DISTRIBUTION OF PHOSPHATES IN A SEWAGE PLANT

AND ITS RECEIVING WATERS

APPROVED:

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DISTRIBUTION OF PHOSPHATES IN A SEWAGE PLANT
AND ITS RECEIVING WATERS

THESIS

Presented to the Graduate Council of the
North Texas State University in Partial
Fulfillment of the Requirements

For the Degree of

MASTER OF ARTS

By

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Denton, Texas

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CHAPTER I

INTRODUCTION

In recent years, much attention has been given to ways of slowing down or preventing the aging process of natural and man-made bodies of water. This aging process, termed eutrophication, has been reviewed by Stewart and Rohlich (1967), and described as the developmental enrichment of waters by nutrients. Along with the increase of nutrients in a body of water, there generally results a prolific growth of aquatic life, especially blue-green algae, and ultimately a reduction of species diversity (Wilhm and Dorris, 1968).

Algal blooms can produce scums, tastes and odors, increase turbidity, and create toxic substances in water (Prescott, 1959). These toxins have been implicated in the deaths of livestock, and in gastrointestinal disturbances of man (Gorham, 1964). Upon the death of high numbers of phytoplankton, such large oxygen demands have occurred that fish "kills" have resulted (Mackenthun et al., 1948). In the long run, decomposing and dead cellular material has the effect of filling in a body of water and making it a "disappearing harbor." These effects make waters and their
basins objectionable for use as water supplies, storage regions, or recreational areas.

Two types of eutrophication manifest themselves in water today (Owens and Wood, 1968). Natural eutrophication is inherent within the system and occurs as a result of the drainage of ground and runoff waters into lakes, reservoirs, and rivers. Not only do these waters carry nutrients, but the atmosphere also affords nutrients in the form of carbon dioxide, oxygen, and nitrogen, to the water. On the other hand, artificial eutrophication results, primarily, from the discharge of sewage effluents and man-made fertilizers into water systems. In most cases, both modes of eutrophication occur simultaneously and result in intensifying the rapidity of the aging process.

To determine the eutrophic state of waters, several indicators have been used. Such methods as algal counts, turbidity, and species diversity are commonly used (Mackenthun and Ingram, 1967). Nevertheless, these are indicative of the effect rather than the cause. The responsibility for the proliferation of aquatic growths lies with the available nutrients present. According to Liebig's Law of the Minimum, the productivity of an area is controlled or limited by the imposing lack of some nutritional element. It is now
generally accepted that the two elements most responsible for aquatic growths are nitrogen and phosphorus. A balanced ratio between these elements is normally considered essential for optimal growth. However, an exact delineation of this ratio is difficult to establish for there is wide variation in species requirement.

Sawyer (1952) concluded that phosphorus must be considered the key element in the fertilization of waters, since earlier results demonstrated that blue-green algae were able to grow in the presence of deficient amounts of nitrogen if sufficient amounts of phosphorus were accessible. Some of the numerous investigations confirming these results have been reviewed by Stewart (1966).

With virtually an unlimited supply of nitrate nitrogen available as a product of natural fixation, phosphorus is possibly the most rate limiting element in the process of eutrophication. Thus, the first task of the laborer who wishes to deter the aging process is to determine the origin, distribution, and quantity of phosphorus present in the waters of concern.

Phosphorus in Surface Waters

Juday et al. (1927), studying eighty-eight lakes situated in northeastern Wisconsin, found only small amounts
of soluble phosphorus with the moderate phytoplankton populations recorded. In a second report, Juday and Birge (1931) described increases of soluble phosphorus in the lower strata of thermally stratified lakes. However, of 497 lakes in the Highland Lake District of northern Wisconsin, a maximum of .015 milligrams per liter (mg./l.) of soluble phosphorus was found in only one.

More recently, Edmondson and Anderson (1956) showed that Lake Washington had undergone a change in kind and quantity of biota since 1950. Previous to this time, various Anabena, diatoms, and dinoflagellates had been the dominant phytoplankton, but in 1955, large masses of Oscillatoria rubescens, a blue-green algae characteristic of polluted waters, were found. This "bloom" was attributed, in part, to the high increase in treated sewage which Lake Washington had been receiving since 1950. Closely associated with the increase in treated sewage inflow, was the increase in phosphorus in the hypolimnion.

Curl (1959) ascertained the origin and distribution of phosphorus in Western Lake Erie and found sufficient accumulations of phosphorus to provide luxurious growth; however, recurrent turbidity often prevented the growth of phytoplankton. Engelbrecht and Morgan (1959) have reported
concentrations of phosphorus in several Illinois surface waters at adequately elevated levels to initiate increased eutrophication rates. Sylvester and Anderson (1964) considered phosphate-phosphorus to be the limiting factor in Green Lake (Seattle, Washington) and responsible for offensive growth of algae, since the phosphate concentration was often above the critical level and the nitrate-nitrogen was seldomly above its critical level.

Other such surveys on natural surface waters have been completed, but very little work has been accomplished on reservoirs, particularly those of the Southwest. One of the early investigators in this field, Connell (1965), conducted an extensive survey of Texas rivers and reservoirs and observed that many contained higher levels of soluble phosphorus than the considered maximum tolerance level endorsed for northern areas.

**Phosphorus in Sewage**

The increased use of synthetic detergents in the past twenty years has resulted in the rise of phosphorus levels in sewage waters. Rudolf's (1947) sampled twelve trickling filter sewage plants and found that the raw sewages contained an average of 5.2 parts per million (p.p.m.) phosphate, while the treated effluents carried an average of only 0.5 p.p.m.
More recently, Hurwitz, Beaudoin, and Walters (1965) have found averages of 26.6 p.p.m. inorganic phosphate in the raw sewage of three activated sludge plants in the Chicago area and 9.4 p.p.m. in the effluents. Vacker, Connell, and Wells (1967) have monitored nine trickling filter and activated sludge plants in Texas and reported monthly averages as high as 51 mg./l. and 44 mg./l. total phosphate for the raw sewages and treated effluents, respectively, with minimums measured at 27 mg./l. and 4.6 mg./l. In England, Harkness and Jenkins (1958) surveyed the sewage works in the Birmingham Tame and Rea District, and recorded soluble phosphates as high as 22.1 p.p.m. with phosphates from synthetic anionic detergents as great as 31.7 per cent.

Purpose

The purpose of this paper is to detail the distribution and quantity of soluble phosphates in an activated sludge plant, its discharge creek, and receiving reservoir. The resultant analyses and comparison of data should provide some better understanding of the fate of phosphorus in a Southwestern waterway system.
CHAPTER II

METHODS AND MATERIALS

Description of Reservoir

Located on the Elm Fork of the Trinity River southeast of Denton, Texas is the Garza-Little Elm Reservoir (Figure 1). This reservoir is one of four built by the Corps of Engineers in the Trinity River Basin which serves as a water supply, flood control, storage basin, and recreational facility for the Dallas area. Originally, only the small area north of the old dam existed as a water reserve and was known as Lake Dallas. Then, in 1955, with the completion of the new Lewisville Dam by the Corps of Engineers, the water conservation capacity of the area was increased from 194,000 to 436,000 acre-feet. As a result, the reservoir has, to a degree, been divided into old (Lake Dallas) and new portions by the remains of the old dam, which was not breached until 1957. Only this old portion of the reservoir, which directly receives phosphates from the activated sludge plant studied, was sampled.

The basin of old Lake Dallas is relatively shallow and rarely, if ever, stratifies, and then, only for very short
Fig. 1 - Garza-Little Elm Reservoir and sampling stations
periods. During the sampling of this basin no thermal stratification was detected.

There are two major inflows of artificially supplied phosphates into the waters of this basin. One is Pecan Creek, on which both of Denton's sewage disposal plants are located. The other inflow comes from the Elm Fork of the Trinity River and also carries sewage effluents from upstream.

Description of Sewage Plant and Its Discharge Creek

Pecan Creek receives a daily average of three to four million gallons of treated sewage from Denton's winter population of an estimated 40,000 persons. This sewage is primarily domestic, with minor contributions from a packing house, a cannery, and a plastics company. One of the disposal plants, located on Pecan Creek, is the original old trickling filter plant which is able to carry only about 0.5 million gallons per day of Denton sewage. Treating the remainder of the sewage is the new activated sludge plant, which is located below the old plant on Pecan Creek. Since the capacity of the new plant will soon be increased from the original two million per day to six million gallons per day, and the old plant phased out, the phosphate distribution in the activated sludge plant was the primary concern of this study.
In the activated sludge plant (Figure 2), the raw influent enters through a grinder into the primary clarifier for first settling. From the primary clarifier, the sewage is carried into the two aeration basins for activated sludge treatment. Mixed liquor from the single-pass aeration basins enters the final clarifier for final settling. Then, the effluent is chlorinated and discharged into Pecan Creek (Figure 3). This effluent mixes with that discharged by the old trickling filter plant and flows approximately four miles down the winding creek into the old Lake Dallas portion of Garza-Little Elm Reservoir.

Collection and Preservation of Samples

Collection of the samples from the sewage plant and its receiving waters occurred in two phases. In the first phase, samples from the sewage plant and its discharge creek were analyzed. The second phase involved the sampling of the reservoir. All samples collected on one date were, for all practical purposes, sampled at one time. Therefore, the quantities of phosphate at each successive station do not represent one slug of water traveling through the plant and waterway. Yet, the average quantity of soluble phosphate that might be expected at any one station can be determined
Fig. 2- Denton Sewage Treatment Plant and sampling stations (U.S. Department of the Interior)
Fig. 3--Pecan Creek and sampling stations
by the several samples taken at one station on the various successive dates.

After collection, the samples were brought immediately to the laboratory and stored at 4 degree centigrade until they could be filtered. Each sample was filtered through an H.A. 0.45-micron Millipore filter, since this size offers a compromise between slow filtration rates and poor particle retention (Jenkins, 1965). Rigler (1964) found that the amount of soluble organic phosphorus in a filtered sample of lake water decreased from 42 to 18 per cent of the total phosphorus as the filter size was reduced from 5 to 0.1 microns.

Chloroform was added to preserve the filtered samples (5 milliliters per liter of sample), and again, the samples were stored at 4 degrees centigrade until the analysis could be completed. Jenkins (1965) found this method to be satisfactory in the preservation of phosphorus in estuarine waters if the samples were stored for periods less than one week. Results showed that storage of estuarine waters preserved by this method demonstrated no more than .0015 mg./l. change in the soluble phosphorus fractions during a three day period. All samples from the sewage plant, creek, and reservoir were analyzed within seventy-two hours after collection.
Cleaning of Glassware

All samples were collected and analyzed in glass containers. This glassware was washed with acid to free it of any phosphates which might have impregnated the glass. At first, the wash used was a solution of warm dilute hydrochloric acid (2N) as described in Standard Methods (American Public Health Association, 1965). However, a change to a solution of dilute hydrochloric acid (2N) and hydrofluoric acid (2%) (Hassenteufel, Jagitsch and Koczy, 1963) was made, since no preliminary attention had to be given to this wash. Both wash solutions gave equally good results, but the latter was more easily used. Glassware not in use between analyses was stored in, or filled with distilled water in order to leach out any phosphate which might contact the glass.

Analysis of Samples

Only the soluble inorganic fractions of the total phosphorus content of the waters in this study, were determined. Analyses of the soluble inorganic phosphorus, which included both orthophosphate and condensed or hydrolyzable phosphate fractions, were performed according to the Stannous Chloride Method described in Standard Methods (American Public Health Association, 1965). In this colorimetric determination, the orthophosphate fraction may be analyzed directly on the
filtered sample. The soluble condensed phosphate fraction had to be first hydrolyzed to simple orthophosphate. Since condensed phosphates are nothing more than "molecularly dehydrated" orthophosphates (Katchman, 1965), this conversion was easily accomplished through mild acid hydrolysis. After the sample has been hydrolyzed, and colorimetric determinations made, the amount of condensed phosphate present in a sample can be roughly calculated by subtracting the amount of orthophosphate in the unhydrolyzed sample from the amount of orthophosphate in the hydrolyzed sample.

In both analyses, the orthophosphate present in the sample was first complexed with ammonium molybdate to form ammonium phosphomolybdate. Reduction of this yellow precipitate with stannous chloride to molybdate blue followed. The blue color produced by this complexed molecule is proportional to the amount of orthophosphate in the sample.

All samples determined in this report were analyzed with a Klett-Sommerson Colorimeter. In the sewage plant and creek, the samples were run in triplicate, and in the reservoir, samples were run in duplicate. (See Appendix.)
CHAPTER III

RESULTS

Phosphate Content in the Sewage Plant

The first phase of sampling was performed in the sewage plant and its receiving creek. Six stations (1-6) within the activated sludge plant were positioned so that effluents from transitional points (Figure 2) could be sampled. Each successive station followed through the sewage plant to the transitional point where the chlorinated effluent flowed into the creek (Station six). The results from these six stations are given in Table I.

These results demonstrated that the activated sludge plant at Denton receives high concentrations of soluble phosphates in the raw sewage influent. The mean total soluble inorganic phosphate (TSIP) in this influent during this study was 27 p.p.m., while the orthophosphate represented 22 p.p.m. of this value. In general, the primary clarifier showed only slightly higher concentrations with 30 p.p.m. and 26 p.p.m., respectively. At the third and fourth stations, the activated sludge aeration basins carried much higher concentrations of soluble phosphates. Basin I averaged
### TABLE I

PHOSPHATE CONTENT IN THE SEWAGE PLANT*

<table>
<thead>
<tr>
<th>Sampling Date</th>
<th>10/1</th>
<th>10/8</th>
<th>10/10</th>
<th>10/15</th>
<th>10/17</th>
<th>10/22</th>
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<tr>
<td>RAW (1)</td>
<td>41</td>
<td>20</td>
<td>15</td>
<td>22</td>
<td>28</td>
<td>38</td>
</tr>
<tr>
<td>Ortho</td>
<td>34</td>
<td>18</td>
<td>12</td>
<td>18</td>
<td>23</td>
<td>25</td>
</tr>
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<td>PRIMARY (2)</td>
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<td>38</td>
<td>11</td>
<td>28</td>
<td>27</td>
<td>38</td>
</tr>
<tr>
<td>Ortho</td>
<td>29</td>
<td>35</td>
<td>10</td>
<td>25</td>
<td>27</td>
<td>27</td>
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<td><strong>TOTAL SOL.</strong></td>
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<td></td>
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<td>BASIN I (3)</td>
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<td>70</td>
<td>26</td>
<td>79</td>
<td>87</td>
<td>84</td>
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<tr>
<td>Ortho</td>
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<td>60</td>
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<td>BASIN II (4)</td>
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<td>73</td>
<td>29</td>
<td>81</td>
<td>81</td>
<td>84</td>
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<tr>
<td>Ortho</td>
<td>64</td>
<td>63</td>
<td>24</td>
<td>71</td>
<td>69</td>
<td>80</td>
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<td>FINAL CLAR. (5)</td>
<td>23</td>
<td>16</td>
<td>10</td>
<td>8</td>
<td>16</td>
<td>18</td>
</tr>
<tr>
<td>Ortho</td>
<td>22</td>
<td>15</td>
<td>9</td>
<td>8</td>
<td>14</td>
<td>17</td>
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<tr>
<td><strong>TOTAL SOL.</strong></td>
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<td>EFFLUENT (6)</td>
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<td>16</td>
<td>12</td>
<td>13</td>
<td>20</td>
<td>20</td>
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<tr>
<td>Ortho</td>
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<td>15</td>
<td>11</td>
<td>11</td>
<td>17</td>
<td>20</td>
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*Concentrations are in p.p.m. and are the average of triplicate runs multiplied by 50.

71 p.p.m. TSIP and 62 p.p.m. orthophosphate. In Basin II, the orthophosphate mean value measured the same as in Basin I, but the TSIP measured slightly less than that in Basin I. Much less TSIP and orthophosphate were contained in the final clarifier effluents. In this case, orthophosphate comprised
of the 15 p.p.m. of TSIP. However, in the final chlorinated effluent which flowed into the creek, the concentrations of soluble inorganic phosphate were higher.

Condensed phosphates represented approximately 18 per cent of the TSIP in both the raw influent and the primary clarifier. In the aeration basins, this value was reduced to 11 per cent of the total. The latter stages of purification showed that condensed phosphates are roughly decreased by a factor of three from the percentage found in the raw sewage.

Sewage plant and Pecan Creek stations, sampled on the tenth of October, showed largely reduced concentrations of phosphate when compared to the other sampling dates. The previous day, rains had deluged the area and greatly exceeded the normal flow through the sewage plant.

Phosphate Content in Pecan Creek

Four stations (7 through 10) along Pecan Creek waterway were sampled during the first phase of sampling (Table II). The upper station, above the activated sludge plant inflow, carried a mean of 15 p.p.m. TSIP while the middle station, below this inflow, conveyed only 16 p.p.m. TSIP. Apparently, a large reduction of soluble phosphate occurs between the upper and middle stations. Since the mean concentrations at
### TABLE II

PHOSPHATE CONTENT IN PECAN CREEK*

<table>
<thead>
<tr>
<th>Sampling Date</th>
<th>10/1</th>
<th>10/8</th>
<th>10/10</th>
<th>10/15</th>
<th>10/17</th>
<th>10/22</th>
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<td>21</td>
<td>7</td>
<td>18</td>
<td>20</td>
<td>7</td>
</tr>
<tr>
<td>Ortho</td>
<td>19</td>
<td>19</td>
<td>6</td>
<td>17</td>
<td>18</td>
<td>7</td>
</tr>
<tr>
<td><strong>Total Sol.</strong></td>
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<td></td>
<td></td>
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<tr>
<td><strong>MIDDLE (8)</strong></td>
<td>26</td>
<td>18</td>
<td>6</td>
<td>14</td>
<td>19</td>
<td>11</td>
</tr>
<tr>
<td>Ortho</td>
<td>24</td>
<td>16</td>
<td>6</td>
<td>13</td>
<td>17</td>
<td>10</td>
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<tr>
<td><strong>Total Sol.</strong></td>
<td></td>
<td></td>
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<tr>
<td><strong>OUTLET (9)</strong></td>
<td>14</td>
<td>22</td>
<td>-2</td>
<td>7</td>
<td>18</td>
<td>12</td>
</tr>
<tr>
<td>Ortho</td>
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<td></td>
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<tr>
<td><strong>INTAKE (10)</strong></td>
<td>8</td>
<td>**</td>
<td>-2</td>
<td>5</td>
<td>10</td>
<td>7</td>
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<tr>
<td>Ortho</td>
<td>7</td>
<td>**</td>
<td>-2</td>
<td>5</td>
<td>10</td>
<td>4</td>
</tr>
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</table>

*Concentrations in p.p.m. and are the average of triplicate runs multiplied by 50.

**Sample broken.

The middle station is only half the amount that would result if the upper, and final effluent from the activated sludge plant were combined. At the lower station on Pecan Creek (the creek outlet), the TSIP average was 13 p.p.m. but only 6 p.p.m. in the reservoir intake. This indicated considerable evidence that reductions in the TSIP do occur as these waters flow downstream. The rise and fall of the total
soluble phosphate concentrations through the sewage plant and along the discharge creek is illustrated by Figure 4.

Phosphate Content in the Reservoir

In the second phase, the old Lake Dallas portion of Garza-Little Elm Reservoir was sampled at eleven stations positioned to survey the entire phosphate distribution in this receiving basin. Both surface and bottom samples were taken except at Stations 10, 13, and 14 where the depths were no greater than 0.5 meters. There was no apparent trend for the phosphate concentrations to vary with depth in this shallow portion of the reservoir. Much smaller concentrations of the soluble phosphates were found in the reservoir than in the creek. The highest amounts of soluble phosphates were found at Station 10, near the Pecan Creek outlet, and on one occasion, at Station 13 and 14, near the mouth of the Trinity River Fork. Results of this second phase of study are shown in Table III.
Fig. 4--Total soluble phosphate concentrations at successive stations through the sewage plant and creek
TABLE III

PHOSPHATE CONTENT IN GARZA-LITTLE ELM RESERVOIR

<table>
<thead>
<tr>
<th>Date</th>
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<td></td>
<td>T</td>
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<td>T</td>
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<tr>
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<td>.82</td>
<td>.36</td>
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</tr>
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<td></td>
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<tr>
<td>Ortho</td>
<td>.80</td>
<td>.79</td>
<td>.33</td>
<td>-</td>
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<tr>
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^a Concentrations are the averages of duplicate runs undiluted and are recorded in p.p.m.

^b Top sample.

^c Bottom sample.

^d Contamination.
CHAPTER IV

DISCUSSION

The inflow of soluble inorganic phosphates in the raw sewage at Denton's Municipal Activated Sludge Treatment Plant is high. This was to be expected, since earlier studies by the Robert S. Kerr Water Research Center (U.S. Department of the Interior, 1966) have demonstrated high total phosphate loads in this sewage plant. Similar values for total phosphates have been reported by Vacker et al. (1967) at sewage plants in the Dallas-Fort Worth area, and at plants in Austin, and San Antonio, Texas. In the activated sludge plants sampled by Vacker et al., reductions of the total phosphate concentrations in the effluent were as high as 88 per cent and as low as 15 per cent. Reduction in the soluble inorganic fraction of the total phosphate, which is demonstrated from the average of six samplings at the Denton plant, is a low 37 per cent in this present study.

Inside the Denton sewage plant, the primary clarifier indicated a slight increase of the soluble phosphates above that found in the raw sewage. Since this is an anaerobic basin, the increase can most likely be ascribed to the
phenomenon of anoxious release of orthophosphate in wastewater. This phenomenon was described by Sekikawa et al. (1966) who concluded that this occurred in activated sludge treatment when such unfavorable conditions as deficiencies in nutrients or oxygen arose, or when a poisonous substance entered the system. Later, Shapiro, Levin, and Zea (1967) reported the release resulted, not only when oxygen values are low (less than 2 p.p.m.), but also when redox potentials are low. Both groups of investigators agreed that only orthophosphate is released when this phenomenon occurs.

High concentrations of total soluble inorganic phosphate in the aeration basins can be attributed to the mixing of return sludge with the inflowing sewage in these basins. During the six sampling days approximately 30 per cent of the sludge produced was being returned to the heads of these aeration basins, and the first half of each basin was used for reaeration of the return sludge. In a report by the Robert S. Kerr Water Research Center (U.S. Department of the Interior, 1966), concentrations of total phosphate as high as 239 p.p.m. were found in the return sludge. A portion of high concentration of soluble phosphates in the aeration basins might also have been due to the low oxygen quantities in the basins during the sampling days.
Although the average percentage reduction of soluble phosphates in the final effluent was low when compared to the average amount found in the raw influent, this reduction is high when compared to the amounts found in the aeration basins. Apparently, the final clarifier, whose average concentration of soluble phosphate was only about one-seventh of that measured in the effluent of the aeration basins, performed very effectively in removing soluble phosphate from the sewage waters. The inefficiency in reducing soluble phosphate concentrations in this activated sludge plant must, then, be attributed to the build-up of phosphates in the aeration basins. The efficiency of the final clarifier in removing soluble phosphates from the aeration basin effluent is a high 78 per cent. This is reduced only slightly by the concentrations found in the final chlorinated effluent which, on each of the sampling dates, received bypassed sewage. Not having received treatment from the final clarifier, the bypassed sewage would certainly be expected to contain high concentrations of phosphates.

The percentage of condensed phosphates was reduced throughout the plant, even though there were higher concentrations measured in the aeration basins. The average concentration of condensed phosphates in these aeration
basins is roughly reduced by one-third this amount in the final clarifier. Certainly these condensed phosphates were subject to settling by coagulation, but they must have also been subject to hydrolysis. Engelbrecht and Morgan (1959) described this hydrolytic degradation of condensed phosphates as controlled by the chemical, physical, and biological characteristics specific to each water source.

Further reduction of the total soluble phosphate load occurred as the effluent flowed into the receiving creek, and progressive reduction was observed as the phosphates flowed downstream into the reservoir. Dilution, increased assimilation by microorganisms, and settling by coagulation are primarily responsible for this reduction. Inside the sewage plant, settling by coagulation and assimilation by microorganisms are perhaps the two principal methods of reduction. However, dilution may play a principal role in the reduction of phosphates in the sewage plant as it does in the receiving waters. This must have been the case on the third sampling date (October 10, 1968) in the first phase of sampling. The daily rainfall throughout the month of October varied from no rain to only trace amounts except on the ninth of October when the area was deluged by rains. The plant recorded 2.7 inches of rainfall, with the majority
of this falling in less than a two hour period. During this period, the daily flow rate was greater than 11 million gallons, or three times the normal flow rate.

The three major degradative processes must demonstrate one of their most drastic effects on the effluent as it flows into the creek. The average concentration of soluble phosphate at the middle station on the creek was approximately one-half that of the combined average amounts of the final effluent and upper stations. Another drastic reduction of soluble phosphate occurred at the reservoir intake (Station 10) near the mouth of Pecan Creek where the degradative processes must be most operative.

According to the average concentrations from stations measured along the creek, there was a decrease in soluble phosphates as they flow downstream. Keup (1967) reported this downstream reduction of phosphates to be primarily the result of assimilation by stream biota, and that it was not significant in the ultimate dispersal of phosphorus. Large concentrations of phosphorus may flow downstream unmeasured in the stream bed, or in floating matter. Thus, the measured decrease of soluble phosphate in the creek gives only a general idea of the assimilation rates, but does not represent a decrease in the eutrophication rate of the reservoir.
In the reservoir, the degree to which the phosphates affect progressive eutrophication is dependent on many factors. More than fifteen years ago, Sawyer (1954) indicated that generally, such factors as contribution from runoff waters, climate, morphometry, winds, depth, temperature, and related chemical factors play an important role in eutrophication. Shapiro (1968) described a chemical factor called the "phosphate sparing factor" which, when present, increased the effect of phosphate on growth production. Many less obvious factors also control the effect of the long term accumulation of phosphates in a reservoir or lake. According to Rigler (1955 and 1964), the turnover rate of phosphorus in a body of water may determine the degree to which eutrophication may express itself at any one time. Since it is generally accepted that soluble inorganic phosphate is the only fraction utilized by phytoplankton, the seriousness of algal "blooms" is dependent not only on the rate at which soluble phosphate is returned from the cellular materials, but also on the amount of soluble phosphate available. At any given time, virtually all of the phosphate may be incorporated inside the biota of the system, and thus, not available for production (Pomeroy, 1960).
In the old portion of Garza-Little Elm Reservoir, there seemed to be no apparent tendency for the soluble phosphates to be higher on the surface, or on the bottom. This was to be expected, since no thermal stratification was detected in the reservoir during sampling. The highest concentrations of soluble phosphates in the reservoir were found near Pecan Creek (Station 10), and on one occasion, near the Trinity River Fork inlet at Stations 13 and 14. These waters carry treated sewage from upstream and might be expected to increase the phosphate concentrations near their outlets.

The generally accepted value for the critical level of available phosphates (soluble inorganic phosphates) in natural waters is 0.01 mg./l. (Sawyer, 1960). However, each body of water, or waterway system, has its own individual seasonal tolerance levels and particular interacting forces. Even though, the soluble inorganic phosphate concentration measured at any one time may be low, the overall data give a representative idea of the amount of soluble phosphate which may create problems in a maturing body of water. The old portion of Garza-Little Elm Reservoir has, for several years, been associated with algal "blooms," tastes and odors, and turbidity. Although the tolerance levels in this reservoir are most likely higher than the accepted critical level, the
measured values, determined in this study, are so large that this portion of Garza-Little Elm Reservoir must be considered a fairly advanced eutrophic body of water.
CHAPTER V

SUMMARY AND CONCLUSIONS

1. Both the warm dilute hydrochloric acid wash, and the dilute hydrochloric-hydrofluoric acid wash gave equally good results. However, the latter wash was preferred since no preliminary attention had to be given it.

2. The Denton Municipal Activated Sludge Plant has a high inflow of soluble phosphates in the raw sewage.

3. The overall efficiency of the sewage plant is relatively low (approximately 37 per cent). Nevertheless, the efficiency of the final clarifier in reducing the soluble inorganic phosphate concentration is a high 78 per cent. The inefficiency of soluble phosphate removal lies with the build-up of phosphates in the aeration basins.

4. A slight increase in soluble phosphate was found in the primary clarifier and in the final chlorinated effluent. This increase lowers the overall efficiency somewhat and can be most likely attributed to the phenomenon described as the anoxicous release of orthophosphate in wastewater in the case of the primary clarifier, since this is an anaerobic
basin. In the final effluent, the increase must be due to the bypassing of untreated sewage.

5. The high concentrations of soluble phosphate that are found in the aeration basins can be ascribed to the mixing of return sludge which is high in phosphate.

6. Condensed phosphates are reduced, percentage wise, throughout the sewage plant even though the numerical value is higher in the aeration basins. Hydrolytic degradation, as well as settling, is probably involved in this reduction.

7. There is a drastic reduction in the soluble phosphate content of the effluent as it enters the creek, and then, as it enters the reservoir. This certainly must be considered the result of dilution, increased assimilation by microorganisms, and settling.

8. By diluting the phosphates, heavy rains may greatly affect the concentrations in a waterway, as demonstrated on the tenth of October sampling date after rains deluged the area the day before.

9. In the reservoir, there is no apparent tendency for the concentrations of soluble phosphate to be higher on the surface or on the bottom. This might be expected, since no thermal stratification was detected during sampling.
The highest concentrations of soluble phosphate were found near Pecan Creek, a source of phosphorus inflow.

10. Garza-Little Elm Reservoir, north of the old dam, (Lake Dallas) must be considered an eutrophic body of water. Although the amounts of soluble phosphates may not represent the maximum amount of soluble phosphate available at any one time, the concentrations measured are generally many times greater than the accepted critical level for dissolved phosphates.
APPENDIX
TRIPlicate RESULTS OF THE TOTAL SOLUBLE INORGANIC PHOSPHATE CONTENT IN THE DENTON ACTIVATED SLUDGE PLANT

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