# SOIL PROFILE MODIFICATION FOR THE DISPOSAL OF DAIRY WASTES

A Technical Completion Report

submitted to

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by

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## Summary and Conclusions

Lack of suitable land for proper waste disposal practice in concentrated livestock production areas oftentime causes overloading of soils with potential contaminants of surface and underground waters. This study was an attempt to increase soil's capacity of receiving wastes without creating excessive leaching of total dissolved salts by modifying the existing soil profile. A brief summary of activities and results of experimentation are as follows:

1. A three-year field trial was set up at Moreno Field Station, University of California, to test the feasibility of modifying the soil profile by installing an 1/8" impervious asphalt membrane 30" below the surface of cropland used for disposing liquid and solid wastes from dairies. This moisture restricting barrier serves the purpose of interrupting the downward movement of salt latent leaching water and of reducing nitrogen in soil solution by induced nitrification and denitrification.

2. Fifty tons per acre of solid dairy wastes were disposed on two 100' x 50' experimental plots twice a year before each crop (barley in the winter season and sorghum in summer) was planted. This waste disposal loading is equivalent to receiving wastes from 30 cows per acre per year. After planting, wastewater from dairies was applied routinely by flood irrigation.

3. The result of this experiment indicated that the asphalt membrane was an effective barrier to prevent excessive leaching of dissolved minerals in soils. Such a modification of soil profile

also created an anaerobic zone immediately above the asphalt membrane where nitrate in soil solution was reduced. However, the lateral movement of water toward a tile drain line which was designed to collect and flush out the accumulated salt latent leachates from the modified soil profile was extremely slow. This resulted in rapid buildup of soil salinity.

4. The unfavorable soil condition for crop growth created by the modification of soil profile and a heavy loading of dairy wastes seriously damaged the planted crops. Yields from experimental plots were only 30-50% of the nearby fields where no dairy wastes were applied.

5. At the present time, no reliable technique is available to install such a barrier economically and deep enough to prevent the damage of crops.

## RECOMMENDATIONS

1. The investigator recommends the experimentaion of installing artificial impervious water barrier in cropland for waste disposal be discontinued until a reliable technique of laying such a barrier in soil becomes available.

2. Since the moisture barrier did show some promising results in preventing salt leaching and inducing denitrification, it is suggested that research efforts in seeking an effective land disposal of animal waste be focused on locating areas where naturally occurring water restricting layer exists. These sites then should be tested for their effectiveness in reducing nitrogen and preventing leaching.

3. The effectiveness of waste disposal should also be tested on tile drained cropland where a water restricting profile is present. Besides the advantage of denitrification and reduced leaching, the tile drain system could convert a nonpoint waste disposal practice into a point source discharge which is much easier to control.

# INTRODUCTION

The most acute problem associated with the intensified confinement of livestock production is waste disposal. When animals are confined in a small feeding area, the amount of wastes deposited on the ground can no longer be assimilated by nature. Frequent removal of large quantities of accumulating wastes from livestock confinement is necessary to prevent public nuisance; in fact, because of its putrescible nature, collected waste requires immediate treatment or disposal. Improperly disposed waste can also be a source of water pollution.

In the 40 square-mile Chino-Corona area, for example, there are more than 300 dairies with approximately 180,000 cows (1,2). In terms of the nitrogen content, these cows produce the amount of waste equivalent to that of 1.8 million people. At present, massive amounts of dairy wastes are being disposed on limited acreage of cropland. It was estimated that irrigated farmland available for waste disposal averages 0.1 acre per cow, while in some eastern and north central states (New York, Pennsylvania, Ohio, Indiana, Illinois, Michigan, Minnesota, Wisconsin, etc.), the disposal acre-to-animal ratio is more than 100 times greater (14 acres per cow) (3). With rapid urbanization and the continuing expansion of dairies in Southern California, land available for waste disposal will become even more scarce.

In irrigated agriculture, soils must be leached to ensure against salt buildup in the root zone. When dairy waste is disposed on land, salt accumulation in soils becomes an even more serious problem. Samples analyzed by the University of California Cooperative Extension Services laboratory at Riverside indicated that dairy wastes contained at least

2-3% dissolved minerals (4). Through conventional cropland disposal practices, a steady state condition in the soil may be reached where all mineral salts in land disposed dairy wastes will be leached out of the root zone. These dissolved minerals in the soil s unsaturated zone form the pool of potential contaminant that will contribute to the quality degradation of groundwater for a long time to come. Unless this pathway of leaching can be interrupted, the disposal of salt-laden dairy wastes on land would be an undesirable practice in water quality management.

# OBJECTIVES

The objective of this study was to test the physical feasibility of a land disposal system for dairy cattle waste in which large amounts of waste would be disposed on a given area where an impervious asphalt membrane was installed 30" below the ground surface. The purpose of this membrane is to create a zone to reduce nitrate in soil solution. The salts resulted from waste disposal can also be intercepted and removed through a tile drainage system. In this way, the continous cycling of adding salts into groundwater can be interrupted.

## Preliminary Study

Some constituents in the dairy wastes may be detrimental to crop growth. Before the experiment started, it is necessary to establish the upper limit of crop tolerance on dairy wastes. The preliminary study was set up to determine the effect of land disposed diary wastes on seed germination of crops of different salt tolerančnce levels and used as the guideline to select a suitable waste disposal rate (1). A brief summary of the results is presented here.

Dairy waste disposal rate equivalent to 0, 50, 100, 150, and 200 tons of wastes per acre were simulated in quart-sized plastic pots. Thirty seeds each were placed in pots representing different treatments for germination tests in a greenhouse. Seven days after first seed emergence, seed germination in each treatment were compared with control pots where no manure was added. The result indicated that waste application up to 50 tons per acre did not have any harmful effect on any crop tested (Fig. 1). For more salt-tolerant crops (barley and sudan grass), applications up to 200 tons of wastes per acre seemed acceptable; however, damage to salt sensitive crops (radish and spinach) become substantial when more than 50 tons of wastes per acre were applied. It was also found that ammonia released from fresh manure had damaging effects on all crops tested. Therefore, the amount of ammonia released after disposal may be a more significant factor in limiting crop growth on waste disposed land.

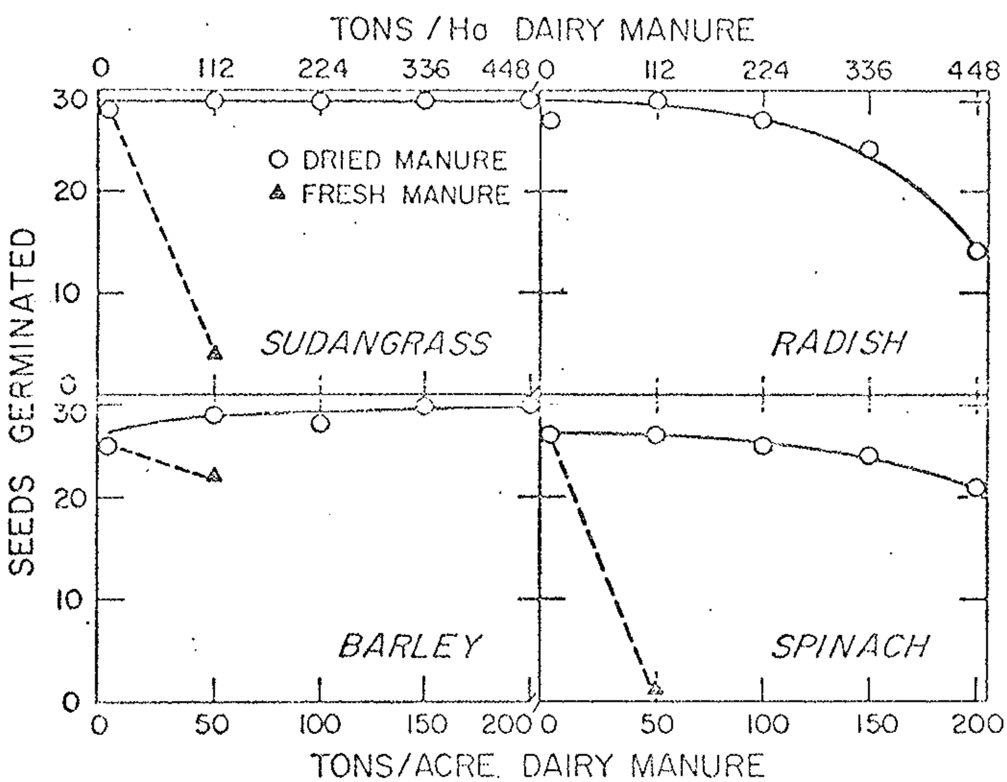


Fig. 1. Seed germination of 4 crops treated with dried and fresh manure at 4 application rates (1).

Description of the System

The proposed land disposal system for dairy cattle waste involved mainly a modification of soil profile, a waste water deliverty system and leachate collection system (Fig. 2). The active waste decomposition and stabilization take place in the biologically and chemically active soil filter. This natural filtering system was underlaid by an artificially installed 1/8" impervious asphalt membrane 30" below the soil surface to prevent the further downward movement of leaching water and its accompanying dissolved minerals. The 30" depth of the soil profile was selected as a compromise between the minimum depth of soil that crops need to establish the root system and the maximum depth beyond which construction costs become prohibitive. The leaching water passing through the profile was intercepted by the barrier and formed a saturated or nearly-saturated zone immediately above the asphalt membrane. This zone serves the purpose of reducing nitrate in soil solution biologically. Salts in the disposed wastes are graduately concentrated and leached out with each application of dairy wastewater. The salt-laden leaching water is then collected and flushed out by the drainage system (Fig. 3).

Crops that are salt-tolerant and suitable for livestock feeding were planted at the disposal site, not only so that plant nutrients contained in the waste could be effectively utilized but also to prevent clogging of the soil surface.

The solid waste disposal was so scheduled that they are applied on land and then plowed into the soil twice a year before each crop was planted. Wastewater was discharged on the disposal site after the removal of suspended solids by a solid separator. It was hoped

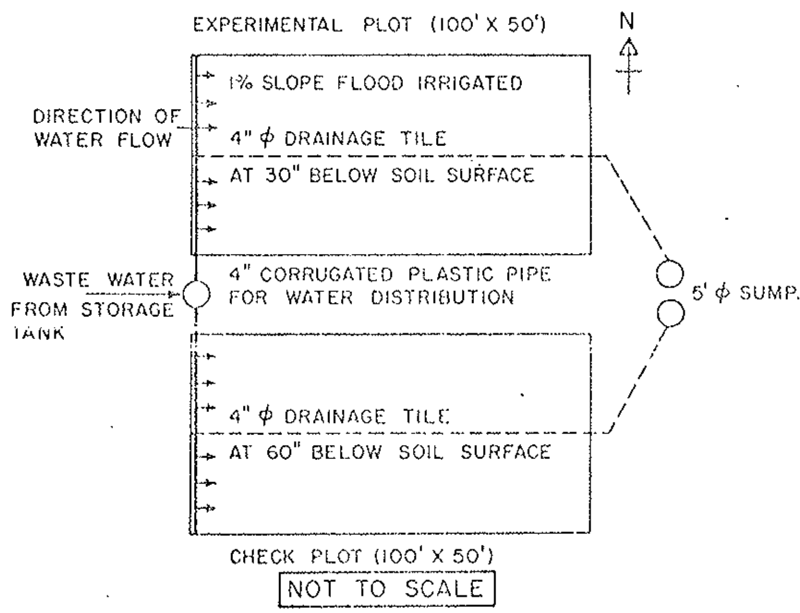


Fig. 2. A schematic layout at experimental site.

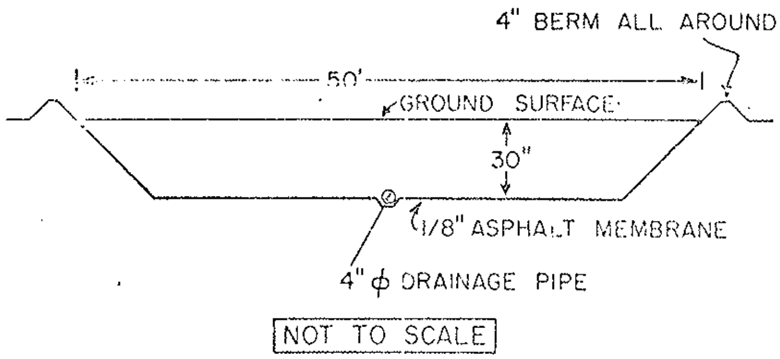


Fig. 3. Cross-sectional profile of the experimental plot.

that a good water and crop management would help to maximize the soil's waste disposal capacity.

## Site Selection

After a general survey of the dairy area and a review of all potential sites, it was decided that the experiment would be set up at the Moreno Field Station, University of California. At this location, land, mechanical equipment and technical support would be available at no cost to the project. However, it suffered the shortcoming of being located away from the area where daires are concentrated. Wastes used for this experiment had to be transported from dairies at least 20 miles away.

## Water Application Rate

If the Chino-Cornoa dairy area were used as an example of a model dairy area, the ratio of cows per disposal acre would exceed 10. Assuming that one-third of the waste receiving land (approximately the amount of land held by dairies) in the area is available for the proposed modification, the complete disposal of all wastes from dairies would be equivalent to 30 cows per disposal acre. The waste application rate thus calculated (assuming 2 tons of solid wastes per cow per year and 50 gallons of wastewater per cow per year) is shown in Table 1. This waste application rate did not exceed the upper limit that may cause damage in seed germination as determined in the preliminary study.

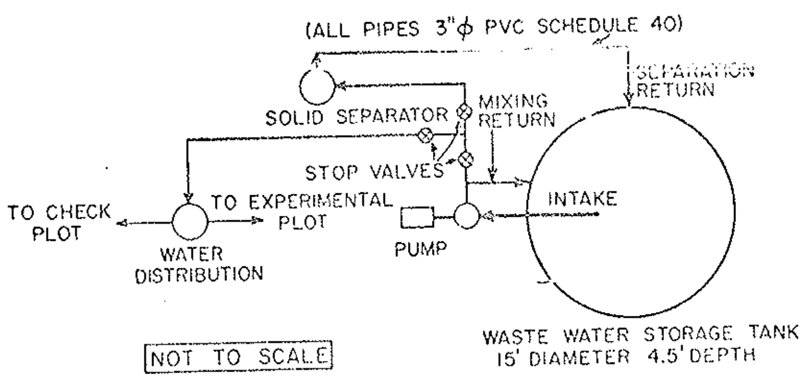


Fig. 4. Wastewater storage, solid separation and delivery system.

solid separator and returned to the reservoir. The stored wastewater would be delivered to experimental plots based on the amount of wastewater generated by 30 cows on each disposal acre. This waste application was done weekly for each plot. Additional water would also be applied if the tensiometer planted 12" below ground surface in the experimental plot indicated a soil moisture content of less than 50% of field capacity. However, such need did not arise during the experiment. Water was also applied to the check plot correspondingly.

The sump for the experimental plot was filled with water to maintain the zone of saturation. Water level in the sump was maintained by a sump pump. Thus, leaching water collected in the drainage tile could not be sampled directly. Instead, 3" porous ceramic cups were planted on the top of the impervious layer. Soil water was withdrawn by vacuum suction to represent the effluent water quality. No water samples were recovered from the check plot because no drainage water was ever collected by the tile.

From the second season on, additional ceramic cups were planted at 15" in the experimental plot and at 6", 18" and 30" in the check plot to determine the chemical composition of soil water moving through the soil profile. However, no water samples have been recovered beyond the 18" level in the check plot. This water sampling was done routinely throughout the experimental period.

Soils of each plot were first sampled after the preparation of land and sampled again after each crop was harvested.

METHOD OF ANALYSIS

Water samples were analyzed for their electrical conductivity, nitrogen contents (ammonium, nitrate and nitrite, Kjeldahl nitrogen), $Cl^-$, $Ca^{++}$, $Na^+$, and chemical oxygen demand (COD). For all analyses except chloride and nitrogen contents, the analytical procedures outlined in the Standard Methods for the Examination of Water and Wastewater (7) were followed. The nitrogen contents of the samples were determined by steam distillation technique and microKjeldahl procedures. Chloride content was analyzed using an automatic chloride ($Ca^{++}$ and $Na^+$) were determined by flame photometry and atomic adsorption techniques. Water extractable phosphorous, available phosphorous, organic phosphorous, and total phosphorus were determined by methods outlined by Chapman and Pratt (4).

Soil samples collected were first weighed and then dried in a drying shed to determine soil moisture content. The soil saturation extracts were prepared by adding approximately 40 ml of deionized water in 200 gm of air dry soil and allowing the mixture to equilibrate overnight. The paste was then filtered through No. 1 filter paper to obtain the extract. Based on the soil moisture content, the result of the analysis can be converted to solution basis. In this report results were reported all in concentrations in the saturation extract.

## RESULTS AND DISCUSSION

The amounts of solid dairy wastes and waste water applied during the experiment are summarized in Table 2. Due to variation in the moisture content of each batch of waste applied, the net amount (dry weight) of wastes applied váried slightly each growing season. The physical and chemical properties of applied wastes and wastewater are summarized in Tables 3 and 4. Except for moisture content, other parameters that characterize the wastes did not seem to vary significantly. The variation in moisture content was caused apparently by seasonal variation of climate. Wastes collected after winter months usually have higher water content. At the first season, the wastewater applied was considerably weaker than normally expected from a dairy operation (9) due to an operator's error. It was corrected in subsequent seasons. This change in wastewater properties created surface clogging and a noticeable reduction of infiltration rate. During the last growing season, irrigation water instead of wastewater was applied. Based on the data of Tables 3 and 4, the average of N and P applied would be equivalent to 693 lbs/acre and 209 lbs/acre, respectively. This application rate far exceeds fertilization rates recommended for normal crop production. Approximately one half inch of wastewater was applied each week. Additional water application was based on indicating tensiometers planted 12" below ground surface at the experimental plot indicating that soil moisture content was less than 50% of field capacity. However, such occasion seldom occurred during the period of experimentation. The unfavorable plant growing soil conditions created by the slowness of water movement in the experimental plot caused the development of a shallow

Table 2. Amount of dairy waste applied

| Season | Crop | Solid waste | Waste water | Precipitation |
|---|---|---|---|---|
| 1st | Barley | 3.0 tons (dry wt.) | 9.0" | 7.5" |
| 2nd | Sorghum | 2.8 tons (dry wt.) | 11.0" | 0 |
| 3rd | Barley | 2.6 tons (dry wt.) | 10.0" | 5.5" |
| 4th | Sudan grass | 3.1 tons (dry wt.) | 18.0" | 0 |

Table 3. Characteristics of applied solid wastes*

| Season | Moisture content | N | P | K | Ca | Na | Cl |
|---|---|---|---|---|---|---|---|
| 1st | 24.0% | 2.18 | 0.49 | 3.21 | 2.29 | 0.77 | 1.38 |
| 2nd | 32.2 | 1.48 | 0.58 | 3.38 | 2.16 | 0.87 | 1.23 |
| 3rd | 34.2 | 1.78 | 0.46 | 3.00 | 1.91 | 0.45 | 1.10 |
| 4th | 26.0 | 0.67 | 0.31 | 2.50 | 1.70 | 0.42 | 2.12 |

*In percent dry weight except moisture content (percent on wet weight basis)

Table 4. Characteristics of applied water*

| Season | E.C. | Nitrogen $NH_4^+$-N | $NO_3^-$-N | Kjeldahl | $Cl^-$ | $Ca^{++}$ | $Na^+$ | COD |
|---|---|---|---|---|---|---|---|---|
| 1st | 0.95 | 0.54 | 1.61 | 7.02 | 157 | -- | -- | 235 |
| 2nd | 1.45 | 28.2 | 14.0 | 86.0 | 180 | 122 | 86 | 2915 |
| 3rd | 1.65 | 31.5 | 5.4 | 94.8 | 176 | 135 | 98 | 3145 |
| 4th | 0.86 | -- | 0.1 | -- | 183 | 40.5 | 112.3 | -- |

*All units in mg/l except E.C. (mmho/cm).

Table 5. Crop Yield

| Season | Crop | Check plot | Experimental Plot |
|---|---|---|---|
| | | tons/acre dry wt. | |
| 1st | Barley | 0.52 | 0.30 |
| 2nd | Sorghum | 1.2 | 1.4 |
| 3rd | Barley | 0.54 | 0.13 |
| 4th | Sudan grass* | 0.58 | 0.40 |

*One cutting.

root system. The tensiometer planted at 12" eventually was proven unsatisfactory to reflect water demand of crops in this experiment.

Crop Yield

The heavy waste application on cropland has great influence on the crop growth. When compared with a nearby field where no wastes were applied, the growth of barley in plots used for the experiment were greatly inhibited. The crop yield of each season is summarized in Table 5. Barley yields of both plots under experimentation were considerably lower than that of the nearby field which yielded 3.5 tons/acre during the first year and 2.6 tons/acre during the second year. The decline of crop yield is also common in experiments of water harvesting which created a similar soil environment with fluctuating soil moisture regime. The depressed yield of crops certainly showed the need for a better managed crop-soil moisture management plan to bring the waste disposal land to a more productive level.

Soil Analysis

All soil analyses were done on soil saturation extract as described in the Method of Analysis section. This measurement approximates the concentration of saluble constituents in soils. Whenever leaching water becomes available these constituents will be leached.

Soil samples were taken from profiles of both the check plot and the experimental plot sites before the project began. They were then sampled after each crop was harvested. The results of each soil analysis are summarized in Tables 6 and 7. The soil used in this experiment was rather high in $Na^+$, especially near the soil surface. Dairy waste material (both liquid and solid) which has a higher calcium than sodium

Table 6. Analysis of soil saturation extracts at check plot.

| Depth (inches) | Electrical Conductance (mmho/cm) | Nitrogen | | | Chloride (meq/l) | $Ca^{++}$ (meq/l) | $Na^{+}$ (meq/l) | Chemical Oxygen Demand (mg/l) |
|---|---|---|---|---|---|---|---|---|
| | | $NH_4^-$-N | $NO_3^-$-N | Kjeldahl-N | | | | |
| | | | BEFORE EXPERIMENTATION | | | | | |
| 0-12 | 3.0 | 1.1 | 16.5 | 12.8 | 1.87 | 2.92 | 32.15 | --- |
| 12-24 | 1.94 | 1.3 | 10.4 | 12.4 | 1.46 | 1.86 | 17.70 | --- |
| 24-36 | 0.86 | 0.46 | 3.1 | 4.2 | 0.90 | 1.13 | 15.53 | --- |
| 36-48 | 0.72 | 0.23 | 0.9 | 3.5 | 0.67 | 0.65 | 9.79 | --- |
| 48-60 | 1.18 | 0.50 | 1.5 | 4.0 | 0.91 | 1.88 | 11.14 | --- |
| | | | AFTER FIRST CROP | | | | | |
| 0-12 | 2.49 | 4.9 | 13.0 | 13.3 | 1.44 | 13.0 | 12.0 | 319.0 |
| 12-24 | 2.24 | 7.2 | 93.7 | 11.2 | 11.50 | 12.3 | 11.3 | 187.0 |
| 24-36 | 1.09 | 6.9 | 139.9 | 10.6 | 1.02 | 4.8 | 9.1 | 97.0 |
| 36-48 | 0.97 | 12.7 | 40.5 | 12.7 | 0.83 | 2.8 | 8.9 | 89.0 |
| 48-60 | 1.10 | 4.5 | 40.4 | 8.9 | 0.81 | 2.9 | 10.0 | 85.0 |
| | | | AFTER SECOND CROP | | | | | |
| 0-12 | 5.20 | 7.6 | 59.9 | 243.6 | 6.8 | 4.5 | 28.3 | 2151.0 |
| 12-24 | 3.98 | 1.6 | 137.9 | 29.8 | 5.8 | 16.6 | 18.9 | 295.0 |
| 24-36 | 2.34 | 2.8 | 137.2 | 17.7 | 2.5 | 8.8 | 14.1 | 68.0 |
| 36-48 | 1.68 | 2.8 | 108.1 | 11.5 | 1.3 | 4.1 | 11.1 | 46.5 |
| 48-60 | 1.15 | 9.6 | 65.9 | 12.8 | 0.8 | 1.5 | 9.8 | 61.6 |
| | | | AFTER THIRD CROP | | | | | |
| 0-12 | 7.7 | --- | 20.68 | 177.0 | 7.4 | 13.3 | 40.3 | 1828 |
| 12-24 | 5.7 | --- | 134.95 | 23.2 | 11.2 | 30.08 | 22.4 | 599 |
| 24-36 | 2.8 | --- | 187.5 | 4.9 | 7.5 | 15.60 | 9.8 | 292 |
| 36-48 | 1.8 | --- | 157.5 | 3.28 | 3.8 | 8.95 | 8.3 | 222 |
| 48-60 | 1.7 | --- | 147.75 | 3.10 | 2.0 | 8.73 | 8.0 | 226 |
| | | | AFTER FOURTH CROP | | | | | |
| 0-12 | 6.3 | 3.11 | 34.65 | 56.27 | 11.05 | 8.5 | 32.2 | 1819.0 |
| 12-24 | 5.5 | 1.72 | 133.73 | 27.26 | 9.4 | 20.0 | 17.0 | 379.0 |
| 24-36 | 2.46 | 1.87 | 143.18 | 15.98 | 3.5 | 11.2 | 10.9 | 194.50 |
| 36-48 | 2.48 | 1.42 | 158.10 | 3.40 | 1.6 | 4.5 | 12.2 | 142.0 |
| 48-60 | 2.59 | 1.11 | 135.63 | 2.29 | 1.5 | 2.7 | 10.9 | 29.5 |

Table 7. Analysis of soil saturation extracts at check plot.

| Depth (inches) | Electrical Conductance (mmho/cm) | Nitrogen | | | Chloride (meq/l) | $Ca^{++}$ (meq/l) | $Na^{+}$ (meq/l) | Chemical Oxygen Demand (mg/l) |
|---|---|---|---|---|---|---|---|---|
| | | $NH_4^-$-N | $NO_3^-$-N | Kjeldahl-N | | | | |
| | | | BEFORE EXPERIMENTATION | | | | | |
| 0-12 | 2.04 | 0.9 | 3.2 | 10.4 | 1.80 | 1.6 | 22.0 | --- |
| 12-24 | 1.25 | 1.3 | 5.1 | 12.1 | 1.03 | 1.6 | 33.8 | --- |
| 24-30 | 2.46 | 1.4 | 9.9 | 17.5 | 1.87 | 3.0 | 29.2 | --- |
| | | | AFTER FIRST CROP | | | | | |
| 0-12 | 1.69 | 2.73 | 69.2 | 20.2 | 1.16 | 5.8 | 12.2 | 193 |
| 12-24 | 1.66 | 9.55 | 250.2 | 18.7 | 1.25 | 6.7 | 11.1 | 136 |
| 24-30 | 3.01 | 10.78 | 209.3 | 10.0 | 3.34 | 14.9 | 14.6 | 196 |
| | | | AFTER SECOND CROP | | | | | |
| 0-6 | 7.20 | 6.4 | 104.2 | 168.9 | 10.9 | 6.0 | 33.9 | 2089 |
| 6-12 | 6.42 | 7.3 | 49.6 | 78.8 | 11.9 | 16.8 | 36.11 | 863 |
| 12-18 | 4.03 | 4.0 | 34.5 | 37.8 | 7.9 | 13.8 | 23.5 | 250 |
| 18-24 | 2.28 | 2.0 | 9.3 | 22.5 | 3.9 | 5.8 | 15.0 | 238 |
| 24-30 | 2.02 | 1.2 | 11.6 | 23.4 | 2.9 | 5.3 | 13.7 | 117 |
| | | | AFTER THIRD CROP | | | | | |
| 0-6 | 7.5 | --- | 8.2 | 218.25 | 12.5 | 7.65 | 40.7 | 2216 |
| 6-12 | 6.0 | --- | 16.45 | 50.28 | 14.2 | 23.13 | 41.9 | 1526 |
| 12-18 | 5.1 | --- | 7.63 | 18.98 | 10.9 | 23.65 | 23.2 | 681 |
| 18-24 | 2.2 | --- | 2.65 | 12.43 | 4.13 | 10.65 | 10.1 | 569 |
| 24-30 | 2.2 | --- | 6.20 | 18.1 | 2.9 | 10.13 | 10.5 | 640 |
| | | | AFTER FOURTH CROP | | | | | |
| 0-6 | 6.30 | 6.2 | 2.4 | 203.2 | 9.6 | 4.0 | 35.7 | 5527 |
| 6-12 | 5.73 | 3.2 | 8.2 | 64.3 | 5.4 | 18.0 | 15.7 | 1711 |
| 12-18 | 3.16 | 4.0 | 4.3 | 18.2 | 1.7 | 8.7 | 9.6 | 560 |
| 18-24 | --- | --- | --- | --- | --- | --- | --- | --- |
| 24-30 | 1.73 | 2.1 | 1.6 | 17.4 | 2.3 | 6.4 | 10.4 | 547 |

content. This further indicated that the reduction of infiltration rate was not due to change in soil characteristics caused by deflocculation of soil particles.

Quality of Drainage Water

In the check plot there was no impervious layer which created a saturated zone. The drainage tile, in this case, did not collect any significant amoutn of drainage water for analysis. In the experimental plot, a constant water level in the sump was maintained to form the reducing zone in the soil. Drainage water samples could not be routinely obtained. Instead, porous ceramic cups were planted to withdraw soil solution on a routine basis for analysis. These water samples were used to approximate the quality of water that is moving toward the drainage tile. The amount of drainage water was recorded by a flow meter on the sump pump and the drainage rate varied from 68 gallons per day to 2.3 gallons per day, with a daily average of 12 gallons. This amounted to approximately 2% of the water applied.

At the start of the first growing season, water samples were first collected when wastewater was not applied and this artificial reduction zone was not formed. Information obtained from these samples was then compared with the data obtained when treatment was applied (Table 8). Before the treatment was applied, large amounts of salts were flushed out of the soil profile by drainage water but nitrate was hardly reduced. After the treatment, nitrate in soil water was reduced considerably. The

Table 8. Quality of tile drainage from experimental plot.

| Treatment* | Electrical Conductance (mmho/cm) | Nitrogen | | | Chloride (meq/l) | $Ca^{++}$ (meq/l) | $Na^{+}$ (meq/l) | Chemical Oxygen Demand (mg/l) |
|---|---|---|---|---|---|---|---|---|
| | | $NH_4^-$-N | $NO_3^-$-N | Kjeldahl-N | | | | |
| Before treatment | 3.31 | 1.4 | 207.0 | 3.68 | 12.0 | -- | -- | 135.6 |
| After treatment | 3.27 | 4.4 | 31.0 | 14.9 | 11.8 | 11.5 | 11.5 | 142.4 |
| After treatment and irrigation with wastewater | 3.96 | 1.4 | 36.4 | 6.1 | 13.2 | 9.5 | 9.5 | 222.1 |

* Treatment indicated a saturated zone above impervious layer was maintained by maintaining a constant water level at the sump.

chemical oxygen demand of the water was used as an index to the availability of organic carbon which is the energy substrate for bacteria denitrification. The quality of water applied did not seem to have a significant effect on the drainage water quality.

From the second season on, the strategy of monitoring water quality was modified. Additional porous cups were installed at the 6" and 15" depths in the experimental plot and at various depths of the check plot so the change of water quaality as it moved through the soil profile could be determined. However, no significant amount of water has been recovered beyond the 18" level in the check plot. Results similar to those of the first growing season were obtained (Table 9). As the water moved downward, organic matter is gradually diminished as indicated by the declining COD in the water. The most apparent difference in the soil water moving through these two plots was in the amount of nitrate it contained. The impervious layer in the experimental plot has created a reducing zone that effectively reduced nitrate in the leaching zone. However, the reducing zone apparently was too close to the soil surface that created an unfavorable soil condition for crop growth.

## Phosphorus Availability

A rather large amount of phosphorous was added into the plots used for this experiment each year. Phosphate was not present in significant amounts in soil solution or in soil saturation extract. Because of rather poor crop yield, phosphorous was not removed in large quantity by crops. An attempt was then made to determine the fate of phosphorous in soils after waste disposal by analyzing total phosphorous, organic

Table 9. Quality of soil water during crop growing seasons.

| Treatment | Depth | Electrical Conductance (mmho/cm) | Nitrogen | | | Chloride (meq/l) | Ca (meq/l) | Na (meq/l) | Chemical Oxygen Demand (mg/l) |
|---|---|---|---|---|---|---|---|---|---|
| | | | NH -N | NO -N | Kjeldahl-N | | | | |
| | | | DURING SECOND CROP | | | | | | |
| Check | 6 | 6.3 | 4.9 | 50.9 | 50.5 | 13.0 | 6.3 | 24.0 | 1896 |
| Check | 18 | 5.4 | 10.2 | 122.3 | 28.0 | 9.4 | 15.6 | 20.5 | 661 |
| Experimental | 15 | 6.7 | 5.4 | 16.1 | 29.7 | 10.0 | 8.5 | 19.9 | 942 |
| Experimental | 30 | 4.4 | 4.1 | 16.6 | 13.2 | 7.2 | 10.7 | 13.9 | 403 |
| | | | DURING THIRD CROP | | | | | | |
| Check | 6 | 8.0 | 5.8 | 42.5 | 28.5 | 9.6 | 25.1 | 37.4 | 1668 |
| Check | 18 | 5.6 | 4.1 | 138.9 | 27.1 | 5.4 | 18.5 | 21.4 | 803 |
| Experimental | 15 | 8.5 | 6.8 | 28.5 | 58.1 | 13.4 | 27.2 | 41.4 | 778 |
| Experimental | 30 | 4.1 | 3.6 | 5.1 | 18.4 | 8.2 | 7.1 | 17.5 | 501 |
| | | | DURING FOURTH CROP | | | | | | |
| Check | 6 | 9.8 | -- | 30.3 | 59.2 | 16.9 | 37.8 | 50.2 | 1341 |
| Check | 18 | 4.9 | -- | 120.0 | 37.0 | 6.1 | 15.5 | 17.9 | 821 |
| Experimental | 15 | 8.7 | -- | 10.22 | 27.9 | 12.1 | 29.16 | 42.3 | 719 |
| Experimental | 30 | 3.6 | -- | 4.9 | 12.3 | 5.2 | 5.8 | 16.15 | 358 |

Table 10. Increase of total phosphorous in soil due to dairy waste disposal.

| Soil Depth (inches | Total phosphorous (ppm in dry soil) | | | | |
|---|---|---|---|---|---|
| | Before waste disposal | After 1st disposal | After 2nd disposal | After 3rd disposal | After 4th disposal |
| 0-12 | 363 | 350 | 579 | 766 | 986 |
| 12-24 | 332 | 467 | 473 | 416 | 556 |
| 24-36 | 349 | 350 | 430 | 418 | 574 |
| 36-48 | 480 | 375 | 450 | 461 | 600 |
| 48-60 | 431 | 313 | 520 | 318 | 633 |

phosphorous and available phosphorous. The results shown in Table 10 indicate that the total phosphorus of the soil profile gradually increased with repeated application of dairy wastes. The increase, however, was immobilized and was not extractable by water. Besides the increase of total phosphorous in the surface soil (0-36"), the most apparent effect of dairy waste disposal on land was the increase of available phosphorous (bicarbonate extractable phosphorous) which would make phosphorous more readily available to plants (Table 11). This undoubtedly would increase the potential of phosphate leaching in to deeper soil strata.

Table 11. Increase of available phosphorus in soil due to dairy waste disposal (% of total phosphorus).

| Location | Background | Sampling After | | | |
|---|---|---|---|---|---|
| | | 1st season | 2nd season | 3rd season | 4th season |
| Check plot | 2.49 | 5.97 | 10.25 | 11.94 | 13.59 |
| Experimental plot | 2.49 | 4.22 | 9.49 | 10.57 | 12.18 |

REFERENCES

1. Adriano, D. C., A. C. Chang, P. F. Pratt and R. Sharpless. 1973. Effect of soil application of dairy manure on germination and emergence of some selected crops. J. Envrion. Qual. 2(3):396-399.

2. Adriano, D. C., P. F. Pratt and S. E. Bishop. 1971. Fate of inorganic forms of N and salt from land disposed manure from dairies. Proc. Intl. Symp. Livestock Waste. Amer. Soc. Agr. Eng., St. Joseph, Mich. pp. 243-246.

3. Albert A. Webb Associates. 1974. Dairy waste management. Task Order No. XIV(S)-1 report submitted to Santa Ana Watershed Planning Agency. Riverside, CA.

4. Chapman, H. D. and P. F. Pratt. 1961. Methods of Analysis for Soils, Plants and Waters. University of California, Division of Agricultural Sciences.

5. Oliver, J. C., and S. E. Bishop. 1968. Dairying in San Bernadino and Riverside Counties. University of California, Agricultural Extension Service.

6. Rible, J. M. 1972. Personal communication.

7. Standard Methods for the Examination of Water and Wastewater. 13th Ed. Amer. Public Health Assoc. 1971.