Deep drilling of soil profiles in the Chino-Corona dairy area, which has an estimated average NO₃ concentration of about 315 ppm (70 ppm NO₂-N) in drainage water underneath croplands and pastures. Predictions for the NO₃ concentration in the drainage water in the unsaturated zone for this disposal rate agree with this determined value. The disposal rate should be lowered to about three to four cows per disposal acre to have an acceptable NO₃ load in the drainage water.

These manure disposal tests were begun in November, 1969, with the drilling of 15 deep holes in the Chino-Corona dairy area, about midway between Los Angeles and Riverside. The tests included two control or undisturbed sites with no manure or irrigation water applied; six acres of irrigated cropland which were disposal sites for barnyard manure, or liquid manure, or both; five irrigated pasture sites where wastes from milking operations were disposed of; and two corral sites where manures were generally scraped twice yearly and discharged to croplands or pastures. Drilling to the water table was done with a power-driven auger.

Additional sites were drilled to the 19-ft depths with hand augers in January 1971 to make a total of nine sites for each category outlined above. Soil samples from these holes were collected and analyzed for ammonium-nitrogen (NH₄-N), nitrate-nitrogen (NO₂-N), and nitrate-nitrogen (NO₃-N). At the same time, waters from the water tables (shallow wells) were sampled for NO₃ and total salt analysis. For comparison, waters from adjacent domestic wells (deep wells) were also collected and analyzed.

**Protein N**

The barnyard manure contained about 2% total N at the time of application to croplands—mostly in organic form (example: protein-N). During farming operations, the manure is plowed under or disked in. Through microbiological transformations, the organic N is converted to NH₄, then to NO₂, and then to NO₃. This process is favored by aerobic conditions. Crops recycle N by absorbing NO₃ or NH₄ and converting it to proteins in plant tissues. However, some NO₃ escapes the root zone with drainage water and may eventually reach the water table. Under anaerobic conditions, soil NO₃ can be microbiologically denitrified to N₂ or N₂O gaseous forms and thus escape to the atmosphere. This process has been shown to be primarily responsible for low NO₃ contents of shallow groundwaters in Imperial Valley. Thus, denitrification may find a new role in the abatement of groundwater contamination with NO₃, if it can occur below the root zone during growing periods.

Nitrate concentration in groundwater is of concern, since high NO₃ is a health hazard if ingested via drinking water. The U.S. Public Health Service has set a standard of 45 parts per million NO₃ (or 10 parts per million as NO₃-N) as the maximum NO₃ content of water for safe drinking. High NO₃ in water, as well as in feeds, has been reported to reduce milk production and in some cases cause abortion in dairy cows.
This dairy area has about 365 dairies totaling nearly 125,000 cows scattered mostly north of the Santa Ana River in an area of about 26 square miles—one of the highest concentrations of dairies in the world.

**Two counties**

Riverside and San Bernardino counties (in contrast) have a total dairy cow population of about 48,000 and 99,000 respectively. Thus, with about 85% of all the dairy cows in these two counties confined in a small area, and with most of the animal waste going on irrigated land, some concern for the groundwater quality in this area is justified.

Graphs 1 and 2 show the NH₃-N and NO₃-N concentrations in the 0- to 31-ft profiles of the sites investigated. Results from below 31 ft are not presented since fewer holes were drilled beyond this depth. Ammonium-N and NO₃-N were...
particularly high in the 0- to 2-ft depths under corrals. Although there were no marked differences in NH₃-N in concentrations in deeper layers, the average concentrations of NH₄-N in profiles under croplands, pastures and corrals were considerably higher than under the controls (graph 1). The NO₃-N load of the profile is presented in graph 3. Only two sites from each category were presented.

For the croplands and pastures, the lowest (sites 3 and 14) and highest (sites 4 and 12) NO₃ concentrations in groundwater were presented. The average (two sites each) NO₃-N concentration was highest under the corrals, followed by the pastures, then the croplands and the controls had the lowest. The NO₃-N concentration in corrals was about three times higher than that under croplands. However, on an areal basis, the croplands would probably contribute more NO₃ to the groundwater than corrals since the cropland area is about 13 times larger than the corral area.

The NO₃ concentrations in waters sampled from the shallow wells and deep wells are shown in graph 4. The NO₃ in shallow wells under pastures ranged from 151 to 930 parts per million, whereas the NO₃ under croplands ranged from 62 to 359 parts per million. In contrast, waters sampled from deep wells had considerably lower NO₃ contents as compared with those sampled in shallow wells, and no NO₃ concentration in deep well waters exceeded the PHS standard of 45 parts per million NO₃. Total salt concentrations were also generally higher in shallow well waters than in deep well waters. Thus, the present practice of diary manure disposal to croplands and pastures is potentially hazardous to groundwater with acceptable NO₃ contents. Shallow wells near corrals and other heavily manured areas could be contaminated with NO₃. A real problem with NO₃ can arise if the profile is sandy.

Disposal rates

Data presented in the table show the method used to predict the NO₃ concentration in the water leaving the root zone of pastures and croplands. Data in the first column show the disposal rate in terms of cows per acre. The total N excreted was based on a daily excretion by a cow of 0.40 lbs N. Assuming 50% of the total N excreted was lost by volatilization of NH₃, only half was available for incorporation into the soil. The amount recycled in crops was estimated from graph 5, based on knowledge of the forage crops and farm management in the area. Likewise, excess N values were estimated from graph 5. The concentration of NO₃ in the unsaturated zone was calculated from simple dilution assuming a drainage volume of 15 surface inches per year, which corresponds to a leaching fraction of about 0.30 (usual for successful irrigation projects). The 35% loss represents the fraction of the excess N that is either lost by denitrification or by becoming a part of the organic N pool in the surface layers. The estimates with low degree of accuracy are the drainage volume, NH₃ volatilization loss, and denitrification loss.

The average cow population in the area is about 10 cows per disposal acre and at this disposal rate and at 35% loss, about 327 ppm NO₃ in the water of the unsaturated zone is predicted. This is in close agreement with the average value of about 315 ppm NO₃ found in the water at a 10- to 19-ft depth underneath croplands and pastures. From these data it is predicted that the disposal rate must be about three to four cows per acre per year to obtain a NO₃ level of less than 45 ppm in the drainage water.

Research needs

The manure disposal problem in the Chino-Corona area is aggravated by (1) high costs of land; (2) the grouping together of many dairies to increase the efficiency of production, which favors even higher concentrations of cows than presently exists; and (3) manure trucking costs which make disposal of wastes on lands outside of the dairy area economically unattractive. If high rates of manure disposal within the dairy area are to continue, research is needed on (1) recycling of N and other nutrients under the local conditions so that proper limits can be placed on the rate of disposal of manure under present handling and disposal practices; and (2) modification of the product to remove salts and N so that rates of disposal can be increased without adverse effects on water quality. Research is also needed on alternatives to land disposal of manures.

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A progress report...