS AS FURNISHED BY THE CITY ENGINEER, AHMEDABAD MUNICIPAL CORPORATION.

| Cell No. | MEASUREMENT OF THE FOUR SIDES (Feet). 1 | 2 | 3 | 4 | Total Depth in ft. | SURFACE AREA Sq. ft. | Acres | VOLUME AT DEPTHS ( Feet ) FOUR C.ft. 100 | x | m. gallons | FIVE C.ft. 100 | x | m. gallon. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | 1090 | 475 | 1100 | 485 | 7 | 573600 | 13.16 | 21944 | | 13.715 | 28680 | | 17.925 |
| 2. | 85 | 475 | 85 | 475 | 8 | 40375 | 0.93 | 1615 | | 1.009 | 2019 | | 1.262 |
| 3. | 450 | 475 | 450 | 475 | 8 | 213750 | 4.97 | 8550 | | 5.344 | 10687 | | 6.679 |
| 4. | 250 | 375 | 260 | 475 | 8 | 127400 | 2.92 | 5096 | | 4.185 | 6270 | | 3.919 |
| 5. | 250 | 255 | 246 | 375 | 8 | 70150 | 1.61 | 2806 | | 1.754 | 3507 | | 2.192 |
| 6. | 238 | 144 | 195 | 255 | 8 | 37275 | 0.86 | 1491 | | 0.932 | 1864 | | 1.165 |
| 7. | 255 | 228 | 144 | - | 8 | 17100 | 0.37 | 684 | | 0.427 | 855 | | 0.534 |
| Total | 2618 | - | - | - | - | 1079650 | 24.82 | 42186 | | 27.366 | 53882 | | 33.676 |

main carrier and the sewage channel which branches off from the main carrier from the spot where the single unit pilot-plant oxidation pond is located in the Pirana sewage Farm (Fig.2b). The sewage after a travel of nearly six miles in these open channels reaches the ponds.

(b) Topography: The area in which the ponds are situated is on the eastern bank of the river Sabarmati, and is open and exposed to prevailing winds.

(c) Soil characteristics: The ponds are situated on a sandy loam extending to a depth of 25 feet.

(d) Shape of the Ponds: The first three ponds are rectangular, the next three are quandrilaterals and the last one is triangular and have been constructed according to the suitability of the available area on site.

(e) Area and Volume: The area of each of the seven ponds and their volumes are given for 4' and 5' depths in Table No. I.

BOTTOM: The bottom is a natural sandy soil made as level as possible and having no obstruction to circulation. No attempt was made at artificial sealing of the bottom as that would have increased the cost of construction of the ponds, which came to about Rs.3000/- per acre. Also this portion of the farm was used as "drying beds" ( Ganapati

et al 1965) for more than a decade and so the bottom had become compacted and relatively tight to prevent excessive seepage.

DYKES: The embankments are also made up of excavated soil from the surrounding sandy area and they were compacted where required by buttressing the sides with the city refuse collected by the municipal conservancy department. Top width is about 4 feet, free board is kept minimum at 2 feet in order to allow the action of wind to play fully upon the water surface of the ponds. No attempt was made to prevent erosion of the inner sides by pitching as that would also have increased the cost; and the inner and outer slopes were kept at two horizontal to one vertical. The embankments were not seeded. Yet rank vegetation was found to grow almost throughout the year on the innerside slopes above water level. They were removed by manual labour of the strength of one person per pond which prevented the likely breeding of mosquito larvae.

Inlet and Outlet arrangements: The inlet and outlet to each pond were made of Hume pipes of one foot in diameter simply placed on the dykes pending the construction of regular weir structures their inverts being 5 feet from the bottom excepting the inlet to the first pond, and the final outlet which were provided with regular steel weirs each measuring 2'-6". The inlets were also located diagonally to the outlets in each of the ponds so that

there was no possibility of short circuiting.

## 3. CLIMATIC CONDITIONS

The climatic conditions for 1963 are shown in Table No.1 (Appenxix). It will be seen from a study of the Table that the range of temperature is highest during summer ( 18.6-41.2) and lowest during the cold weather (12.3-33.6). The range of monthly hours of bright sunshine (357.7-281.3) is also highest during the hot weather and lowest (119.8-202.1) during the monsoon season. During the cold weather the range of monthly hours of bright sun-shine is comparatively higher than in the monsoon and post-monsoon seasons although the temperature range is comparatively lower. In the post-monsoon season the temperature and the hours of bright sunshine are comparatively higher than the respective minimum ranges. Also the total annual rain fall and the monthly fall are not high. So it would appear that all the year round favourable conditions for growth of algae for the production of photosynthetic oxygen seem to exist in Ahmedabad. The total evaporation per annum is about 5 ft.

## 4. FEED SEWAGE: ITS QUALITY & QUANTITY.

The essential characteristics of the sewage of Ahmedabad have been described in detail by Kothandaraman

et al (1962). Suffice it to say that the sewage which was feeding these ponds had travelled over a distance of nearly six miles in open carriers of channels as a result of which a certain amount of natural purification had taken place (Ganapati and Bppardikar 1962). It is a strong domestic sewage mixed with textile mill wastes in the ratio of nearly 4:1. The quality of sewage entering the first pond is described at the appropriate places in the body of this paper.

The quantity of sewage flowing into the first pond was found to fluctuate between 1.0 and 5.0 mgd. depending upon the time of the day.

## 5. COLLECTION OF SAMPLES

Grab samples were taken once a week and in special cases twice a week at about 11.00 a.m. and 12 noon, from all the seven ponds from one and the same place i.e. near the inlet of Pond 1 and from the outlets of each of them. Two sets of samples were taken from each pond in the following order. Samples for Chemical examination were taken first, next for biological examination. Two separate samples; one for dissolved oxygen and the other for BOD were taken in narrow mouthed glass stoppered bottles of 250 ml capacity, taking the usual precautions for excluding air bubbles.

All examinations were done under comparable conditions and the maximum time between collection and analysis did not exceed one hour. Temperature and colour of the liquid as it appeared to the naked eye were recorded for studying the physical conditions. Tests for dissolved oxygen, 5-day BOD, oxygen consumed from acid permanganate at 27 °C, alkalinity, chloride, ammoniacal nitrogen and phosphates were done for studying the important chemical conditions. Numerical estimation of the dominant algal organisms was also made by the drop-sedimentation method. The methods followed for the tests were the same as those described in the first paper, Part II. The data collected under physico-chemical, and biological conditions are presented in a series of basic tabulations condensed to form monthly averages separately in appendix. A discussion of the salient features of each important factor is made in the body of the paper. All results are expressed in milligrams per litre or parts per million unless otherwise stated.

## 6. PHYSICAL CONDITIONS

(a) Temperature (°C): Maximum and minimum variations: The monthly averages are shown in Table 2 in the appendix from which the maximum and minimum values for each of the seven ponds are shown below:

TABLE NO. "2"

| Source | Maximum Temp. | Month | Minimum Temp. | Month | Annual average |
|---|---|---|---|---|---|
| Inlet to Pond I | 32.8 | May & June | 24.5 | Jan. | 30.2 |
| Effluent from Pond No. I | 30.6 | May | 29.8 | Jan. | 27.9 |
| - do - II | 30.7 | May | 20.9 | Jan. | 28.1 |
| - do - III | 29.8 | July | 20.1 | Jan. | 27.4 |
| - do - IV | 29.9 | May | 19.8 | Jan. | 27.1 |
| - do - V | 29.5 | July | 20.0 | Jan. | 27.1 |
| - do - VI | 30.3 | July | 19.5 | Jan. | 27.1 |
| - do - VII | 30.7 | May | 19.5 | Jan. | 27.4 |
| Average | 30.2 | | 20.1 | | 27.4 |

The temperature of the effluents from the seven ponds was always less than the temperature of the influent. Maximum reduction of 20.4% was found in January and the minimum reduction (nil) in December. The annual average reduction was 9.3 % ( Table II, Appendix).

SEASONAL VARIATIONS:

The results are shown in Table NO. 3

TABLE NO. 3

| SOURCE | | Cold weather Dec. Jan. & Feb. | Hot weather Mar. to June | Monsoon July to Sept. | Post-monsoon Oct. to Nov. |
|---|---|---|---|---|---|
| Inlet to Pond | I | 26.2 | 31.9 | 30.9 | 30.7 |
| Outlet from Pond | I | 25.6 | 28.9 | 29.4 | 28.2 |
| " " " | II | 24.8 | 29.2 | 29.8 | 28.5 |
| " " " | III | 23.7 | 28.3 | 29.3 | 28.3 |
| " " " | IV | 22.4 | 28.4 | 29.3 | 28.2 |
| " " " | V | 23.3 | 29.1 | 29.0 | 27.8 |
| " " " | VI | 23.0 | 28.0 | 29.6 | 28.0 |
| " " " | VII | 23.1 | 29.4 | 28.7 | 28.0 |
| Seasonal Average | | 23.7 | 28.6 | 29.2 | 28.1 |

The seasonal averages, also, were always less than the corresponding figures for the raw sewage entering the first pond.

(b) Colour: (vide Table III, Appendix): The colour of the raw sewage entering Pond I was black or greyish but the colour of the effluents emanating from the seven ponds varied from purple to green. The effluent from Pond I was purple from January to May and later it was pale green or dark green with an occasional pink, during the remaining months of the year. The effluent from Ponds 2,3,4,5,6 and 7 were also purple from January to April, and later on they turned pale green or dark

green with an occasional pink for a few days during the remaining eight months of the year. On the whole the ponds turned out pale green effluents for the major portion of the year.

7. CHEMICAL CONDITIONS

(a) Dissolved oxygen: The monthly averages expressed in mg./l. are shown in Table No. 4 Appendix from which the following data have been gathered.

MAXIMUM & MINIMUM VALUES:

TABLE NO. 4

| SOURCE | Maximum Value | Maximum Month | Minimum Value | Minimum Month | Annual averages |
|---|---|---|---|---|---|
| Inlet to Pond I | Nil | - | Nil | - | Nil |
| Effluent from Pond I | 4.62 | Sept. | " | Jan.- May | 1.89 |
| " " " II | 9.04 | " | " | Jan.- April | 2.62 |
| " " " III | 3.92 | " | " | " | 1.37 |
| " " " IV | 5.72 | " | " | " | 2.25 |
| " " " V | 5.92 | " | " | " | 1.96 |
| " " " VI | 6.23 | Oct. | " | " | 1.83 |
| " " " VII | 7.14 | Sept. | " | " | 2.50 |
| Average | 6.08 | Sept. | Nil | Jan.- April | 2.06 |

Maximum production of oxygen was found in the effluent from Pond II and the minimum from Pond III. Oxygen was found

TABLE NO. 5

| SOURCE | | COLD WEATHER | | | HOT WEATHER | | | MONSOON | | | POST-MONSOON | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | D.O. (mg./l.) | Increase (+)or(-) Decrease over the preceding | Cumula-tive increase | D.O. (mg./l.) | Increase (+)or(-) Decrease over the preceding | Cumu-lative Increase | D.O. (mg./l.) | Increase (+)or(-) Decrease over the preceding | Cumu-lative Increase | D.O. (mg./l.) | Increase (+)or(-) Decrease over the preceding | Cumu-lative |
| Effluent from Pond ..... | I | 0.85 | - | - | 0.98 | - | - | 3.01 | - | - | 3.57 | - | - |
| " " | II | 0.35 | -0.50 | 1.20 | 2.03 | +1.05 | 3.01 | 5.47 | +2.46 | 8.48 | 3.40 | -0.17 | 6.97 |
| " " | III | 0.29 | -0.06 | 1.49 | 0.69 | -1.34 | 3.70 | 2.42 | -3.05 | 10.90 | 3.28 | -0.12 | 10.25 |
| " " | IV | 0.65 | +0.36 | 2.14 | 0.87 | +0.18 | 4.57 | 4.41 | +1.99 | 15.31 | 2.20 | -1.18 | 12.45 |
| " " | V | 1.05 | +0.40 | 3.19 | 0.59 | -0.28 | 5.16 | 4.29 | -0.12 | 19.60 | 3.08 | +0.88 | 15.53 |
| " " | VI | 0.74 | -0.31 | 3.93 | 1.14 | +0.55 | 6.30 | 5.49 | +1.20 | 25.09 | 2.90 | -0.18 | 18.43 |
| " " | VII | 0.48 | -0.26 | 4.41 | 1.72 | +0.58 | 8.02 | 5.42 | -0.07 | 30.51 | 3.49 | +0.59 | 21.92 |
| Average | | 0.63 | - | - | 1.15 | - | - | 4.36 | - | - | 3.12 | - | - |

from June to December only in all the ponds. The annual average was found to be 2.06 mg./l.

SEASONAL VARIATIONS: The seasonal averages for each of the seven ponds are shown in Table No. 5.

The production of oxygen was found to be maximum in the monsoon season and to be least in the cold weather.

The seasonal increase or decrease in oxygen content over the preceeding pond and the cumulative increase for the series of ponds in each season are shown in Table No.5.

The cumulative increase for the whole series of ponds is found to be highest in the monsoon season and lowest in the cold weather period. The maximum cumulative production was 30.51 mg./l. in the monsoon season and the least was 4.41 in the cold weather period. There was a progressive increase in the average oxygen content from the cold weather to the monsoon season and then there was a slight fall in the post-monsoon season.

(b) B.O.D. ( 5 days at 20° C):

The results of analysis of the quantity of oxygen required for satisfactory oxidation of organic matter by aerobic bacteria are shown in Table 5 (Appendix) from which the following observations are made:

TABLE NO. 6

| SOURCE | Maximum B.O.D. | Month | Minimum B.O.D. | Month | Annual Average |
|---|---|---|---|---|---|
| Inlet to pond I | 257 | Jan. | 133 | May | 189 |
| Effluent from Pond I | 210 | Dec. | 60 | May | 125 |
| " " " II | 152 | Feb. | 40 | Aug. | 98 |
| " " " III | 130 | Feb. | 38 | Aug. | 83 |
| " " " IV | 118 | Jan. | 36 | Aug. | 69 |
| " " " V | 82 | Jan. & Feb. | 30 | Oct. | 58 |
| " " " VI | 75 | Jan. | 25 | Oct. | 44 |
| " " " VII | 74 | April | 12 | Oct. | 37 |
| Average | 120 | | 34 | | 73 |

It will be seen from Table No. 6 that there is a progressive reduction in BOD values both in the maximum, minimum and annual averages. Maximum percentage reduction of 94.1% in October and the minimum percentage reduction of 57.7% in April have been recorded ( Table No.V), appendix.

Seasonal Changes are shown in Table No. 7:

From a study of the above table it will be seen that (i) the greatest percentage reduction in BOD takes place in Pond II being 55 in the post-monsoon season and the lowest percentage reduction of 3 in Pond VII in the monsoon season.

TABLE NO. 7

| | | COLD WEATHER | | | HOT WEATHER | | | MONSOON | | | POST MONSOON | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | BOD mg./l. | % reduction over the previous pond | Cumulative reduction % | BOD mg./l. | % reduction over the previous pond | Cumulative reduction % | BOD mg./l. | % reduction over the previous pond | Cumulative reduction % | BOD mg./l. | Cum % reduction over the previous pond | Cumulative reduction % |
| Inlet to Pond | I | 191 | - | - | 197 | - | - | 168 | - | - | 200 | - | - |
| Effluent from Pond . . . . . | I | 176 | 8 | - | 114 | 42 | - | 91 | 46 | | 182 | 9 | - |
| " " | II | 130 | 26 | 32 | 108 | + 5 | 45 | 63 | 31 | 62 | 82 | 55 | 59 |
| " " | III | 106 | 18 | 44 | 115 | + 6 | 42 | 60 | 5 | 64 | 76 | 7 | 62 |
| " " | IV | 86 | 19 | 55 | 70 | 39 | 65 | 56 | 7 | 67 | 63 | 17 | 68 |
| " " | V | 69 | 20 | 64 | 62 | 11 | 69 | 50 | 11 | 70 | 44 | 30 | 78 |
| " " | VI | 53 | 19 | 72 | 54 | 13 | 73 | 32 | 36 | 81 | 28 | 37 | 86 |
| " " | VII | 44 | 17 | 77 | 55 | + 2 | 72 | 31 | 3 | 82 | 14 | 50 | 93 |
| Average/ % Reduction | | 95/ 56.3 | 18/ - | 57/ - | 82/ 58.4 | 15/ - | 61/ - | 55/ 67.3 | 20/ - | 71/ - | 70/ 65.0 | 29/ - | 74/ - |

The greatest cumulative percentage reduction of 93% takes place in Pond No. VII in the post-monsoon season and the lowest of 72% in the hot weather.

(c) OXYGEN CONSUMED ( 4 hours at 27° C)

This test measures the quantity of oxidisable carbonaceous matter and the results are shown in Table No.VI (Appendix) from which the following conclusions are made.

MAXIMUM & MINIMUM VALUES:

TABLE NO. 8

| SOURCE | | MAXIMUM Oxygen consumed | Month | MINIMUM Oxygen consumed | Month | ANNUAL AVERAGE |
|---|---|---|---|---|---|---|
| Inlet to Pond | I | 74 | April | 39 | August | 52 |
| Effluent from Pond ..... | I | 84 | " | 21 | " | 48 |
| " " | II | 87 | " | 20 | " | 45 |
| " " | III | 76 | " | 20 | July & Oct. | 44 |
| " " | IV | 87 | " | 16 | October | 43 |
| " " | V | 85 | " | 12 | " | 40 |
| " " | VI | 80 | " | 10 | " | 39 |
| " " | VII | 86 | " | 7 | " | 36 |
| Average | | 83 | April | 15 | October | 42 |

TABLE NO. 9

| SOURCE | | COLD WEATHER | | | HOT WEATHER | | | MONSOON | | | POST-MONSOON | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Oxygen Cons. mg./l. | % Reduction over the previous pond | Cumulative % reduction. | Oxygen Cons. mg./l | %Reduction over the previous pond | Cumulative % reduction | Oxygen Cons. mg./l. | % Reduction over the previous pond | Cumulative % reduction | Oxygen Cons mg./l. | %Reduction over the previous pond | Cumulative % reduction. |
| Inlet to Pond | I | 44 | - | - | 62 | - | - | 43 | - | - | 54 | - | - |
| Effluent from Pond ..... | I | 46 | + 4 | - | 64 | + 3 | - | 33 | 23 | - | 40 | 26 | - |
| " " | II | 45 | 2 | + 2 | 58 | 9 | 6 | 28 | 15 | 35 | 38 | 5 | 30 |
| " " | III | 40 | 11 | 9 | 55 | 5 | 11 | 25 | 11 | 42 | 37 | 3 | 31 |
| " " | IV | 41 | + 2 | 7 | 56 | + 2 | 10 | 22 | 12 | 50 | 30 | 20 | 45 |
| " " | V | 40 | 2 | 9 | 54 | 4 | 13 | 21 | 4 | 51 | 23 | 30 | 56 |
| " " | VI | 41 | + 2 | 7 | 50 | 7 | 19 | 19 | 10 | 56 | 20 | 13 | 63 |
| " " | VII | 42 | + 2 | 5 | 51 | + 2 | 18 | 16 | 16 | 63 | 14 | 30 | 75 |
| Average/ | | 42 | 1 | 6 | 55 | 2 | 13 | 23 | 13 | 49 | 29 | 18 | 50 |
| % Reduction | | 5.0 | - | - | 11.3 | - | - | 46.5 | - | - | 46.3 | - | - |

Maximum values have been recorded in April and the minimum in October. The annual averages show a gradual decrease from first to the last pond.

There is an increase in organic matter content varying between 16.0 and 23.0% in the final effluent during January to April due to the presence of sulphides in all the ponds. From May to December, the final effluent shows a reduction varying between 44.0% and 83.0%, when there is algal development in the ponds. In the final effluent maximum reduction of 44.0% in May is seen. In the first four months i.e. from January to April there is an increase in the values which vary between 16% and 23% and this increase is attributed to the presence of sulphides, resulting from anaerobic decomposition of sulphates and sulphur containing organic matter in the individual ponds (Table VI appendix). Seasonal variations are shown in Table No.9. The seasonal average reduction is lowest in the cold weather and highest in the monsoon season taking all the ponds into consideration. But the cumulative reduction in the final effluent is lowest in the cold weather (5%) and highest in the post monsoon season (75%).

(d) PHENOLPHTHALEIN ALKALINITY:

This test is an indication of bacterial or algal activity. In the case of the former the figures are phenolphthalein alkalinity will be lower or nil and in the case of latter the figures will be higher. The maximum, minimum and

the seasonal variations in phenolphthalein alkalinity have been taken from table No. VII (Appendix) and are shown in Table No.10.

MAXIMUM & MINIMUM VALUES:

TABLE NO. 10

| S O U R C E | | MAXIMUM P.Alka-linity | Month | MINIMUM P. Alka-linity | Month | Annual average |
|---|---|---|---|---|---|---|
| Inlet to Pond | I | 52 | May | 15 | Nov. | 34 |
| Effluent from P. | I | 95 | July | 25 | Feb. | 47 |
| " " | II | 167 | Sept. | 23 | Jan. & Feb. | 67 |
| " " | III | 120 | Sept. | 15 | Jan. | 57 |
| " " | IV | 130 | Sept. | 28 | Feb. | 56 |
| " " | V | 140 | Sept. | 24 | April | 66 |
| " " | VI | 138 | June | 10 | Feb. | 62 |
| " " | VII | 166 | Sept. | 20 | Jan. | 64 |
| A v e r a g e | | 136 | - | 21 | - | 60 |

The pond water is alkaline throughout, the annual average maximum being 136 ppm which is about 161 % over the raw water maximum. The average minimum is 21 which is about 40% over the raw water minimum. The annual average is 60 ppm.

TABLE NO. 11

| SOURCE | COLD WEATHER | | | HOT WEATHER | | | MONSOON | | | POST-MONSOON | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | P. Alkalinity. | % increase (+)or (-)Decrease | Cumulative(+) increase or(-)Decrease % | P. Alkalinity | %increase(+) or(-) Decrease | Cumulative(+) increase or (-) decrease % | P.Alkalinity | %increase(+) or(-) decrease | Cumulative(+) increase or (-)decrease % | P.Alkalinity | %increase (+)or (-)decrease | Cumulative (+)increase or(-) decrease % |
| Inlet to Pond I | 31 | - | - | 47 | - | - | 28 | - | - | 20 | - | - |
| Effluent from Pond I | 31 | 0 | - | 44 | - 6 | - | 63 | +125 | - | 54 | +170 | - |
| " " " II | 39 | + 26 | + 26 | 68 | +32 | + 45 | 69 | + 9 | +147 | 51 | + 6 | +155 |
| " " " III | 35 | + 10 | + 10 | 58 | -15 | + 24 | 86 | + 25 | +207 | 46 | - 10 | +130 |
| " " " IV | 43 | + 22 | + 40 | 61 | + 5 | + 30 | 92 | + 7 | +230 | 60 | + 30 | +200 |
| " " " V | 45 | + 2 | + 45 | 65 | + 7 | + 40 | 80 | + 13 | +186 | 75 | + 25 | +275 |
| " " " VI | 38 | - 16 | + 20 | 61 | - 5 | + 30 | 72 | - 10 | +160 | 85 | + 13 | +325 |
| " " " VII | 43 | + 13 | + 40 | 78 | +30 | + 66 | 96 | - 33 | +243 | 67 | - 21 | +235 |
| Average | 40 | - | + 30 | 62 | - | + 34 | 80 | - | +186 | 62 | - | +220 |
| % Increase | 30.0 | - | - | 32.0 | - | - | 186.0 | - | - | 210 | - | - |

Taking the final per centage of increase or decrease into consideration, it is seen that there is decrease in values from January to April the range being (38 to 61%) and that there is an increase in values during the rest of the year, when a maximum per centage increase of 403 in September and a minimum per centage increase of 60 in August are recorded (Vide Table VII Appendix).

SEASONAL VARIATIONS: are shown in Table No.11.

The seasonal averages show a definite increase over the corresponding raw sewage figures from the cold weather to post-monsoon season. The increase is greatest during the post-monsoon season being 22% increase over the corresponding raw sewage value. Lowest increase of 30% is recorded in cold weather. The increase in the values has to be attributed to algal activity.

(E ) TOTAL ALKALINITY:

The values for this test are shown in Table No. VIII (Appendix) from which the following inferences are drawn.

MAXIMUM & MINIMUM VALUES:

TABLE NO. 12 (see next page).

TABLE NO. 12

| SOURCE | | MAXIMUM M.O. Alkalinity | Month | MINIMUM M.O. Alkalinity | Month | Annual Average |
|---|---|---|---|---|---|---|
| Inlet to Pond | I | 713 | Jan. | 475 | April | 613 |
| Effluent from Pond ..... | I | 773 | Feb. | 497 | August | 609 |
| " " | II | 727 | Jan. | 487 | " | 598 |
| " " | III | 770 | Feb. | 490 | " | 617 |
| " " | IV | 770 | Feb. | 475 | " | 607 |
| " " | V | 800 | Feb. | 490 | October | 607 |
| " " | VI | 690 | Jan. | 446 | Sept. | 564 |
| " " | VII | 838 | Feb. | 459 | " | 587 |
| Average | | 766 | - | 478 | - | 598 |

The maximum values are found to fluctuate between 690 and 838 ppm (in January and February) the average being 766 ppm. The minimum values also are found to fluctuate between 446 and 497 ppm (in August, September & October), the average being 478 ppm. The annual average for the ponds is found to be 598 and that for raw sewage to be 613 so that there is a small reduction of 2.4% only which has to be attributed to the fact that from January to April (excepting March) there is an increase of 9 to 22% and that from May to December there is a decrease of 4 to 30% in the values of final effluent.

TABLE NO. 13

| SOURCE | COLD WEATHER | | | HOT WEATHER | | | MONSOON | | | POST-MONSOON | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total Alkalinity | % increase (+) or (-) decrease | Cumulative %increase (+)or(-)decrease | Total Alkalinity | %increase (+)or(-) decrease | Cumulative % increase (+)or(-) decrease | Total Alkalinity | %increase(+)or (-) Decrease | Cumulative %increase (+)or(-)decrease | Total Alkalinity | %increase (+)or(-) decrease | Cumulative % increase(+)or (-)decrease |
| Influent to Pond I | 670 | - | - | 585 | - | - | 587 | - | - | 622 | - | - |
| Effluent from Pond I | 698 | +4.2 | - | 587 | + .4 | - | 562 | -4.3 | - | 589 | -5.3 | - |
| " " " II | 667 | -4.4 | - .5 | 611 | +4.1 | +4.4 | 554 | -1.4 | -6.0 | 565 | -4.1 | -9.2 |
| " " " III | 667 | nil | - .5 | 610 | nil | +4.2 | 582 | +5.0 | -1.0 | 598 | +6.0 | -3.8 |
| " " " IV | 685 | +2.7 | +2.7 | 610 | nil | +4.2 | 529 | -9.1 | -10.0 | 600 | nil | -3.5 |
| " " " V | 707 | +3.2 | +5.5 | 610 | nil | +4.2 | 537 | -1.4 | -8.3 | 555 | -7.5 | -10.7 |
| " " " VI | 636 | -5.0 | -5.0 | 564 | -7.5 | -3.6 | 500 | -6.9 | -15.0 | 502 | -9.5 | -20.0 |
| " " " VII | 708 | +11.3 | +5.7 | 759 | +34.6 | +3.0 | 509 | +1.8 | =11.6 | 558 | -11.1 | -10.3 |
| Average | 681 | - | +1.3 | 622 | - | +6.2 | 539 | - | -8.2 | 567 | - | -9.0 |
| % increase (+) or(-) decrease | +1.7 | - | - | +6.3 | - | - | -8.2 | - | - | -8.8 | - | - |

SEASONAL VARIATIONS: (See Table No.13)

The seasonal averages do not show a definite increase or decrease only, but increases are found to fluctuate. Sometimes there is an increase and sometimes there is a decrease. The annual average increase is found to be 1.3% in the cold weather and 6.2% in the hot weather. But it is found to decrease by 8.2% and 9.0% in the monsoon and post-monsoon seasons, respectively.

(f) Chlorides: do not seem to have any biological significance. The results are shown in Table No.IX in the appendix from which the following Tabular statements, have been prepared.

MAXIMUM AND MINIMUM VALUES:

TABLE NO.14

| SOURCE | MAXIMUM Value | MAXIMUM Month | MINIMUM Value | MINIMUM Month | Annual Averages |
|---|---|---|---|---|---|
| Inlet to Pond I | 464 | Nov. | 272 | Aug. | 338 |
| Effluent from Pond I | 450 | " | 310 | Sept. | 366 |
| " " " II | 451 | " | 300 | Sept. | 358 |
| " " " III | 457 | April | 290 | October | 370 |
| " " " IV | 420 | May & June | 335 | Sept. | 381 |
| " " " V | 477 | April | 280 | Sept. | 384 |
| " " " VI | 485 | April | 300 | Sept. | 386 |
| " " " VII | 455 | April | 270 | Sept. | 377 |
| Average | 456 | - | 298 | - | 375 |

TABLE NO. 15

| | COLD WEATHER | | | HOT WEATHER | | | MONSOON | | | POST-MONSOON | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Chlorides | %increase(+)or (-)decrease | Cumulative % increase (+) or (-) decrease | Chlorides | %increase(+) or (-) decrease | Cumulative % increase (+)or(-) decrease | Chlorides | %increase (+)or (-)decrease | Cumulative% increase(+) or (-) decrease | Chlorides | %increase (+) or (-) decrease | Cumulative % increase(+) or (-)decrease |
| Influent to Pond I | 353 | - | - | 382 | - | - | 295 | - | - | 332 | - | - |
| Effluent from Pond I | 376 | + 6.5 | - | 373 | - 2.3 | - | 333 | +12.9 | - | 385 | + 1.6 | - |
| " " " II | 366 | - 2.6 | + 3.7 | 379 | + 1.6 | + 1.0 | 308 | + 8.4 | + 4.4 | 380 | + 1.3 | +14.5 |
| " " " III | 372 | + 1.6 | + 5.4 | 401 | + 6.0 | + 5.0 | 330 | + 7.1 | + 1.2 | 357 | - 6.1 | + 7.5 |
| " " " IV | 377 | + 1.3 | + 7.0 | 406 | + 1.2 | + 6.3 | 355 | + 7.6 | +20.4 | 374 | + 5.0 | +12.6 |
| " " " V | 384 | + 1.9 | + 9.0 | 426 | + 4.4 | +11.5 | 333 | + 6.2 | +12.9 | 377 | + 1.0 | +13.5 |
| " " " VI | 383 | nil | + 8.5 | 432 | + 1.4 | +13.1 | 335 | nil | +13.5 | 375 | + 0.5 | +13.4 |
| " " " VII | 365 | - 4.7 | + 3.4 | 423 | - 2.1 | +10.8 | 331 | - 1.2 | +12.2 | 371 | + 1.0 | +12.7 |
| Average | 375 | - | + 6.2 | 406 | - | + 6.5 | 332 | - | +12.2 | 374 | - | +12.7 |
| % increase | 6.8 | - | - | 6.8 | - | - | 12.5 | - | - | 12.7 | - | - |

The maximum value is shown in April, May, June or November and the minimum value in September or October. The annual average value shows an increase of about 11.0% in the final effluent over the corresponding values for raw sewage and this may be attributed to ~~xxx~~ evaporation and the resulting concentration.

SEASONAL VARIATIONS: The results are summariesed in Table No. 15.

In the above Table there is a cumulative annual average increase of 6.2% in the cold weather, 6.5% in the hot weather, 12.2% in the monsoon season and 12.7% in the post-monsoon season. This increase has to be attributed again to evaporation, and the resulting concentration.

(g) Ammoniacal nitrogen: The maximum and minimum values and the seasonal variations are discussed below:

MAXIMUM AND MINIMUM VALUES:

TABLE NO. 16

| SOURCE | | MAXIMUM | | MINIMUM | | Annual average |
|---|---|---|---|---|---|---|
| | | Value | Month | Value | Month | |
| Inlet to Pond | I | 30.0 | May | 17.0 | Sept. | 23.5 |
| Outlet from Pond | I | 28.0 | April | 10.0 | Dec. | 17.5 |
| " " " | II | 28.0 | Feb. | 7.5 | " | 15.8 |
| " " " | III | 29.0 | Jan. | 5.5 | " | 16.9 |
| " " " | IV | 27.0 | Jan. | 6.0 | " | 15.8 |
| " " " | V | 29.5 | Mar. | 4.0 | " | 14.6 |
| " " " | VI | 22.0 | Jan. | 3.0 | Oct. | 10.8 |
| " " " | VII | 28.0 | Mar. | 2.0 | " | 11.6 |
| Average | | 27.3 | - | 4.2 | - | 14.7 |

TABLE NO. 17

| SOURCE | | COLD WEATHER | | | HOT WEATHER | | | MONSOON | | | POST-MONSOON | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | AM-N | %increase(+) or(-) decrease | Cumulative % increase (+) or (-) decrease | AM-N | %Increase (+) or (-) decrease | Cumulative % increase (+) or (-) decrease | AM-N | %increase (+) or (-) decrease | Cumulative % increase (+) or (-) decrease | AM-N | %increase (+) or (-) decrease | Cumulative % increase (+) or (-) decrease |
| Influent to Pond | I | 25.0 | - | - | 27.5 | - | - | 20.0 | - | - | 18.5 | - | - |
| Effluent from Pond ..... | I | 18.7 | 25.2 | - | 21.0 | 24.0 | | 13.0 | 35.0 | | 15.6 | 15.7 | - |
| " " | II | 18.5 | 0.8 | 26.0 | 16.5 | 21.4 | 40.0 | 14.3 | +10.0 | 28.5 | 12.8 | 17.9 | 30.8 |
| " " | III | 19.8 | +5.2 | 20.8 | 25.6 | +55.1 | 7.0 | 13.6 | 5.0 | 32.0 | 13.0 | + 1.6 | 30.0 |
| " " | IV | 18.4 | -7.1 | 26.4 | 18.0 | 30.0 | 34.6 | 13.5 | 1.0 | 32.5 | 11.5 | 11.5 | 38.0 |
| " " | V | 18.4 | nil | 26.4 | 18.4 | + 2.2 | 33.1 | 10.3 | 24.0 | 48.5 | 8.5 | 26.0 | 54.1 |
| " " | VI | 15.5 | 15.8 | 38.0 | 15.0 | 18.4 | 45.4 | 5.8 | 43.6 | 71.0 | 3.5 | 59.0 | 81.1 |
| " " | VII | 16.5 | +6.0 | 35.0 | 16.2 | + 8.0 | 41.1 | 9.2 | +60.0 | 54.0 | 2.0 | 43.0 | 89.2 |
| Average | | 17.8 | - | - | 18.7 | - | - | 11.4 | - | - | 9.6 | - | - |
| % Reduction | | 28.8 | - | - | 36.0 | - | - | 43.0 | - | - | 49.1 | - | - |

It will be seen from a study of Table No. X in the appendix that the effluents from the ponds do not show any reduction till April due to the production of $H_2S$ and the concomitant development of purple coloured sulphur bacteria in the ponds. From May onwards reduction in ammoniacal nitrogen was noticed accompanied by algal growths in the ponds. So, maximum values were found to be higher, and they were reached during January to April; and the minimum values were reached during October or December. But the annual average value for each of the ponds is lower showing greater reduction from May onwards. The reductions varied between 4.2% and 89.0%. The annual average reduction was only 50.6% in the final effluent.

SEASONAL VARIATIONS: (See Table No.17).

The average highest reduction of 49.1% and the lowest reduction of 28.8% were seen in the post-monsson and the cold weather periods respectively. But the cumulative percentage reduction was 89.2% in the post-monsoon season and 35.0% in the cold weather period.

(h) Phosphates ($PO_4$):

The maximum and minimum values and the seasonal variations are shown in Table No.18).

From the above Table the maximum average reduction was 70.4% and the minimum average reduction was 46.9% and the annual average reduction was 56% taking all the ponds into consideration.

SEASONAL VARIATIONS: (See Table No. 19).

TABLE NO. 18

| SOURCE | | MAXIMUM Value | MAXIMUM Month | MINIMUM Value | MINIMUM Month | Annual average |
|---|---|---|---|---|---|---|
| Inlet to Pond | I | 19.4 | June | 13.5 | Jan. | 17.0 |
| Outlet from Pond | I | 12.2 | Sept. | 6.2 | Nov. | 9.8 |
| " " " | II | 12.2 | Sept. | 4.6 | Mar. | 8.5 |
| " " " | III | 10.9 | Sept. | 4.7 | Oct. | 7.8 |
| " " " | IV | 10.0 | Aug. | 3.0 | Mar. | 7.2 |
| " " " | V | 9.6 | Aug. | 3.0 | Nov. | 6.7 |
| " " " | VI | 8.4 | June | 3.0 | Mar. & Nov. | 6.3 |
| " " " | VII | 9.2 | June | 3.7 | Nov. | 6.5 |
| Average | | 10.3 | - | 4.0 | - | 7.5 |

The maximum average reduction was 80.1% in November and the minimum average reduction was 41.6% in August and the annual average reduction was 61.8% taking all the ponds into consideration ( Vide Table XI, appendix).

TABLE NO. 19

| | | COLD WEATHER | | | HOT WEATHER | | | MONSOON | | | POST-MONSOON | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Phosphate ($PO_4$) | %increase(+) or (-) decrease | Cumulative % increase (+)or(-) decrease | Phosphate (PO ) | %increase(+) or (-) decrease | Cumulative % increase (+) or (-) decrease | Phosphate (PO ) | %increase(+) or (-) decrease | Cumulative% increase(+) or (-) decrease | Phosphate (PO ) | %increase(+) or (-) decrease | Cumulative % increase (+) or (-) decrease |
| Influent to Pond | I | 12.4 | - | - | 17.3 | - | - | 15.8 | - | - | 18.2 | - | - |
| Effluent from pond ..... | I | 9.8 | 21.0 | - | 14.1 | 18.5 | - | 10.4 | 34.1 | - | 7.2 | 60.4 | - |
| " " | II | 8.4 | 14.3 | 32.2 | 7.6 | 46.1 | 56.0 | 8.2 | 21.1 | 48.1 | 6.9 | 4.0 | 62.1 |
| " "" | III | 7.4 | 12.0 | 40.3 | 7.6 | nil | 56.0 | 10.0 | +22.0 | 36.7 | 5.3 | 23.2 | 70.9 |
| " " | IV | 7.7 | +4.0 | 38.0 | 6.3 | 17.1 | 63.5 | 8.8 | 12.0 | 44.2 | 5.9 | +11.3 | 67.6 |
| " " | V | 6.4 | 1.7 | 48.4 | 6.5 | +3.2 | 62.4 | 8.4 | 5.0 | 60.0 | 4.6 | 22.0 | 74.7 |
| " " | VI | 6.3 | 1.6 | 49.2 | 5.8 | +10.8 | 66.5 | 8.2 | 2.4 | 48.1 | 4.2 | 8.7 | 77.0 |
| " " | VII | 6.2 | 1.6 | 50.0 | 6.5 | +12.1 | 62.4 | 7.6 | 7.3 | 52.0 | 5.0 | +19.0 | 72.5 |
| A v e r a g e | | 7.5 | - | - | 7.8 | - | - | 8.8 | - | - | 5.6 | - | - |
| % Reduction | | 40.0 | - | - | 55.0 | - | - | 44.3 | - | - | 69.2 | - | - |

The highest average reduction of 69.2% is seen in the post-monsoon season and the lowest 40.0% reduction in the cold weather period. Also, the cumulative percentage reduction was highest (72.5%) in the post-monsoon and lowest (50.0%) in the cold weather period.

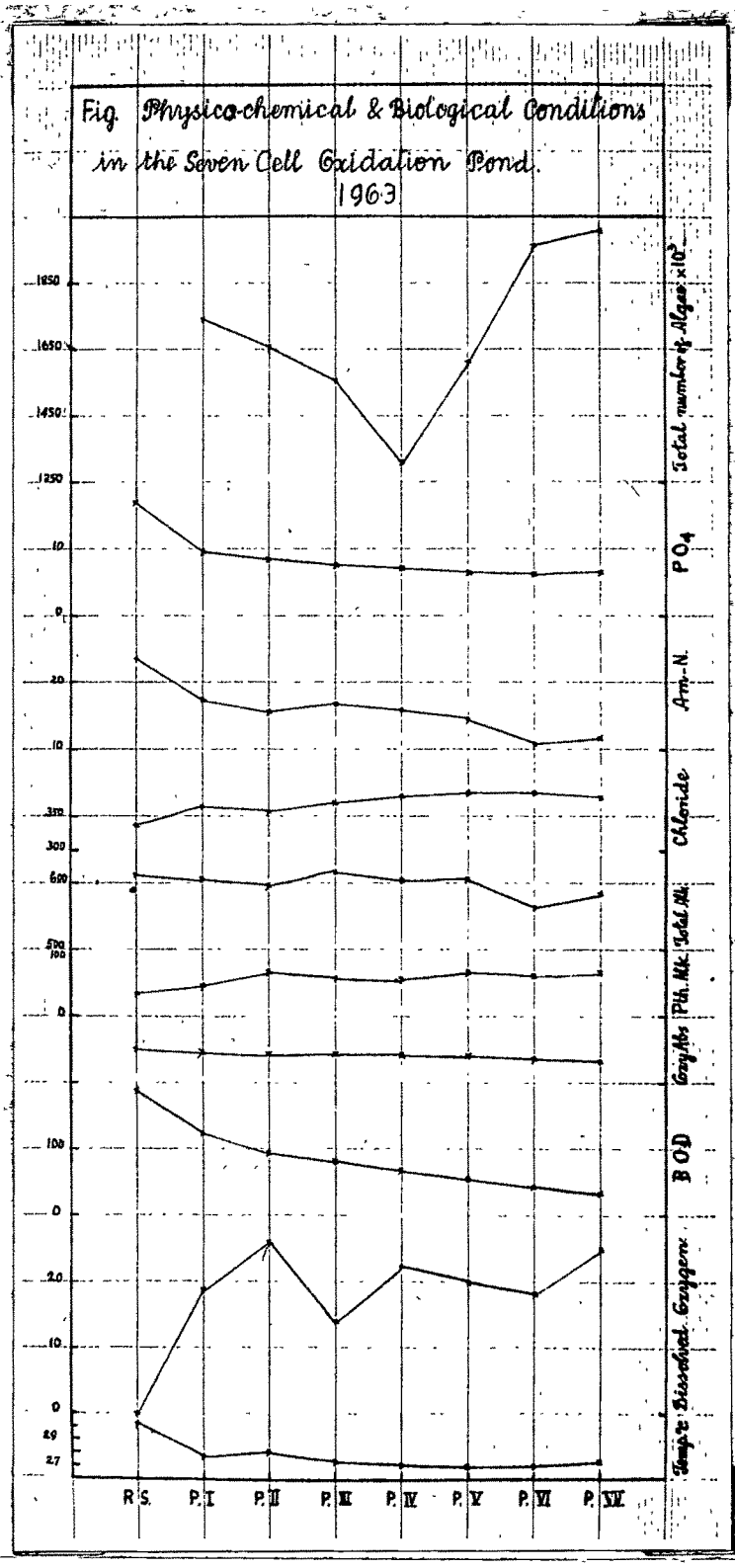


Fig. 37. Graph showing the physico-chemical and biological conditions in the seven oxidation pond.

## 8. BIOLOGICAL CONDITIONS

### LIST OF THE ALGAL AND OTHER ORGANISMS RECORDED IN THE SERIES OF SEVEN OXIDATION PONDS DURING 1963.

A. CHLOROPHYTA

1. Ankistrodesmus falcatus
2. Chlamydomonas sp.
3. Chlorococcum humicola
4. Chlorella pyrenoidosa
5. Micractinium sp.
6. Pandorina morum
7. Pyrobotrys sp.
8. Scenedesmus quadricauda.

B FLAGELLATA

9. Euglena gracilis
10. Phacus longicauda

C. CYANOPHYTA

11. Oscillatoria chalybea
12. Oscillatoria limosa
13. Chroococcus turgidus
14. Arthrospira khannae Dr. & Strickle.

D. PURPLE COLOURED SULPHUR BACTERIUM

15. Thiopedia rosea Winogradsky.

### II. THE DOMINANT AND SUB-DOMINANT ORGANISMS RECORDED AT ONE TIME OR ANOTHER.

1. Chlorella pyrenoidosa
2. Euglena gracilis
3. Arthrospira khannae
4. Oscillatoria chalybea
5. Thiopedia rosea

The maximum and minimum number of organisms per ml recorded in each of the ponds during the year.

TABLE NO. 20

| SOURCE | | Maximum Value $x10^3$ per ml. | Month | Minimum Value $x10^3$ per ml. | Month | Annual average |
|---|---|---|---|---|---|---|
| Pond | I | 6613.0 | May | 32.5 | July | 1747.4 |
| Pond | II | 6297.7 | May | 36.1 | Sept. | 1661.2 |
| Pond | III | 4296.7 | May | 25.4 | July | 1558.7 |
| Pond | IV | 4368.6 | April | 25.0 | Sept. | 1301.1 |
| Pond | V | 4227.8 | Jan. | 27.0 | Sept. | 1609.2 |
| Pond | VI | 8978.8 | Feb. | 31.0 | Nov. | 1958.0 |
| Pond | VII | 8405.2 | Feb. | 32.5 | Nov. | 2007.9 |

Maximum number of organisms was recorded in the sixth pond and the minimum number of in the fourth pond.

The names of the dominant organisms in each of the ponds in each month during the year is shown below:-

TABLE NO. 21

| Month | I | II | III | IV | V | VI | VII |
|---|---|---|---|---|---|---|---|
| Jan. | ..... | | Thiopedia rosea | | ..... | | |
| Feb. | ..... | | " | | ..... | | |
| Mar. | ..... | | " | | ..... | | |
| April | ..... | | " | | ..... | | |
| May | Thiopedia ..... | | Chlorella | | ..... | | |
| June | ..... | | " | | ..... | | |
| July ½ | ..... | | " | | ..... | | |
| July ½ | ..... | | Arthrospira | | ..... | | |
| Aug. ½ | ..... | | Thiopedia | | ..... | | |
| Aug. ½ | ..... | | Chlorella | | ..... | | |
| Sept. | ..... | | Arthrospira | | ..... | | |
| Oct. ½ | ..... | Euglena ..... | | | .....Arthrospira..... | | |
| Oct. ½ | ..... | | Thiopedia | | ..... | | |
| Nov. | Euglena | Arthrospira | Euglena | | .....Arthrospira..... | | |
| | | Thiopedia ..... | | | .....Thiopedia ..... | | |
| Dec. | ..... | | Chlorella ..... | | | | |

The dominant organism was Thiopedia rosea during the first four months of the year in all the seven ponds, when bacterial photosynthesis was taking place. In May, Thiopedia rosea continued to be dominant in the first pond only and in the remaining six ponds Chlorella was dominant; and the same organism continued to be dominant in all the ponds in June and July. In July Arthrospira also was dominant towards the latter part. In August Thiopedia was first dominant and later it was succeeded by Chlorella. Arthrospira was the only dominant organism in September. In October Euglena was dominant in the first three ponds and Arthrospira in the remaining four ponds. Later the two organisms were replaced by Thiopedia rosea in the same month. In November Euglena became dominant in the first pond, Arthrospira and Thiopedia in the second, Euglena in the third, and Arthrospira and Thiopedia in the remaining ponds. Chlorella became dominant in all the seven ponds during December.

Viewed from the standpoint of seasonal variations, it was found that in the cold weather period the dominant organism was Thiopedia rosea; and it continued its dominance in the first half of the hot weather period. In the latter half Chlorella became dominant. Arthrospira, Thiopedia and Chlorella were dominant in the monsoon season; and in the following post-monsoon season, Euglena, Arthrospira and Thiopedia were dominant.

## DISCUSSION OF RESULTS

Parker (1962) had tried to purify Australian sewage by making it pass through a series of eight oxidation ponds. The chief point of difference between our series of seven ponds and his was that his first two ponds were anaerobic and the last six were aerobic while all our ponds, though considered aerobic were working anaerobically for the first four months and aerobically for the rest of the year. Also we used only seven ponds. All the same an attempt is made below to compare his results with ours in respect of the three important parameters such as BOD and ammoniacal nitrogen and orthophosphates for the two seasons i.e. summer and cold weather or winter for which he has furnished figures. The results are shown below:

TABLE NO. 22

| Analysis | Raw sewage | AUSTRALIAN PONDS NUMBER 1 | 2 | 4 | 5 | 6 | 7 | 7 | 8 | Final Red % |
|---|---|---|---|---|---|---|---|---|---|---|
| SUMMER | | | | | | | | | | |
| 5 day BOD | 521 | 100 | 46 | 22.7 | 22.7 | 13.5 | 10.1 | 10.0 | 10.6 | 98.0 |
| Am-N | 32.4 | 46.4 | 52.5 | 48.7 | 45.0 | 42.5 | 40.0 | 28.1 | 18.9 | 42.0 |
| WINTER | 341 | | | | | | | | | |
| 5 day BOD | 341 | 94 | 45.6 | 33.6 | 38.3 | 29.6 | 13.9 | - | - | 96.0 |
| Am-N | 21.9 | 90.1 | 42.5 | 40.0 | 38.0 | 33.0 | 29.9 | - | - | 36.5 |

| Analysis | Raw sewage | AHMEDABAD POND NUMBERS 1 | 2 | 3 | 4 | 5 | 6 | 7 | Final Red % |
|---|---|---|---|---|---|---|---|---|---|
| SUMMER | | | | | | | | | |
| 5 day BOD | 197 | 114 | 108 | 115 | 70 | 62 | 54 | 55 | 72.0 |
| Am-N | 27.5 | 21.0 | 16.5 | 25.6 | 18.0 | 18.4 | 15.0 | 16.2 | 41.1 |
| PO4 | 17.3 | 14.1 | 7.6 | 7.6 | 6.3 | 6.5 | 5.8 | 6.5 | 62.5 |
| WINTER | | | | | | | | | |
| 5 day BOD | 191 | 176 | 130 | 106 | 86 | 69 | 53 | 44 | 77.0 |
| Am-N | 25.0 | 18.7 | 18.5 | 19.8 | 18.4 | 18.4 | 15.5 | 16.5 | 35.5 |
| PO4 | 12.4 | 9.8 | 8.4 | 7.4 | 7.7 | 6.4 | 6.3 | 6.2 | 50.0 |

In respect of BOD, Parker's final effluent had given 96-98% reduction in summer and winter. In our case, the reduction was 72-77% during the same periods.

With regard to ammoniacal nitrogen, Parker's final effluent showed reductions ranging from 36.5 - 42.0% while our ponds showed 35.5 - 41.1% which were almost similar.

Unfortunately, Parker had not given any data regarding phosphate reduction. Our ponds showed greater reduction than ammoniacal nitrogen and ranged from 50.0-62.5% during the same periods.

Another point of difference between Parker's and our ponds was that the purple coloured sulphur bacterium - Chromatium sp. was dominant in his first two anaerobic ponds during the summer season only. In the case of our ponds, although none of them was working anaerobically, still the

purple coloured sulphur bacterium, Thiopedia rosea was the most dominant organism from January to April.

Next, a comparative study of the results of the final effluents from the single unit (pilot plant) oxidation pond and from the series of seven ponds of Ahmedabad, is made. The results are shown in Table No.23.

From a study of the above results (Table No.23), it will be seen that there is a greater reduction in the series of oxidation ponds in respect of 5-day BOD at 20° C, ammoniacal nitrogen, and phosphates which are the most important factors to reckon with in purification of sewage.

The production of dissolved oxygen is greater in the single unit than in the multiple unit. There is the same amount of chloride concentration in both the cases.

So, it would appear that there is an advantage in running a series of ponds than a single unit alone.

TABLE NO. 23

| DESCRIPTION | ANNUAL AVERAGES Single Unit Value (mg./l.) | % Reduction or increase | Seven Units Value (mg./l) | % Reduction or increase |
|---|---|---|---|---|
| A. PHYSICAL CONDITIONS | | | | |
| 1. Temp. (°C) | 27.5 | - | 27.4 | - |
| 2. Colour | Green | - | Purple & Green | |
| B. CHEMICAL CONDITIONS | | | | |
| 3. 5-day BOD at 20°C. | 47.5 | 74.4 | 37.0 | 79.6 |
| 4. $KMnO_4$ value | 30.2 | 29.6 | 36.0 | 19.0 |
| 5. Dissolved oxygen | 6.68 | - | 2.50 | - |
| 6. Phenolphthalein alkalinity | 74.5 | +109 | 64.0 | +223 |
| 7. Total alkalinity | 650 | +10.4 | 587.0 | 4.0 |
| 8. Ammoniacal nitrogen | 12.2 | 47.1 | 11.6 | 50.6 |
| 9. Chloride | 365.5 | +12.5 | 377.0 | +11.0 |
| 10. Orthophosphates | 7.1 | 52.4 | 6.5 | 51.8 |
| C. BIOLOGICAL CONDITIONS | | | | |
| 11. Algal numbers per ml x $10^3$ | 1369.6 | | 2007.9 | |
| 12. Dominant organisms: | Chlorella, Micractinium, Chlorococcum, Arthrospira, Oscillatoria, Euglena, and Thiopedia rosea | | Chlorella, Arthrospira, Euglena, Thiopedia rosea | |

## SUMMARY

The working of a seven unit oxidation pond in the Pirana Sewage farm at Ahmedabad is described.

The ponds were working anaerobically during January to April and aerobically for the remaining period of the year. During the first period there was bacterial photosynthesis and the dominant organism was the purple coloured sulphur bacterium Thiopedia rosea, which was also effectual in bringing about sewage purification. A reduction of 57.0% to 74% in 5-day BOD at 20°C. was noticed.

During the rest of the period there was algal photosynthesis when the reduction in BOD alone varied from 68% to 94%.

A comparison of the results obtained for the single unit and the multiple unit for 1963 has been made. It would appear that the multiple unit is more advantageous to use than the single unit.

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## REFERENCES

Pl. see pages 288 - 292.

TABLE NO. I

CLIMATOLOGICAL DATA FOR AHMEDABAD FOR 1963.

| Month | Season | Temperature (°C) | | Monthly Average hours of bright sunshine |
|---|---|---|---|---|
| | | Maximum | Minimum | |
| Dec. | Cold weather | 29.5 | 15.1 | 273.2 |
| Jan. | " | 26.3 | 12.3 | 292.0 |
| Feb. | " | 33.6 | 14.7 | 286.5 |
| Average | " | 29.8 | 14.0 | 283.9 |
| Mar. | Hot weather | 31.3 | 18.6 | 289.8 |
| April | " | 38.7 | 23.4 | 293.4 |
| May | " | 41.2 | 25.9 | 357.7 |
| June | " | 39.3 | 27.1 | 281.3 |
| Average | " | 37.6 | 23.7 | 305.5 |
| July | Monsoon | 33.0 | 25.8 | 151.3 |
| Aug. | " | 30.5 | 24.8 | 119.8 |
| Sept. | " | 30.1 | 21.6 | 202.1 |
| Average | " | 31.2 | 24.1 | 157.7 |
| Oct. | Post-monsoon | 35.6 | 21.1 | 286.2 |
| Nov. | " | 32.2 | 18.5 | 268.1 |
| Average | " | 33.9 | 19.8 | 277.1 |

TABLE NO. II

AVERAGE TEMPERATURE ( $^{o}$ C) OF THE SURFACE WATER TAKEN BETWEEN 11.00 A.M. AND 12.00 NOON ONCE A WEEK.

| 1963 Months | 'Influ-'ent to' 'Pond I' | Effluent from Ponds numbering 1 | 2 | 3 | 4 | 5 | 6 | 7 | 'Final % 'Reduction' |
|---|---|---|---|---|---|---|---|---|---|
| Jan. | 24.5 | 28.8 | 20.9 | 20.1 | 19.8 | 20.0 | 19.5 | 19.5 | 20.4 |
| Feb. | 27.2 | 24.6 | 25.7 | 23.8 | 23.1 | 23.0 | 22.6 | 22.9 | 15.7 |
| Mar. | 29.5 | 26.8 | 27.0 | 26.0 | 25.7 | 25.2 | 25.2 | 28.1 | 4.8 |
| April | 32.5 | 28.4 | 29.1 | 28.8 | 28.4 | 28.9 | 27.8 | 29.8 | 8.3 |
| May | 32.8 | 30.6 | 30.7 | 29.3 | 29.9 | 29.3 | 30.0 | 30.7 | 6.4 |
| June | 32.8 | 29.8 | 30.1 | 29.2 | 29.8 | 29.2 | 29.0 | 29.1 | 11.3 |
| July | 31.9 | 30.2 | 30.2 | 29.8 | 29.7 | 29.5 | 30.3 | 30.0 | 6.0 |
| Aug. | 29.9 | 29.0 | 28.8 | 28.9 | 28.6 | 28.4 | 29.2 | 27.2 | 22.4 |
| Sept. | 31.0 | 29.2 | 30.4 | 29.1 | 29.6 | 29.1 | 29.2 | 29.0 | 6.5 |
| Oct. | 30.5 | 28.5 | 29.2 | 28.8 | 28.9 | 28.8 | 29.0 | 29.0 | 5.0 |
| Nov. | 30.9 | 28.0 | 27.8 | 27.9 | 27.5 | 27.4 | 27.0 | 27.0 | 12.6 |
| Dec. | 26.8 | 28.0 | 27.7 | 27.1 | 24.3 | 27.0 | 27.0 | 26.8 | 0.0 |
| Average | 30.2 | 27.9 | 28.1 | 27.4 | 27.1 | 27.1 | 27.1 | 27.4 | 9.3 |

## TABLE NO. III

## COLOUR OF THE WATER IN THE PONDS AS IT APPEARED TO THE NAKED EYE

| 1963 Months | 'Influ-'ent to 'Pond I | Effluent from Ponds numbering | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Jan. | Black | Purple | Purple | Purple | Purple | Purple | Purple | Purple |
| Feb. | Grey | " | " | " | " | " | " | " |
| March | " | " | " | " | " | " | " | " |
| April | Black | " | " | " | " | " | " | " |
| May | " | " | P.Green | P.Green | P.Green | P.Green | P.Green | P.Green |
| June | " | P.Green | " | " | " | " | " | " |
| July | " | " | Green | " | " | " | " | " |
| Aug. | " | Pink +Pale Green | P.Green | Green | " | Pink | Pink | Pink |
| Sept. | " | Green | Green | Green | Green | Green | Green | Green |
| Oct. | " | Green + Pink | Green + Pink | Green + Pink | Green + Pink | " | " | " |
| Nov. | " | Green | " | Green | Green | Green + Pink | Green + Pink | Green+ Pink |
| Dec. | " | P.Green | P.Green | P.Green | P.Green | P.Green | P.Green | P.Green |
| Average | Black | P.Green | Green | Green | P.Green | Green | P.Green | P.Green |

TABLE NO. IV

THE CONTENT OF DISSOLVED OXYGEN IN THE EFFLUENT FROM EACH POND.

(Results expressed in mg./per litre)

| 1963 | 'Inlet ' ' to ' 'Pond I' | Effluent from Ponds numbering 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Jan. | Nil | Nil | Nil | Nil | Nil | Nil | Nil | Nil |
| Feb. | " | " | " | " | " | " | " | " |
| Mar. | " | " | " | " | " | " | " | " |
| April | " | " | " | " | " | " | " | " |
| May | " | " | 4.12 | 1.62 | 1.93 | 0.92 | 1.51 | 3.04 |
| June | " | 3.91 | 4.00 | 1.14 | 1.54 | 1.43 | 3.06 | 3.83 |
| July | " | 3.42 | 3.56 | 1.26 | 3.96 | 5.04 | 4.62 | 6.42 |
| Aug. | " | 1.00 | 1.82 | 1.07 | 1.54 | 0.92 | 0.81 | 0.70 |
| Sept. | " | 4.62 | 9.04 | 3.92 | 5.72 | 5.92 | 1.05 | 1.14 |
| Oct. | " | 3.23 | 3.35 | 2.83 | 3.53 | 3.33 | 6.23 | 3.54 |
| Nov. | " | 3.91 | 3.35 | 3.73 | 4.86 | 2.83 | 2.46 | 3.45 |
| Dec. | " | 2.54 | 1.04 | 0.88 | 1.94 | 3.14 | 2.21 | 1.43 |
| Average | " | 1.89 | 2.62 | 1.37 | 2.25 | 1.96 | 1.83 | 2.50 |

TABLE NO. V

THE 5-DAY BOD AT 20°C OF THE EFFLUENT FROM EACH POND

(Results expressed in mg./per litre)

| 1963 Months | 'Influ '-ent to 'Pond I | Effluent from Ponds numbering | | | | | | | 'Final % 'Reduc- 'tion |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| Jan. | 180 | 155 | 122 | 90 | 118 | 82 | 75 | 64 | 64.4 |
| Feb. | 153 | 162 | 152 | 130 | 72 | 82 | 55 | 51 | 66.7 |
| March | 257 | 127 | 140 | 103 | 80 | 78 | 70 | 68 | 73.5 |
| April | 175 | 135 | 127 | 97 | 83 | 70 | 66 | 74 | 57.7 |
| May | 133 | 60 | 54 | 50 | 43 | 40 | 39 | 42 | 68.4 |
| June | 223 | 135 | 110 | 96 | 75 | 60 | 39 | 38. | 83.0 |
| July | 175 | 94 | 89 | 90 | 82 | 66 | 47 | 26 | 85.1 |
| Aug. | 155 | 107 | 40 | 38 | 36 | 42 | 26 | 21 | 87.0 |
| Sept. | 173 | 72 | 60 | 52 | 49 | 42 | 23 | 15 | 91.3 |
| Oct. | 206 | 93 | 75 | 68 | 47 | 30 | 25 | 12 | 94.1 |
| Nov. | 195 | 155 | 90 | 85 | 79 | 57 | 31 | 17 | 91.3 |
| Dec. | 240 | 210 | 117 | 98 | 67 | 43 | 28 | 16 | 93.3 |
| Average | 189 | 125 | 98 | 83 | 69 | 58 | 44 | 37 | 79.6 |

TABLE NO. VI

THE VALUES FOR THE OXYGEN CONSUMED TEST IN THE EFFLUENT FROM EACH POND.

( Results expressed in parts per million )

| 1963 Months | 'Influ-' 'ent to' 'Pond I' | Effluent from Pond numbering | | | | | | | 'Final % 'Reduction |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| Jan. | 42 | 48 | 47 | 46 | 48 | 46 | 50 | 50 | +19.5 |
| Feb. | 48 | 53 | 58 | 48 | 50 | 54 | 53 | 59 | +23.0 |
| March | 56 | 69 | 62 | 58 | 59 | 60 | 64 | 66 | +18.0 |
| April | 74 | 84 | 87 | 76 | 87 | 85 | 80 | 86 | +16.2 |
| May | 50 | 46 | 43 | 42 | 40 | 36 | 32 | 28 | -44.0 |
| June | 67 | 56 | 39 | 43 | 39 | 33 | 26 | 23 | -65.7 |
| July | 46 | 38 | 29 | 20 | 18 | 15 | 10 | 8 | -82.6 |
| August | 39 | 21 | 20 | 27 | 25 | 24 | 20 | 18 | -54.0 |
| Sept. | 55 | 41 | 34 | 28 | 24 | 23 | 28 | 21 | -62.0 |
| Oct. | 41 | 25 | 24 | 20 | 16 | 12 | 10 | 7 | -83.0 |
| Nov. | 67 | 55 | 52 | 55 | 43 | 34 | 29 | 20 | -70.1 |
| Dec. | 42 | 38 | 31 | 27 | 25 | 21 | 19 | 16 | -62.0 |
| Average | 52 | 48 | 45 | 44 | 43 | 40 | 39 | 36 | +19.2 ( -65.4 ( |

TABLE NO. VII

THE VALUES FOR PHENOLPHTHALIN ALKALINITY IN THE EFFLUENT FROM EACH POND

( Results expressed in parts per million )

| 1963 Months | 'Inlet 'to 'Pond I' | Effluent from Pond numbering | | | | | | | 'Final % 'Reduction |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| Jan. | 36 | 27 | 23 | 15 | 29 | 29 | 25 | 20 | -44 |
| Feb. | 37 | 25 | 23 | 21 | 28 | 30 | 10 | 23 | -40 |
| March | 67 | 27 | 28 | 40 | 32 | 26 | 18 | 26 | -61 |
| April | 45 | 26 | 31 | 17 | 33 | 24 | 24 | 28 | -38 |
| May | 52 | 31 | 112 | 70 | 85 | 76 | 64 | 98 | +102 |
| June | 23 | 93 | 100 | 105 | 93 | 135 | 138 | 160 | +208 |
| July | 30 | 95 | 87 | 83 | 93 | 60 | 60 | 90 | +200 |
| August | 20 | 47 | 52 | 56 | 53 | 35 | 36 | 32 | +60 |
| Sept. | 33 | 47 | 167 | 120 | 130 | 146 | 120 | 166 | +403 |
| October | 26 | 65 | 53 | 50 | 70 | 91 | 86 | 75 | +190 |
| November | 15 | 43 | 50 | 43 | 50 | 60 | 84 | 60 | +300 |
| December | 20 | 40 | 172 | 70 | 73 | 76 | 80 | 85 | +325 |
| Average | 34 | 47 | 67 | 57 | 56 | 66 | 62 | 64 | - 24 ( +223 ( |

TABLE NO. VIII

THE VALUES FOR TOTAL ALKALINITY IN THE EFFLUENT FROM EACH POND

( Results expressed in parts per million )

| 1963 Months | Inlet to Pond I | Effluent from Pond numbering 1 | 2 | 3 | 4 | 5 | 6 | 7 | Final % increase or decrease |
|---|---|---|---|---|---|---|---|---|---|
| Jan. | 713 | 732 | 727 | 687 | 701 | 731 | 690 | 780 | + 9 |
| Feb. | 687 | 773 | 701 | 770 | 770 | 800 | 678 | 836 | +22 |
| March. | 603 | 623 | 642 | 647 | 647 | 640 | 656 | 573 | - 5 |
| April | 475 | 535 | 630 | 623 | 623 | 623 | 466 | 568 | +20 |
| May | 572 | 582 | 566 | 540 | 510 | 525 | 530 | 526 | - 8 |
| June | 690 | 610 | 608 | 630 | 660 | 653 | 606 | 610 | -12 |
| July | 610 | 586 | 514 | 640 | 526 | 530 | 505 | 531 | -13 |
| Aug. | 500 | 497 | 487 | 490 | 475 | 513 | 550 | 538 | - 7 |
| Sept. | 650 | 603 | 600 | 615 | 587 | 567 | 446 | 459 | -30 |
| Oct. | 600 | 553 | 543 | 597 | 588 | 490 | 488 | 490 | -18 |
| Nov. | 645 | 625 | 587 | 600 | 612 | 620 | 616 | 626 | - 3 |
| Dec. | 610 | 590 | 573 | 563 | 583 | 590 | 540 | 508 | -17 |
| Average | 613 | 609 | 598 | 617 | 607 | 607 | 564 | 587 | - 4 |

TABLE NO. IX

CHLORIDE CONTENT IN THE EFFLUENT FROM EACH POND

( Results expressed in parts per million )

| 1 9 6 3 Months | Inlet to Pond I | Effluent from Pond numbering | | | | | | | Final % increase or decrease |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| Jan. | 375 | 418 | 358 | 357 | 384 | 398 | 410 | 389 | + 3.7 |
| Feb. | 340 | 370 | 347 | 347 | 350 | 353 | 357 | 320 | - 6.0 |
| March. | 383 | 313 | 356 | 383 | 393 | 403 | 400 | 393 | + 2.6 |
| April | 415 | 445 | 420 | 457 | 390 | 477 | 485 | 455 | + 9.6 |
| May | 345 | 372 | 360 | 371 | 420 | 400 | 380 | 427 | +24.0 |
| June | 303 | 360 | 380 | 393 | 420 | 423 | 463 | 417 | +37.6 |
| July | 290 | 378 | 320 | 380 | 388 | 400 | 393 | 373 | +29.0 |
| Aug. | 272 | 312 | 305 | 317 | 343 | 320 | 312 | 350 | +28.7 |
| Sept. | 323 | 310 | 300 | 294 | 335 | 280 | 300 | 270 | +16.4 |
| Oct. | 300 | 320 | 310 | 290 | 330 | 340 | 343 | 307 | + 2.4 |
| Nov. | 364 | 450 | 451 | 424 | 418 | 415 | 407 | 435 | +19.5 |
| Dec. | 345 | 340 | 393 | 413 | 397 | 400 | 383 | 387 | + 6.4 |
| Average | 338 | 366 | 358 | 370 | 381 | 384 | 386 | 377 | +11.0 |

TABLE NO. X

THE VALUES FOR AMMONIACAL NITROGEN IN THE EFFLUENT FROM EACH POND

( Results expressed in parts per million )

| 1 9 6 3 Months | Inlet to Pond I | Effluent from Pond numbering | | | | | | | Final % increase or reduction |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| Jan. | 24 | 20 | 20 | 29 | 27 | 27 | 22 | 23 | 4.2 |
| Feb. | 29 | 26 | 28 | 25 | 22.3 | 24.3 | 20.5 | 22 | 24.1 |
| Mar. | 25 | 27 | 20.5 | 21 | 21 | 29.5 | 20 | 28 | +12.0 |
| April | 27 | 28 | 20.5 | 27.7 | 23 | 21 | 21 | 20 | 26.0 |
| May | 30 | 18 | 16 | 17 | 14 | 10 | 8 | 6 | 80.0 |
| June | 28 | 11.2 | 9 | 11 | 13 | 13.3 | 11 | 11 | 61.0 |
| July | 24 | 16 | 15 | 19 | 14 | 13 | 8 | 11 | 54.1 |
| Aug. | 14 | 11 | 16 | 10.2 | 10 | 10 | 6 | 7 | 63.2 |
| Sept. | 17 | 12 | 12 | 11.5 | 16.5 | 7.8 | 3.4 | 3.7 | 78.2 |
| Oct. | 19 | 13.3 | 9.6 | 10 | 7.8 | 6.6 | 3.0 | 2.0 | 89.5 |
| Nov. | 18 | 18 | 16 | 16 | 15.2 | 10.5 | 4.0 | 2.0 | 88.8 |
| Dec. | 22 | 10 | 7.5 | 5.5 | 6.0 | 4.0 | 4.0 | 4.5 | 80.0 |
| Average | 23.5 | 17.5 | 15.8 | 16.9 | 15.8 | 14.6 | 10.8 | 11.6 | 50.6 |

TABLE NO. XI

THE QUANTITY OF ORTHO-PHOSPHATE ($PO_4$) FOUND IN THE EFFLUENT FROM EACH POND.

( Results expressed in parts per million )

| 1 9 6 3 Months | Influent to Pond I | Effluent from Pond numbering | | | | | | | Final % Reduction |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| Jan. | 13.5 | 10.5 | 10.0 | 7.3 | 7.5 | 4.2 | 5.0 | 4.5 | 66.7 |
| Feb. | 17.3 | 8.5 | 8.5 | 3.5 | 9.0 | 8.5 | 7.5 | 8.0 | 53.2 |
| Mar. | 16.2 | 12.5 | 4.6 | 7.5 | 3.0 | 4.6 | 3.0 | 4.9 | 69.7 |
| April | 15.6 | 7.5 | 7.2 | 6.5 | 4.5 | 5.4 | 4.1 | 4.0 | 74.4 |
| May | 18.0 | 10.5 | 8.4 | 7.6 | 9.0 | 8.4 | 7.6 | 8.1 | 55.0 |
| June | 19.4 | 11.8 | 10.1 | 9.1 | 8.2 | 7.8 | 8.4 | 9.2 | 52.6 |
| July | 16.4 | 12.1 | 10.8 | 10.8 | 8.4 | 8.1 | 7.5 | 7.1 | 56.6 |
| Aug. | 14.9 | 7.0 | 9.9 | 9.8 | 10.0 | 9.6 | 9.8 | 8.7 | 41.6 |
| Sept. | 16.2 | 12.2 | 12.2 | 9.2 | 8.1 | 7.5 | 7.2 | 7.0 | 56.7 |
| Oct. | 17.9 | 8.3 | 7.3 | 4.7 | 6.8 | 6.3 | 5.5 | 6.4 | 64.2 |
| Nov. | 18.6 | 6.2 | 6.6 | 5.9 | 5.1 | 3.0 | 3.0 | 3.7 | 80.1 |
| Dec. | 19.0 | 10.4 | 6.7 | 6.5 | 6.7 | 6.5 | 6.5 | 6.0 | 68.4 |
| Average | 17.0 | 9.8 | 8.5 | 7.8 | 7.2 | 6.7 | 6.3 | 6.5 | 61.8 |

TABLE NO. XII

DOMINANT & SUB-DOMINANT ALGAE FOUND IN THE EFFLUENT FROM POND NO. 1 DURING 1963.

| Month | Total No. per ml. x $10^3$ | Dominant | % Total | Sub-dominant | % Total |
|---|---|---|---|---|---|
| Jan. | 492.2 | Thiopedia rosea | 61.5 | Chlorella | 15.0 |
| Feb. | 5040.0 | " | 87.7 | - | - |
| Mar. | 1603.5 | " | 73.6 | " | - |
| April | 4657.0 | " | 67.0 | Chlorella | 22.3 |
| May | 6613.0 | " | 11.4 | " | 8.0 |
| June | 2797.3 | Chlorella | 47.7 | Thiopedia rosea | 17.2 |
| July | 1788.0 | Chlorella | 66.0 | " | 25.2 |
| | 32.5 | Arthrospira | 78.1 | - | - |
| Aug. | 1237.0 | Thiopedia rosea | 71.4 | - | - |
| | 2328.0 | Chlorella | 74.4 | Thiopedia rosea | 19.0 |
| Sept. | 37.6 | Arthrospira | 67.5 | Oscillatoria | 32.0 |
| Oct. | 50.8 | Euglena | 76.0 | - | - |
| Nov. | 162.6 | Thiopedia rosea | 87.5 | - | - |
| Nov. | 187.0 | Euglena | 59.0 | - | - |
| Dec. | 1184.0 | Chlorella | 71.6 | Thiopedia rosea | 28.3 |

TABLE NO. XIII

DOMINANT & SUB-DOMINANT ALGAE FOUND IN THE EFFLUENT FROM POND NO.2 DURING 1963.

| Month | Total No. per ml x $10^3$ | Dominant | % of the Total | Sub-dominant | % of the Total |
|---|---|---|---|---|---|
| Jan. | 661.6 | Thiopedia rosea | 31.2 | Chlorella | 14.6 |
| Feb. | 1941.0 | " | 32.6 | - | - |
| Mar. | 1731.5 | " | 72.5 | - | - |
| April | 4636.0 | " | 57.2 | Chlorella | 3.8 |
| May | 6297.7 | Chlorella | 72.2 | Thiopedia rosea | 16.9 |
| June | 3032.0 | " | 75.5 | " | 15.8 |
| July | 2692.5 | " | 78.8 | - | 20.2 |
| | 41.8 | Arthrospira | 92.4 | - | - |
| August. | 459.6 | Thiopedia rosea | 76.9 | - | - |
| | 2050.0 | Chlorella | 82.7 | Thiopedia rosea | 13.8 |
| Sept. | 36.1 | Arthrospira | 70.4 | Oscillatoria | 28.0 |
| Oct. | 66.0 | Euglena | 76.0 | - | - |
| | 78.2 | Thiopedia rosea | 72.6 | - | - |
| Nov. | 42.7 | Arthrospira | 66.6 | - | - |
| | 1679.0 | Thiopedia rosea | 84.2 | - | - |
| Dec. | 1184.0 | Chlorella | 17.6 | Thiopedia rosea | 28.3 |

TABLE NO. XIV

DOMINANT & SUB-DOMINANT ALGAE FOUND IN THE EFFLUENT FROM POND NO.3 DURING 1963.

| Month | Total No. per ml x $10^3$ | Dominant | % of the Total | Sub-dominant | % of the Total |
|---|---|---|---|---|---|
| Jan. | 1718.3 | Thiopedia rosea | 65.5 | Chlorella | 13.2 |
| Feb. | 3346.7 | " | 83.2 | - | - |
| Mar. | 1553.0 | " | 77.5 | - | - |
| April | 3986.3 | " | 50.1 | Chlorella | 47.4 |
| May | 4296.7 | Chlorella | 68.6 | Thiopedia rosea | 20.4 |
| June | 1758.6 | " | 80.7 | " | 1.9 |
| July | 2186.5 | " | 22.4 | " | 9.4 |
| | 25.4 | Arthrospira | 92.0 | - | - |
| Aug. | 1538.0 | Thiopedia rosea | 41.3 | Chlorella | 30.6 |
| | 2050.0 | Chlorella | 82.7 | Thiopedia rosea | 13.8 |
| | 52.6 | Arthrospira | 90.7 | - | - |
| Sept. | [illegible]41.2 | " | 69.1 | Oscillatoria | 24.5 |
| Oct. | 56.9 | Euglena | 50.0 | - | - |
| | 78.2 | Thiopedia rosea | 72.6 | - | - |
| Nov. | 1067.0 | Euglena | 62.8 | Arthrospira | 20.0 |
| Dec. | 1184.0 | Chlorella | 71.6 | Thiopedia rosea | 28.3 |

TABLE NO. XV

DOMINANT & SUB-DOMINANT ALGAE FOUND IN THE EFFLUENT FROM POND NO. 4 DURING 1963.

| Month | Total No. per ml x $10^3$ | Dominant | % of the Total | Sub-dominant | % of the Total |
|---|---|---|---|---|---|
| Jan. | 1563.1 | Chlorella | 43.1 | Thiopedia rosea | 33.3 |
| Feb. | 1999.2 | Thiopedia rosea | 96.4 | - | - |
| Mar. | 2041.0 | " | 72.3 | - | - |
| Apr. | 4368.6 | " | 75.3 | Chlorella | 13.0 |
| May | 2184.5 | Chlorella | 68.0 | Thiopedia rosea | 18.2 |
| June | 2550.6 | " | 70.4 | " | 16.7 |
| July | 1788.0 | " | 61.4 | " | 5.5 |
| | 39.6 | Arthrospira | 95.0 | - | - |
| Aug. | 1308.0 | Thiopedia rosea | 59.4 | Chlorella | 35.1 |
| | 901.4 | Chlorella | 70.6 | Thiopedia rosea | 21.5 |
| | 37.6 | Arthrospira | 86.5 | - | - |
| Sept. | 25.0 | " | 67.1 | Oscillatoria | 32.5 |
| Oct. | 50.8 | " | 72.0 | - | - |
| | 79.5 | Thiopedia rosea | 54.9 | - | - |
| Nov. | 54.9 | Arthrospira | 75.8 | - | - |
| | 1165.0 | Thiopedia rosea | 69.6 | - | - |
| Dec. | 1962.0 | Chlorella | 65.7 | Thiopedia rosea | 34.2 |

TABLE NO. XVI

DOMINANT & SUB-DOMINANT ALGAE FOUND IN THE EFFLUENT FROM THE POND NO. 5 DURING 1963.

| Month | Total No. per ml x $10^3$ | Dominant | % of the Total | Sub-dominant | % of the Total |
|---|---|---|---|---|---|
| Jan. | 4227.8 | Thiopedia rosea | 69.5 | Chlorella | 22.7 |
| Feb. | 2771.0 | " | 91.8 | - | - |
| Mar. | 1936.0 | " | 68.4 | - | - |
| Apr. | 3349.7 | " | 76.8 | Chlorella | 22.0 |
| May | 3094.7 | Chlorella | 75.1 | Thiopedia rosea | 19.0 |
| June | 2217.0 | " | 57.9 | " | 30.1 |
| July | 1597.0 | " | 68.5 | " | 11.7 |
| | 436.9 | Arthrospira | 90.7 | - | - |
| Aug. | 1025.0 | Thiopedia rosea | 72.4 | Chlorella | 20.7 |
| | 411.6 | Arthrospira | 97.5 | - | - |
| Sept. | 27.0 | " | 78.2 | Oscillatoria | 19.0 |
| Oct. | 27.6 | " | 53.8 | - | - |
| Nov. | 32.5 | " | 95.2 | - | - |
| | 1165.0 | Thiopedia rosea | 69.6 | - | - |
| Dec. | 1829.0 | Chlorella | 79.5 | - | - |

TABLE NO. XVII

DOMINANT & SUB-DOMINANT ALGAE FOUND IN THE EFFLUENT FROM THE POND NO. 6 DURING 1963.

| Month | Total No. per $ml \times 10^3$ | Dominant | % of the Total | Sub-dominant | % of the Total |
|---|---|---|---|---|---|
| Jan. | 1182.4 | Chlorella | 50.7 | Thiopedia rosea | 41.8 |
| Feb. | 8978.0 | Thiopedia rosea | 87.8 | - | - |
| Mar. | 1925.5 | " | 73.2 | - | - |
| Apri | 3824.6 | " | 66.0 | Chlorella | 26.4 |
| May | 3560.0 | Chlorella | 67.2 | Thiopedia rosea | 20.0 |
| June | 2132.6 | " | 57.2 | " | 34.2 |
| July | 1788.0 | " | 61.4 | " | 5.5 |
| | 43.7 | Arthrospira | 90.7 | - | - |
| Aug. | 1255.0 | Thiopedia rosea | 65.0 | Chlorella | 31.0 |
| Sept. | 24.4. | Arthrospira | 61.6 | Oscillatoria | 31.9 |
| Oct. | 412.2 | " | 74.0 | - | - |
| Nov. | 31.0 | " | 65.5. | - | - |
| | 990.0 | Thiopedia rosea | 67.8 | - | - |
| Dec. | 1264.0 | Chlorella | 79.6 | - | - |

TABLE NO. XVIII

DOMINANT & SUB-DOMINANT ALGAE FOUND IN THE EFFLUENT FROM THE POND NO. 7 DURING 1963

| Month | Total No. per $ml \times 10^3$ | Dominant | % of the Total | Sub-dominant | % of the Total |
|---|---|---|---|---|---|
| Jan. | 1319.1 | Thiopedia rosea | 49.4 | Chlorella | 45.0 |
| Feb. | 8405.2 | " | 95.0 | - | - |
| Mar. | 2306.0 | " | 58.0 | - | - |
| Apr. | 3831.3 | " | 52.8 | Chlorella | 25.3 |
| May | 2356.7 | Chlorella | 63.2 | Thiopedia rosea | 22.4 |
| June | 2215.6 | " | 68.0 | " | 20.1 |
| July | 1597.0 | " | 68.7 | " | 11.7 |
| Aug. | 2704.0 | Thiopedia rosea | 62.4 | Chlorella | 21.2 |
| Sept. | 243.9 | Arthrospira | 70.8 | Oscillatoria | 29.2 |
| Oct. | 42.7 | " | 76.3 | - | - |
| Nov. | 32.5 | " | 95.0 | - | - |
| | 489.7 | Thiopedia rosea | 67.8 | - | - |
| Dec. | 159.0 | Chlorella | 81.8 | - | - |