STATE OF CALIFORNIA
THE RESOURCES AGENCY

STATE WATER QUALITY CONTROL BOARD

WASTEWATER RECLAMATION
AT
WHITTIER NARROWS

1966

Publication No. 33

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FOREWORD

The reclamation of usable water from sewage and industrial wastes is becoming more urgent in southern California, and other arid regions as the need for water increases rapidly while the available supply remains constant or even diminishes. However, in southern California, where ground water is most important as a water supply, reclamation of waste waters by spreading and percolation of treated effluent into subterranean water basins conceivably might lead to pollution. Such reclamation, therefore, is of concern to the State Water Quality Control Board and the nine regional water quality control boards.

Late in 1961 the Los Angeles County Supervisors provided funds for the construction of a demonstration plant at Whittier Narrows in connection with reclamation and reutilization of domestic sewage from the San Gabriel Valley. Beginning in August 1962, effluent from the activated-sludge plant constructed and operated by the Los Angeles County Sanitation Districts was turned over to the Los Angeles County Flood Control District for surface spreading to recharge underground basins. The construction and operation of this demonstration plant afforded a rare opportunity to conduct fundamental research on the effects of treatment and travel through the soil of several components of sewage.

In response to this opportunity, the State Board on January 25, 1962, contracted with the California Institute of Technology, Pasadena, for a research study with the general objective of investigating certain aspects of the reclamation of sewage by activated-sludge treatment and by percolation of the effluent into subterranean water basins. The succeeding pages present the contractor's final report, dated September 30, 1965, and submitted following the third and terminal year of the project. Background information is given in Chapter I "Introduction". Findings are shown in the "Summary and Conclusions" and the "Recommendations".

Printing and distribution of the report as Publication No. 33 was authorized by the State Board on December 16, 1965.

The investigations reported herein were conducted under the sponsorship of the State Water Quality Control Board (formerly the State Water Pollution Control Board). The investigations and their direction were under the responsibility of the California Institute of Technology. The conclusions and recommendations are, therefore, those of the research contractor, and do not necessarily reflect opinions or policies of the State Water Quality Control Board.

FINAL REPORT

of

RESEARCH

on

WASTEWATER RECLAMATION AT WHITTIER NARROWS

by

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30 September 1965

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30 September 1965

State Water Quality Control Board
The Resources Agency of California
Room 316, 1227 "O" Street
Sacramento, California 95814

Gentlemen:

In compliance with Standard Agreement No. 12-16, dated 1 July 1964, between the California Instititue of Technology and the State Water Quality Control Board, we are pleased to submit herewith the Final Report of Research on Wastewater Reclamation at Whittier Narrows.

A summary of these investigations and their conclusions is presented at the front of the report, followed by brief recommendations. The body of the report contains detailed descriptions and explanations, tabulations, and figures to make the presentation as complete as possible.

It has been a privilege to serve the State Board in this capacity. It is hoped that the report will meet with your approval and that it will do much to further knowledge about the intermittent spreading of wastewater effluents and their effects on the quality of ground water.

Respectfully yours,

J. E. McKee

J. E. McKee
Professor of Environmental
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JEM:mc

SUMMARY AND CONCLUSIONS

The general objective of this investigation has been to determine the effects of intermittent percolation through soil of highly treated activated-sludge effluent on the quality of ground water in the Whittier Narrows area. More specifically, the project was designed to study the fate of significant mineral, organic, and biological constituents of renovated wastewater and the phenomena associated with their removal or transformation.

The investigations were divided into three major categories. First, a total of 25 wells in the vicinity of Whittier Narrows were monitored with respect to water quality at various elevations by means of a selective-depth pumping unit. Such monitoring was performed to determine if the spreading of reclaimed wastewater had any impact on the quality of ground water at various depths. Second, test spreading basins were constructed and operated to study the phenomena associated with intermittent vertical percolation through the upper few feet of soil. Third, laboratory soil columns were utilized to compare the degradation of the new linear alkylate sulfonates (LAS) with the conventional alkyl benzene sulfonates (ABS).

It has long been known that vertical percolation through the zone of aeration in soil and lateral movement in a saturated aquifer or ground-water basin are effective mechanisms for the purification and stabilization of water. Indeed, the passage of polluted river water through soil into collection galleries has been used as a treatment process for many decades, especially in Europe. The percolated water undergoes physical, chemical, and biological transformations that tend to bring it into equilibrium with the soil environment and cause it to lose its identity. Where lateral movement below the water table or in confined aquifers is involved, velocities are so slow (generally less than 0.5 feet per day) that the prolonged time of exposure favors many mechanisms of purification and also provides opportunities for mixing and blending. A review of some of the literature associated with ground-water recharge is presented in Chapter 2.

The Whittier Narrows Water Reclamation Plant, constructed and operated by the Los Angeles County Sanitation Districts, has been discharging about 12 to 16 mgd of highly treated activated-sludge effluent since August 1962. The effluent is metered and turned over to the Los Angeles County Flood Control District (LACFCD) which conveys it in pipelines, open ditches, and river channels to the spreading basins of the Montebello forebay along the Rio Hondo and San Gabriel River, where it is allowed to percolate into water-bearing strata. The water reclaimed by this operation is purchased by the Central and West Basin Water Replenishment District, at a price comparable to that of untreated Colorado River water.

To determine the effect of intermittent spreading on the quality of percolating effluent, two small test basins were constructed. One was located behind the Whittier Narrows Dam near the reclamation plant to receive undiluted effluent. The other was situated among the Rio Hondo Spreading Basins to evaluate the mixed waters percolated at that location. Each test basin was equipped with sampling pans located two, four, six, and eight feet below the spreading surface. The Whittier Narrows Test Basin, 50 feet by 70 feet in plan with dikes initially two feet high, was constructed in relatively tight loamy soil that had been used for irrigated agriculture for many years. The initial ground-water table was only about nine feet below the spreading surface. In January 1964, a six-inch layer of pea gravel was placed on this bed, primarily to discourage the growth of weeds. The Rio Hondo Test Basin, 32 feet by 109 feet in plan with high dikes, was favored by a homogeneous permeable bed of fine to medium sand. The initial depth to the ground-water table was 16 feet.

Analyses were conducted on samples taken three times a week at the surface and at each sampling pan at both test basins. These analyses comprised tests for dissolved solids, fixed and volatile dissolved solids, pH, temperature, COD, dissolved oxygen, long-term BOD, all nitrogen components, chlorides, ABS, phosphates, turbidity, and coliform organisms. After an initial period of "ripening", i.e. accumulating biological growths capable of degrading many organic compounds and stabilizing the effluent, the test basins performed reliably and predictably.

The principal findings and conclusions resulting from this investigation are summarized as follows:

1. The effluent discharged from the Whittier Narrows Water Reclamation Plant from April 1963 through April 1965 met all of the requirements promulgated by Regional Water Pollution Control Board No. 4.

2. This effluent also met all of the mandatory chemical standards of the U.S. Public Health Service Drinking Water Standards of 1962 and almost all of the recommended (i.e. non-mandatory) chemical standards. The only chemical analyses that failed to meet the non-mandatory standards of the USPHS were total dissolved solids (500 mg/l limit), ABS (0.5 mg/l limit), and nitrogen if it later becomes oxidized to nitrate (10 mg/l limit as N). Tests for carbon chloroform extract were not run by this project. Physical and biological parameters are discussed later in this summary.

3. The Whittier Narrows effluent contains less total dissolved solids and much lower sulfates than does Colorado River water, which is the alternative supply purchased for spreading.

4. From January 1963 through February 1965, the LACFCD spread 193,515 acre feet of Colorado River water, 33,640 acre feet of local water, and 28,373 acre feet of reclaimed water, for a total of 255,528 acre feet. Hence, the reclaimed water constituted only about 11.0 percent of the total water spread. Expressed otherwise, the reclaimed water was subjected to a dilution of more than eight to one by natural waters in the process of spreading and subsequent underground mixing.

5. The best analyses for tracing changes in water quality in this investigation appeared to be chlorides, sulfates, and ABS. Local ground water upstream from Whittier Narrows Dam and the rising water in Mission Creek are characterized by 10 to 30 mg/l of chlorides, 20 to 160 mg/l of sulfates, and no apparent ABS. Natural Colorado River water has about 95 mg/l of chlorides, about 310 mg/l of sulfates, and no apparent ABS. Reclaimed wastewater at Whittier Narrows has about 115 mg/l of chlorides, about 128 mg/l of sulfates, and during this investigation about 1.8 mg/l of ABS. Hence, the spreading of Colorado River water should produce a significant rise in chlorides and a large increase in sulfates, but no trace of ABS. The spreading of wastewater should have about the same influence on chlorides but considerably less impact on sulfates, or perhaps none at all. Where it is not subject to much adsorption or biodegradation, ABS can signal the presence of wastewater.

6. Well No. 2936, upstream from Whittier Narrows Dam and apparently not influenced by Colorado River water released to the Rio Hondo or the San Gabriel River, is low in chlorides (14 mg/l or less) at depths of 36 to 81 feet, moderate in sulfates, low in nitrates, and free from apparent ABS. Wells No. 1590D, 1590F, 1590M, 1600L, 1592A, and 1592X, all in or near the Rio Hondo Spreading Grounds exhibit concentrations of chlorides and sulfates closely approaching those of Colorado River water, a condition that reflects the spreading of large volumes of Colorado River water since 1954. Insofar as chlorides are concerned, the multiple-depth sampler revealed no significant stratification. Nitrates are low and there is no evidence of ABS within the limits of reliability of this test (i.e. 0.2 mg/l). In view of the fact that wastewater effluent is diluted over 8 to 1 by other water and ABS is readily removed by intermittent percolation in aerobic soil, it was highly unlikely that any impact of wastewater on the quality of water beneath the spreading grounds could be detected. None of the water from wells sampled in this investigation showed any tendency to foam.

7. The shallow toe-drain wells at the downstream edge of Whittier Narrows Dam occasionally showed concentrations of apparent ABS in excess of 1.0 mg/l in fall and winter seasons but not in spring and summer. None of these samples of high ABS concentrations, however, produced any foam when shaken vigorously. There is no intentional spreading of wastewater effluent upstream from the Dam (except for the small volume at the Whittier Narrows Test Basin), but some reclaimed water may reach the shallow ground-water table from the unlined transport canals.

8. The hydraulic performance of the well-ripened Whittier Narrows Test Basin has been phenomenal. In the latter part of the investigation, 2.0 feet of effluent was applied every day (except Saturdays and Sundays) at about 4:00 P.M. The bed was generally dry in less than 10 hours and was subject to aeration for the remainder of each 24-hour period. The average rate of infiltration, measured by the rate of change of a stage recorder, was 1.45 feet per day during the first month of operation, decreased in the first five months to 0.59 feet per day, and then began a spectacular rise, reaching 5.20 feet per day in August 1964, decreasing slightly during the next winter, but rising again with warmer weather. It is apparent, therefore, that the intermittent daily application of highly treated activated-sludge effluent not only failed to cause plugging of the basin but actually improved the infiltration capacity markedly. The reasons for this spectacular performance were not explored to satisfaction, but it is hypothesized that biological growths within the basin forced the soil structure to open somewhat and to remain open during periods of drying and aeration.

9. Much of the improvement in hydraulic acceptance at the Whittier Narrows Test Basin occurred immediately after the bed received a six-inch layer of pea gravel. It is believed that the turbulent flow through the pea gravel served to flocculate the colloidal solids in the activated-sludge effluent, with most of the agglomerated material being removed by and oxidized on the surfaces of the pea gravel or the top surface of the soil. Hence, the pea gravel prevented colloids from penetrating and plugging the soil.

10. The hydraulic performance of Rio Hondo Test Basin was somewhat less than satisfactory, considering that initially it had a higher infiltration capacity than did the Whittier Narrows Test Basin. This difference is attributable to three factors: (a) the Rio Hondo Test Basin did not receive nearly as much organic load or nutrient, (b) it was flooded continuously for seven days at a time and allowed to dry for 14 days for about six months midway in the experiment, and (c) it was not coated with pea gravel. Owing to the less-favorable circumstances under which the Rio Hondo Test Basin operated, most of the observations reported below are based on performance at the Whittier Narrows Test Basin.

11. Prior to the start of this investigation in January 1962, the belief was widely held that the portion of ABS surviving conventional activated-sludge treatment was resistant to biochemical degradation. This study, however, demonstrated conclusively that, under favorable aerobic conditions, a well-ripened intermittent spreading basin can decrease the concentration of resistant ABS to 0.2 mg/l or less in a few feet of vertical percolation and that about 97 percent of the removed ABS is degraded biochemically.

12. In partially ripened columns of medium-coarse sand in the laboratory, each only 26 inches deep, about 57 to 60 percent of the ABS was removed and degraded biochemically; whereas for the new LAS, the removal and degradation totalled 89 to 91 percent. With further ripening and perhaps with finer sand the percentages for both detergents would probably improve, but this study was sufficient to show that the new LAS is considerably more amenable to biochemical degradation than the former ABS. Parenthetically it should be noted that the detergent manufacturers completed their conversion from ABS to LAS prior to mid-1965. This conversion has already had an impact on activated-sludge plants throughout the country. At Whittier Narrows, the effluent prior

to foam separation formerly averaged about 3.7 mg/l of apparent ABS. By September 1965 this concentration had dropped to about 1.5 mg/l owing to the biodegradability of the new LAS.

13. Although the conventional 5-day 20°C BOD of the final effluent at Whittier Narrows is characteristically less than 10 mg/l, the long-term BOD (e.g. 30 to 100 days) is in the order of 150 mg/l. More important, in a well-ripened spreading basin, this high total oxygen demand is exerted within a few hours in percolation through the upper two to four feet of soil. Expressed otherwise, the supposedly well-oxidized activated-sludge effluent exerts an oxygen demand of about 150 mg/l in percolating through the first few feet of ripened soil.

14. The long-term or total biochemical oxygen demand equals the chemical oxygen demand plus the oxygen required to convert ammonia and organic nitrogen to nitrates. This value can be computed from rapid chemical tests without waiting for 30 to 100 days of incubation.

15. In a well-ripened spreading basin, the nitrogeneous oxygen demand is exerted more rapidly and more completely than the carbonaceous oxygen demand. For the Whittier Narrows effluent, the nitrogeneous demand is more than four times the carbonaceous demand. Insofar as oxygen balances are concerned, it would be desirable to spread an activated-sludge effluent in which the nitrogen was already in the form of nitrates.

16. Approximately three quarters of the carbonaceous oxygen demand, as measured by COD, is removed from the percolating water in passage through the first four feet of a well-ripened intermittently operated basin. This is a zone that is highly aerobic. Below the four-foot level, however, the COD increased again to about 40 percent of the surface concentration. It is hypothesized that this increase in a zone that is frequently anaerobic is attributable to the growth of soil bacteria and their presence in the percolate, as described under item 19 which follows.

17. The COD of the soil in the upper two meters of the well-ripened Whittier Narrows Test Basin was more than five times the COD of the effluent added to the basin during the entire recharging operation. It is apparent, therefore, that much of the carbonaceous and nitrogeneous residue in the activated-sludge effluent is being converted to biological growth in the basin, and indeed that the organisms are getting supplementary nutrients from carbon dioxide, bicarbonates, and possibly atmospheric nitrogen. Whatever the mechanism, the basin appeared to function as a tremendously efficient biological system.

18. The sum of organic and ammonia nitrogen is diminished by more than 95 percent in percolation through the upper two feet of well-ripened soil. Furthur percolation to eight feet does not increase this percentage, nor is there a measurable reconversion back to organic nitrogen or ammonia. Most of the total nitrogen applied to the basin can be accounted for as nitrates in the percolates at various depths.

19. Nitrates in the percolate from undiluted effluent at Whittier Narrows exceed the recommended limit of the USPHS Drinking Water Standards by a factor of two or three. Natural ground waters in this area generally contain less than one quarter of the USPHS limits. Consequently it is desirable that effluent be diluted with natural waters prior to spreading (as is presently being done) or that ample opportunity be afforded underground for percolated effluent to blend with natural ground waters before subsequent repumping.

20. Contrary to the findings of previous investigators that vertical travel through four to seven feet of soil removed almost all coliform organisms from the percolate, this project demonstrated that a well-ripened bed generates coliforms as well as myriads of other bacteria. The median MPN of the chlorinated applied effluent was only 190 coliforms per 100 ml, yet the percolates at the four sampling pans produced median MPN concentrations in the order of 1,000 to 20,000 per 100 ml. In all probability, these bacteria were removed by deeper percolation or by lateral travel in the zone of saturation.

21. Further tests reveal that the coliforms in the percolates were of non-fecal origin, i.e. they were normal soil bacteria that thrived on the nutrients in the effluent and in the environment created by intermittent operation. Confirmation tests for fecal coliforms with the EC medium gave negative results consistently. On the other hand, fecal streptococci were found occasionally in the percolates at all sampling pans, but in very low concentrations. It is concluded, therefore, that vertical percolation through a well-ripened bed is an effective method for removing bacteria of fecal origin, despite the heavy growths of coliforms of soil origin.

22. Limited virological analyses indicated that the density of enteric viruses in wastewater from the San Gabriel Valley is quite low (i.e. less than 100 PFU per liter) except possibly during summer and early fall months, and during massive feedings of Sabin oral polio vaccines. Samples taken during and shortly after the Sabin Oral Sunday inoculations of February 1963 showed about 250 PFU of enteric viruses per liter in the Whittier Narrows effluent but no measurable concentration in the percolate from the two-foot pan. A subsequent addition of Sabin Type-III vaccine to the effluent applied to the Whittier Narrows Test Basin failed to produce measurable concentrations of enteric viruses in the percolates.

23. In the recharge of ground-water basins by surface spreading of wastewater effluents, there are two primary objectives, *viz.,*

a. to obtain the highest possible rate of hydraulic acceptance so as to minimize the land area required for spreading, and

b. to achieve an optimum degree of tertiary treatment so that the percolated water will be suitable for subsequent beneficial uses.

24. The objectives in item 23 can best be achieved by maintaining a highly aerobic environment in the spreading basin. To do so requires intermittent application of the effluent in a manner that will optimize the reaeration of the soil.

25. With the cycle of operation employed ultimately at the Whittier Narrows Test Basin (i.e. application of two feet of effluent per day, about nine hours wet and 15 hours dry), the total oxygen demand of the effluent was in the order of 75 to 100 gms of oxygen per square meter per day, mostly from the oxidation of ammonia and organic nitrogen. Diffusion of air from the surface during a half day of dryness alone appears to be capable of supplying about 110 grains of oxygen per square meter. Undoubtedly the piston effect of the percolating water will draw into the soil even more oxygen. The dissolved oxygen in the applied water is a negligible factor. For cycles longer than one day, the total oxygen demand of the applied water exceeds the reaeration capacity of the soil. Loading half as much effluent twice a day would be even more favorable than daily loading of the full amount, but practical considerations might preclude this method of operation.

RECOMMENDATIONS

On the basis of this investigation, the following recommendations are submitted for consideration by the California State Water Quality Board, the Los Angeles County Sanitation Districts, the Los Angeles County Flood Control District, and any other agency interested in the recharge of ground-water basins by surface spreading of municipal wastewater effluents:

1. Insofar as the quality of ground water at or below Whittier Narrows is concerned, there should be no fear that the present rate of spreading of effluent from the Whittier Narrows Water Reclamation Plant will have any marked or deleterious effect. Indeed, the output from the Whittier Narrows Plant could well be increased by a factor of two or three without concern. The concentration of nitrates in the blended ground water will probably be the limiting factor on expansion of wastewater reclamation at this location.

2. Spreading basins that receive undiluted effluent should be operated intermittently on as short a cycle as may be operationally feasible, preferably not to exceed half a day wet and half a day dry. Where effluent is blended with other waters prior to spreading, as generally is the case in the Montebello forebay, the cycle can be lengthened, but short cycles will favor optimum tertiary treatment and maximum hydraulic acceptance.

3. The application of a six-inch layer of pea gravel to spreading basins that are used for the intermittent dosing of wastewater effluent is strongly recommended, first to decrease maintenance costs and second to improve infiltration rates.

4. Where optimum intermittent spreading cannot be achieved, activated sludge plants might well be operated to convert organic and ammonia nitrogen to nitrates so as to minimize the oxygen demand in the upper layers of soil and provide more opportunity for further stabilization of the carbonaceous demand.

5. It would be desirable for the L. A. County Flood Control District or perhaps the California Department of Water Resources to continue to monitor the 25 test wells used in this investigation. Sampling about once each year at multiple depths should be adequate, with analyses for chlorides, nitrates, sulfates, and ABS.

6. If possible, the Whittier Narrows Test Basin should be retained and flooded daily with undiluted effluent by LACFCD for continuing subsequent studies as described below.

7. Observations of the infiltration capacity at the Whittier Narrows Test Basin should be continued to determine if this rate maintains a steady improvement, if it stabilizes, or if it regresses with further aging. If possible, tests should be conducted to attempt to ascertain the reasons for the phenomenal hydraulic behavior of this basin.

8. Further studies of the biology of the soil in the Whittier Narrows Test Basin are indicated. There is strong reason to believe that fungi, operating symbiotically with bacteria, play a major role in biochemical stabilization during aerobic intermittent percolation.

9. There is a need for improvements in the techniques for making quantitative assays of enteroviruses in wastewater effluents. The staffs at LACSD, LACFCD, and Caltech should be alert to any further massive inoculations of Sabin polio vaccines so that samples can be taken of effluent and percolates at Whittier Narrows for freezing and subsequent assay.

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