Disposal of Industrial Wastes by Irrigation

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RESPONSIBLE officials are interested in a waste disposal or treatment facility that is economical to build and operate, requires little attention, and still does a satisfactory job. Disposal by irrigation meets these specifications for some industrial wastes, and it has attracted a great deal of interest recently. Irrigation as a means of disposal is not new; this method was used extensively on sewage farms beginning in the 1860's and 1870's.

The two principal methods of using irrigation to dispose of waste water on the land are ridge and furrow irrigation and spray irrigation. In the ridge and furrow method, wastes are disposed of in furrowed plots. Early systems used a single or a few furrows, and the wastes were directed manually to another furrow when one was full, a technique that can also be used with contour furrows on sloping land. On relatively flat land, two or more plots are usually developed.

Wastes are discharged to a main or header ditch, which may be in the center of the plot or at the side, and then flow into the furrows which are nearly level but at a higher elevation. Furrows are 3 to 15 feet apart, 1 to 3 feet deep, and 1 to 3 feet wide. When wastes in one section build up to about 6 inches from the ridge tops, a control gate can be set for overflow into another area. Control gates can also be used to take an area out of service for maintenance or to rest the land.

Compared with spray irrigation, ridge and furrow systems have a higher original cost and a lower operating cost, and can handle higher volumetric loadings. They have no problems caused by freezing during cold weather. But they are more likely to develop into a nuisance and may require additional land to get farther away from factories, dwellings, or public roads. Because land irrigated in this manner is difficult to crop, grasses are frequently left uncut, but noxious weeds must be destroyed.

Disposal by spray irrigation is a recent development in this country. The first installation of this type appears to have started operating in 1947. Only a few had been installed prior to 1950, but since that time use of this method has mushroomed. Wastes are sprayed onto the land, usually through revolving nozzles. Lightweight metal or plastic pipe is frequently used to convey wastes from a wet well or holding pit to the disposal field. Pipe sections can be moved easily to change spray areas, and, in some cases, extra piping and a valving arrangement can divert wastes to different locations.

The land does not require special preparation and moderate slopes can be tolerated. Woodland, brush areas, pastures, and cropland have been used successfully for waste disposal. Generally, it has been easier to obtain land for spray irrigation than for ridge and furrow systems. In a few cases, industry has been given use of land in exchange for the wastes and their possible fertilizer and moisture

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value. Spray-irrigated grasslands are sometimes cropped. The biggest disadvantage of spray irrigation is the difficulty of operation during freezing weather. Some factories which dispose of wastes daily use spray irrigation during warm weather and ridge and furrow or other methods in the colder months.

Dairy Wastes

Dairies, many of them in rural areas and small villages close to the milk supply, are the source of the industrial waste most prevalent in Wisconsin. In June 1956, the State had a total of 1,625 factories engaged in the processing of milk and allied products from a yearly farm production of 16 billion pounds.

These factories create a variety of wastes, depending on the type of operations, the inclusion of concentrated wastes, and whether or not all or part of their cooling water is used in irrigation. The wastes may have a biochemical oxygen demand (BOD) ranging from less than 200 ppm for receiving station wastes to 15,000 ppm for a cheese factory discharging excess whey along with wash water wastes.

In 1954 the Mindoro Cooperative Creamery in western Wisconsin began operation of a ridge and furrow system with pumping facilities. Its irrigation area of about 3 acres is divided into 3 plots which are underlaid with 2 lines of drain tile. Cost of the completed system, including $2,000 for land and $2,000 for pumping facilities, was approximately $8,000. This system accomplished a high degree of treatment; the BOD increase in the receiving stream is only 0.1 ppm, compared with 41.6 and 26.0 ppm before ridge and furrow facilities were installed.

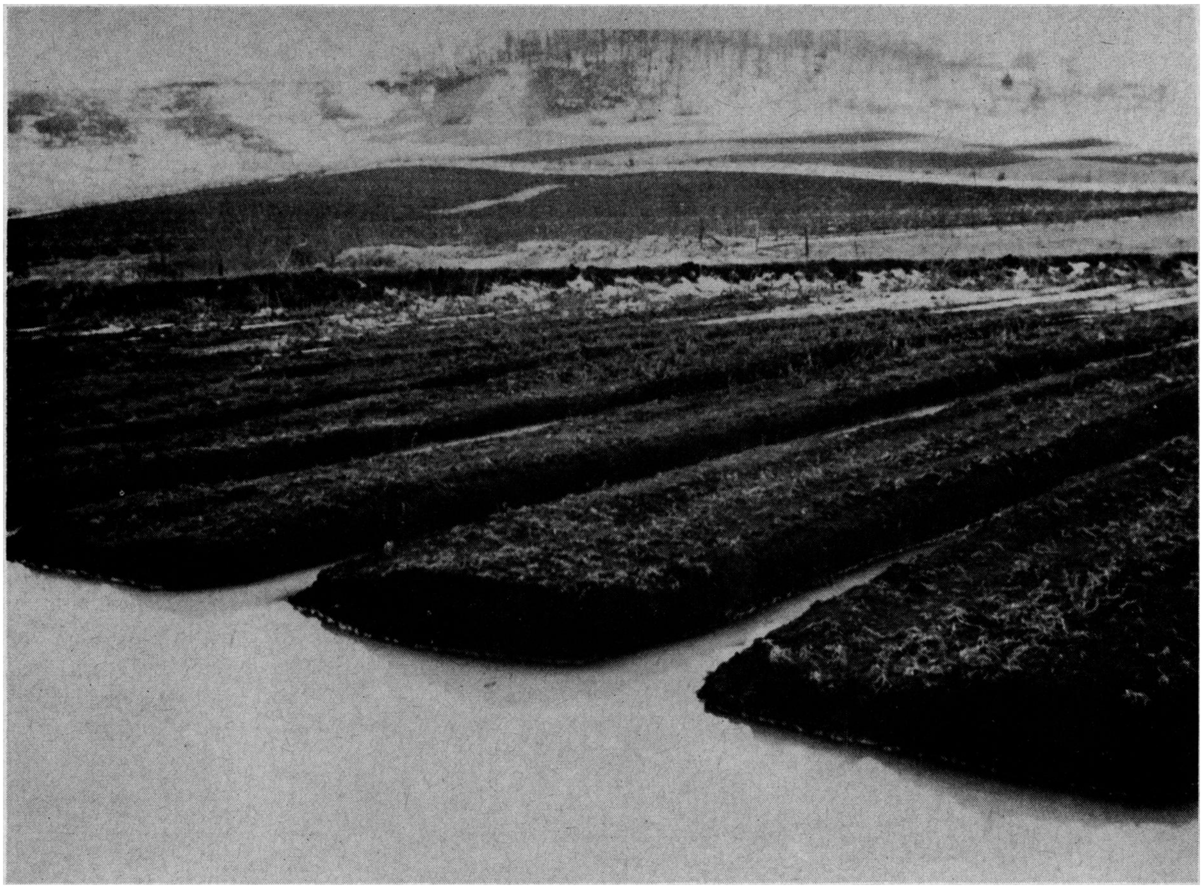
About 20 other Wisconsin milk plants, mainly creameries, now have ridge and furrow systems. Minimum rates of waste disposal vary from less than 3,000 to more than 32,000 gallons per acre per day (gpad). Original costs ranged from $300, for a small factory where 3 furrows were dug and gravity flow was used, to approximately $25,000, for a large plant where the disposal field required extensive leveling.

A nuisance is more likely to develop in warm weather when a ridge and furrow system is used for wastes with high BOD concentration; therefore, cheese factories have been encouraged to adopt spray irrigation. Occasional excess whey apparently can be handled without difficulty, but operators are cautioned about overloading systems with whey. Milk wastes have little gross solids in them, and elaborate screening is not required. The systems usually need a small basket screen or bucket with holes under the holding tank influent line to collect bits of curd, steel wool, brush bristles, and matchsticks, thus keeping them out of the nozzles. Scum and sludge will develop and accumulate in the holding tank, but this can be prevented by tapping off a ⅜-inch or ½-inch line beyond the pump, and returning some flow to the tank to agitate its contents.

Wisconsin now has about 30 milk plants using spray irrigation. Original cost, excluding land, ranged from $300, for a small factory whose operators used old equipment and did most of the construction work, to $5,000. Some disposal rates average only 2,000 gpad in extremely heavy soils while in favorable soils, rates of 10,000 to 15,000 gpad are sometimes achieved.

Six plants, mostly cheese factories in southern Wisconsin, continue spray irrigation during the winter. To prevent freezing in their systems these plants use a holding tank large enough to store 1 day's waste, a well-insulated pump and motor, and a heat lamp. The pump is started around noon, generally the warmest time of the day, and runs continuously for about 2 hours until the end of the work day. Pipes are supported on posts and slope back to the wet well. An icecap up to 2 feet thick may develop around the sprays. Most of the vegetation under the ice is permanently killed off, and these spots must be reseeded in the spring.

Waste temperatures of 90° to 100° F., an advantage for winter spraying, have been found at some of the cheese plants. A whey processing plant whose wastes at 135° F. killed vegetation solved this difficulty by extending the discharge to 10 feet above the ground and using a finer spray nozzle. Whey condensate at one plant caused corrosion of the aluminum pipe, which was replaced with copper tubing.



Ridge and furrow irrigation system serving a milk plant. Furrows lead away from the main, or header, ditch in the foreground.

Spray irrigation during the warmer months has vastly improved conditions around some milk plants where wastes previously were a nuisance. One operator felt the change was worth $1,500 to him. In small communities near a resort area or a summer military camp where a milk plant contributes a significant part of the normal municipal waste, it may be easier and cheaper to irrigate the milk wastes than to enlarge sewerage facilities for the larger summer population.

Vegetable Processing Wastes

A 1913 report by the Water Survey of Illinois, mentioned in a 1939 bulletin, Methods of Treating Cannery Wastes (*1*), indicates that irrigation of pea and corn wastes in a large field gave best results. At the 1947 Purdue Industrial Waste Conference, Bolton (*2*) discussed Iowa canning plants which had started using ridge and furrow disposal 13 years earlier. In 1934 Iowa had 10 such installations for

The milk plant's system, photographed from the same point, after grass became established.

disposal of cannery wastes. He described the operations at the Hampton and Waverly plants in detail, since they had been functioning for several years. The Hampton cannery had a BOD loading of about one-ninth that of Waverly's, or 230 pounds of BOD per acre per day compared with 2,030 pounds of BOD per acre per day, although volumetric loadings for both averaged about 50,000 gpad.

Monson (*3*) reported that the Green Giant factory at Watertown, Minn., disposed of an average of 4.3 inches per day, or 116,000 gpad, on a ridge and furrow field. Generally, application rates for such systems range from about 5,000 to more than 100,000 gpad.

Canning operations are usually conducted during the summer when infiltration and evapotranspiration are highest. To my knowledge, no canneries in Wisconsin have used ridge and furrow irrigation exclusively for waste water disposal. However, in 1954 the California Packing Co. at Arlington used ridge and furrow for temporary disposal of wastes when its lagoon became full, and several pea viner stations have handled their stack juices by this method.

Spray irrigation of wastes from canning plants has become popular. There were no such installations in Wisconsin until 1951, when 11 were installed; by 1955, there were 40, representing 30 percent of the State's canning plants. The results, on the whole, have been gratifying, and many chronic pollution situations have been eliminated. The factories are requested to provide duplicate or standby pumping facilities, have thorough screening, and operate the system without ponding or runoff. When these conditions are met at an approved site, there is little danger of pollution or a nuisance.

Poultry and Tannery Wastes

A poultry processing establishment of Vallo-Will Farms, Inc., near Lake Geneva, Wis., treated its wastes, approximately 120,000 gpd with 220 pounds of BOD, in a high-rate trickling filter which accomplished an 80 percent BOD removal. This treatment was inadequate for the small receiving stream, and complaints were frequent. The effluent was chlorinated in 1954, and spray irrigation was started during the nonfreezing months. These measures eliminated discharge to the stream and also most of the complaints.

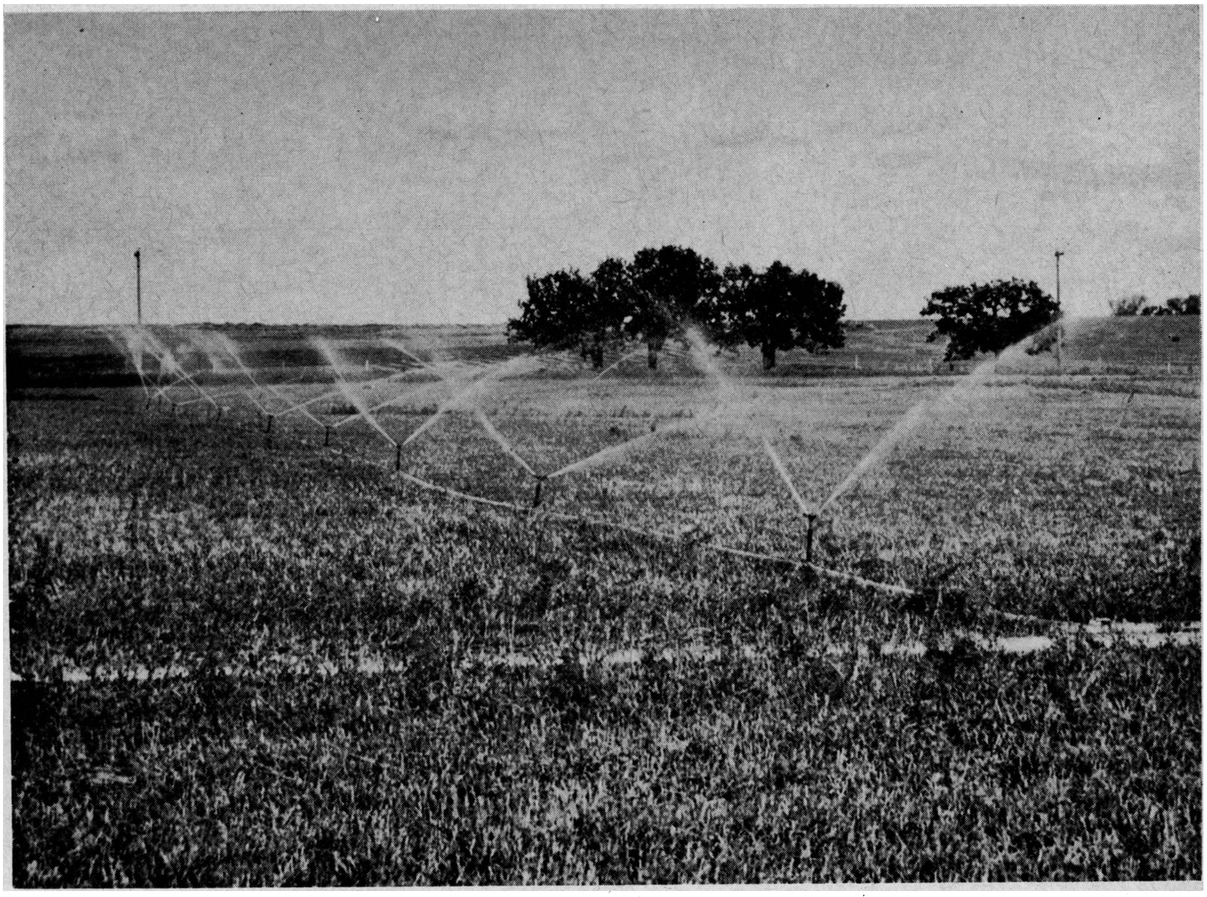
A ridge and furrow system was installed in the summer of 1957 when Edward Alf and Son of Endeavor, Wis., began operating a chicken processing plant. Two adjoining plots with a combined area of 1.05 acres and underdrained by two lines of 6-inch drain tiles were used. A "sparkling" effluent was noticed upon occasional observation, although wastes in the ditches and furrows are quite red. As yet, a detailed survey of the system has not been conducted. However, the waste volume amounts to an estimated 60,000 gpd on the 4 days a week the plant operates. A single grab sample from the drain tile in November 1957 had a BOD of 5.5 ppm. Solids, particularly feathers, are beginning to accumulate and improved screening is needed. An additional area of sandy soil is available for expansion.

A tanning plant which uses vegetable dyes in Pennsylvania spray irrigates wastes during critical stream periods from mid-May to late November (*4*). Wastes amount to 425,000 gpd and have a BOD of 2,300 ppm associated with a total solids concentration of 10,550 ppm. A 1,200-gpm pump, powered by a 150-hp diesel engine, applies the screened raw wastes to the land over a 6- to 7-hour period. Fifteen acres of land, whose soil consists of about 4 feet of sand over gravel, is used for disposal. Grasses were killed off originally, but in areas which are not sprayed for a time, vegetation grows profusely. A sludge layer accumulates and the plot is disk-harrowed every 3 weeks. Apparently no odor has been associated with spray irrigation of these wastes.

Pulp Wastes

Several Wisconsin pulping mills have experimented with and used irrigation to dispose of spent sulfite liquor. Approximately a ton of solids is dissolved from the wood for each ton of pulp produced. A 100-ton mill produces 200,000 gallons per day of this liquor, which has a BOD of 28,000 to 40,000 mg. per liter.

Studies of soil filtration were conducted by



Spray irrigation system in operation. Revolving nozzles are in a line perpendicular to the main line which crosses the foreground.

the Sulphite Pulp Manufacturers' Research League and reported by Wisniewski and associates (*5*). Ten-foot columns of mixtures of various media were used for experimental purposes, and different filtration rates were applied. Generally, BOD removal varied with the loading rates from a high of 95 percent, when 0.18 pound of solids was applied daily per square yard, to a low of 10 percent, with 12.3 pounds of solids. A field trial was made at a spray irrigation system, and removals of 40 percent were experienced with mean temperatures above freezing. During very cold weather the removal dropped almost to zero. In warm spring weather the BOD removal returned to about 30 percent.

In their report, the authors suggested consideration of the following principles of design and operation: (*a*) the effectiveness of microbiological reactions of the soil is greatly reduced if loadings of unstabilized organic matter exceed the rate of complete reaction; (*b*) the amount of water fed to the soil must be so controlled as to avoid sustained periods of flooding and the anaerobic conditions which result from flooding; and (*c*) geologic conditions must be such as to avoid the possibility of contamination of ground water supplies.

The Flambeau Paper Co. at Park Falls began using the irrigation method of disposal for some of its wastes in 1954. During critical stream conditions spent sulfite liquor is hauled out to a 40-acre disposal area by truck. The trucks dump along the road, constructed on a ridge in the area, which is wooded and has rock outcroppings. A bulldozer is used to construct absorption ditches. An aerial survey showed that about 40 percent of the trees were killed.

This pulp mill also spray irrigates some of its wastes on a 2-acre island which has a bark and sawdust fill. The system has been able to apply the wastes satisfactorily through the winter but with a marked reduction in effectiveness.

The Kimberly-Clark mill at Niagara disposes of up to 250,000 gpd of spent sulfite liquor to a plot of sandy soil over rock. A pump, mounted on a trailer, is towed behind a truck and fogs the wastes out to a distance of 40 feet along each side of the road at a rate of less than three-fourths of a pound of solids per square yard. Four miles of road have been constructed to carry out the disposal of wastes in this manner.

Irrigation treatment of pulping wastes is poor compared with the treatment of wastes from food processing industries, and there is also danger of the sulfite liquor concentrating in underground pockets and polluting ground water supplies for extended periods. For these reasons irrigation of pulp wastes is considered only a temporary means of disposal.

Meat Packing Wastes

Oscar Mayer and Co., Madison, Wis., began experimenting with irrigation disposal of wastes in 1951 and started field disposal in 1953. Wastes are pretreated to remove grit, paunch manure, and grease, then subjected to flocculation and sedimentation. Secondary treatment, accomplished through trickling filters and sedimentation, is provided before discharge either to the Madison Metropolitan Sewerage District or to the irrigation fields.

The plant has 200 acres of land available for irrigation. In 1954, 17 percent of its wastes were disposed of by irrigation, with an application rate during the irrigation period of 10,000 gpad. The largest daily waste quantity that has been irrigated is 2,900,000 gallons. Quantities may vary considerably from day to day depending on such factors as rainfall and cropping. Wastes were spray irrigated until 2 years ago when the practice was discontinued because of complaints about odor by residents of an area near the disposal field. But it was not shown that the complaints were justified. Since that time, disposal on land has been mostly by flood irrigation. Mosquitoes caused the most trouble in 1957, and the best method of control was to dry out the various disposal areas at least every 6 days. Diking and careful operation are required so that wastes do not overflow.

Because wastes containing nutrients for algae must be kept out of the Madison lakes, irrigation is carried on only during the growing season, from mid-April to early November, when vegetation utilizes the fertilizer constituents of the wastes. The high sodium concentration of the wastes, about three times the maximum acceptable for irrigation, may eventually cause a soil problem if this concentration is not reduced.

The purposes of the plant's system are to reduce the sewer service charges and to demonstrate the use of a waste effluent for land irrigation. Because the campus of the University of Wisconsin in Madison is nearby, the project has received close study from its inception, and information about it has been published (7). Undoubtedly further findings will also be made available.

Evapotranspiration

What happens to an irrigated waste? Part is evaporated, some may be transpired, and the remainder is filtered away into the ground. A relatively small amount of mineral matter is used by the vegetation, but only water is transpired and evaporated so that the soil solution will contain higher quantities of solids than were present in the original waste water. The rate of evaporation of the liquid depends on temperature, humidity, and the area exposed, while the rate of transpiration depends mainly on leaf area, humidity at plant level, amount of solar energy, and available moisture. Under field conditions it is difficult to consider separately the water consumed by evaporation and that by transpiration, and the two are frequently lumped together as evapotranspiration, or consumptive use. The maximum consumptive rate for water is about 0.3 inch per day, or slightly more than 8,000 gpad during the hot, dry months. This rate is affected little by the type of forage crop. Normal evapotranspiration is 3,500 to 7,000 gpad.

Vegetation, by transmitting water and keeping the soil loose, is important to the success of a disposal system. Reed canary is probably by far the grass best suited for ridge and furrow irrigation plots in Wisconsin. It is a permanent grass and a heavy producer, has a substantial root structure, and endures water and ice sheet coverage very well. A seeding rate of

8 to 10 pounds per acre with the seed not covered too deeply is recommended. Brome grass and Kentucky bluegrass are probably next best suited, but they do not endure water and ice coverage as well. Some systems have developed good growths by seeding a mixture of these grasses. Trees and brush also do a good job of water transmission at some locations.

Pulp and tannery wastes from some plants have killed the vegetation originally present. The pH, temperature, or waste constituents may not have been suitable. Also, aeration in the root zone is considered essential for most vegetation. Hydrogen sulfide and nitrites are toxic to plant roots, and these compounds can be formed by waste decomposition when sufficient oxygen is not available. Occasional flooding can be tolerated, and flooding can be more frequent when plant life is dormant.

Opinions and findings as to what constitutes a suitable irrigation water vary greatly. Soil, drainage, crops, and climate are among the determining factors. Sandy and gravelly soils that are well drained can tolerate much higher concentrations than clay and poorly drained soils. Irrigation water is considered for total salts and the ionic concentration as shown by the water's specific conductivity; quantity of sodium and its ratio to other cations; amount of bicarbonate; and concentrations of boron, chloride, and sulfate.

Infiltration

Excluding the runoff, excess moisture can only percolate or infiltrate the soil at some periods. Evaporation and transpiration cease at times, and precipitation, in addition to waste waters, must also be handled.

According to Musgrave (*6*) the major factors that affect the intake of water by soil are surface condition and amount of protection against the impact of rain; internal characteristics of the soil mass, including pore size, depth, or thickness of the permeable portion, degree of swelling of clay and colloids, content of organic matter, and degree of aggregation; moisture content and degree of saturation; duration of rainfall or application of water; and season of the year and temperature of soil and water.

Musgrave also stated that, in the same soil, intake rates were higher when irrigation was applied by flooding than they were from artificial rainfall; infiltration rates increased progressively from bare ground to row and cover crops; infiltration rates increased progressively for more than 20 years after a soil was taken out of cultivation; seepage was better when the soil was protected by mulch, burlap, or grass from surface compaction by raindrops; rates were better when wheat stubble was left than when the area had been burned off; and infiltration rates increased with temperature.

In a 72-hour continuing test with varying water and soil temperatures, the infiltration rate varied diurnally with the temperature from 0.18 inch per hour at 35° F. to 0.54 inch per hour at 70° F. Nearly an exact correlation was found between infiltration and viscosity. Musgrave also included a tabulation of more than 100 soil types tentatively arranged according to their minimum infiltration rates.

Treatment and Drainage

Waste is purified by micro-organisms as it filters through the soil. General principles of filtration indicate that progressively higher BOD reductions, within limitations, are achieved by finer filtering materials, lower rates, and warmer temperatures. Although much progress has been made in sewage treatment, we still have nothing that can produce a better effluent than the intermittent sand filter. The theory of sand filter operation indicates that the best results are achieved by giving the filtering media a chance for aeration.

Vegetation and drain tile should help maintain aeration of the soil, but intermittent operation may be advisable at times. A nearly complete removal of suspended solids and a large reduction in bacteria will be achieved by percolation through the soil pores. In addition to the treatment the wastes receive, irrigation usually acts as an effective flow equalization unit in distributing percolate flow and strength over 24 hours rather than the 6 to 8 hours per day that small factories operate, and stream improvement is greater than the degree of treatment indicates.

If a system is operating satisfactorily and has been properly located, there should be little danger of contaminating wells unless the disposal field is in an area with creviced limestone near the surface of the ground or unless the waste contains sulfite liquor. This type of waste is acidic and concentrated, responds slowly to biological treatment, and can cause pollution over a long distance and time.

Some soils are naturally well drained, and, in others, drain tile can frequently be used to advantage. Drainage not only permits higher volumetric loadings but removes concentrated salt solutions and, through soil re-aeration favors the treatment processes involved in waste stabilization.

Care must be exercised in using drain tile. Difficulty from earlier drain tiling occurred at some dairy and cannery spray irrigation fields. Short circuiting due to shallow depth or broken tile and the effects of strong wastes must be watched. A minimum tile depth is 2½ feet; vegetation growths increase with drain tile to depths of 3 or 4 feet. The water table between the tile lines will be arced, but even on tight soils it is doubtful if a distance of less than 20 feet between lines is warranted.

An open ditch or a nearby stream with a water level several feet lower than the furrows helps drainage. An irrigation system might be laid out parallel to the bank or on the inside loop of a meandering stream to insure good drainage.

Conclusions

In general, waste irrigation has accomplished a good degree of treatment at low cost. Adverse effects have occurred in only a few cases. Waste irrigation is not a cure-all but rather should be considered as another method of treatment that can be used when conditions are suitable.

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Epidemiology Course for Nurses

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