will not result from applying wastes to the land.

The future will demand that the Nation adequately use agricultural wastes since they are a valuable part of our national resources.

Water Quality and Farming

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NEEDED increase in agricultural production by the year 2000 will require greater use of fertilizers and pesticides. But these materials and others of agricultural origin can pollute our water supplies. Much research is now being done to determine the extent of pollution from intensive agriculture and to devise ways of controlling it.

Natural waters contain many substances that affect water quality. These include nutrients essential for plant and animal life in lakes and streams. Other substances can enter water from municipal, industrial, agricultural, or natural sources.

For most purposes, absolutely pure water is not desired. Low concentrations of many salts can be tolerated in drinking water, but poisonous metals and pathogenic bacteria obviously cannot. Water used for recreational fishing must maintain the proper temperature range and supply enough oxygen and nutrients to support the growth of desirable fish. But too much nutrient can cause excessive growth of algae.

Farmers are directly affected by the quality of water available for crop and livestock production. In 1970, more than 130 million acre-feet of water was used for irrigation in the United States. (One acre-foot of water is enough to cover an acre of land a foot deep.) Another 2 million acre-feet was used for watering livestock. By 2000, these requirements will increase to nearly 170 million acre-feet for irrigation and around 4 million acre-feet for watering livestock, according to the U.S. Water Resources Council.

Agricultural use in 1965 amounted to nearly 10 percent of the total runoff carried in rivers of the 48 contiguous States.

One would expect farming to have considerable effect on water quality because most of the land area is devoted to agriculture. Around a fourth of the U.S. land area is cropland and a third is pasture. These fractions are not expected to change much by the year 2000, but production will be more intensive on the land that is used.

Deserving special attention among the many materials that would enter water from agricultural lands are: sediment, plant nutrients, pesticides, animal wastes, and salts.

Sediment constitutes by far the greatest mass of material moved by water. Some 4 billion tons of sediment are washed into streams in the United States each year. Around a fourth of this reaches the oceans. Most plant nutrients and pesticides in water are carried on sediment.

Dr. C. H. Wadleigh, director of USDA's Soil and Water Conservation Research Division, has estimated that at least half the sediment arises from agricultural lands and another 30 percent may be considered geologic erosion. Construction sites may be important local sources of sediment. Construction activity will probably increase greatly by 2000.

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Sediment should be reduced for many reasons. It is fertile topsoil lost. It is unsightly in streams. It fills reservoirs and stream channels, sometimes resulting in disastrous floods. It necessitates filtration of water for drinking and many other purposes.

Studies have shown that soil losses from meadow or small grain fields are much lower than from cultivated row crop fields. This is because crop or crop residue cover absorbs most of the energy of raindrops before they strike the soil and also slows the velocity of water flow. Even with continuous corn cropping, soil losses have been reduced by using winter cover crops, leaving the crop residues, or plowing under manure.

Soil conservation practices have been developed for both agricultural lands and construction sites. On agricultural lands, strip cropping, contour cultivation, and terracing can be used to interrupt the flow of water across the soil surface, and thus to reduce the velocity and erosive power of water.

Construction sites should be fitted to the topography, saving trees and vegetation where possible. Graded land should be exposed in small areas and for short periods of time whenever practical. The structures should be completed and vegetation planted as soon as possible. Sediment basins can be used to catch sediment from the runoff water during development.

Sediment yields from agricultural watersheds where good conservation practices have been used have ranged from 10 to 50 percent of those without such practices. Dramatic reductions in sediment yields from construction sites have been observed, although controlled experimental studies have not been possible.

Crop or crop residue covers and soil conservation practices usually increase infiltration of rainfall and reduce the amount of runoff. While this prevents some sediment from reaching streams, it increases the movement of water-soluble, mobile substances through soils. Thus, measures taken to control sediment production may increase the likelihood of salt, nitrate, or certain pesticides entering ground water.

Plant nutrients of most significance in water quality are nitrogen and phosphorus. In the forms of nitrate and phosphate, respectively, they are readily absorbed by plants. Concentrations of nitrate and phosphate in lake water are thought to often control the growth of algae.

However, sediments usually contain much more nitrogen and phosphorus in organic forms than is found as nitrate and phosphate in the surrounding water. Phosphate is readily adsorbed (bonded onto particle surfaces) on most sediments. Organic nitrogen and phosphorus and absorbed phosphate are potential sources of nitrate and phosphate in water. All of these forms must be considered in maintaining water quality.

Eroded topsoil carries much of the nitrogen and almost all of the phosphorus that enters streams and lakes. The concentration varies greatly, but each ton of eroded topsoil probably contains from 5 to 10 pounds of phosphorus and a slightly greater amount of nitrogen. Soil conservation measures that reduce soil losses will help control this movement of nitrogen and phosphorus.

Very little phosphorus moves through the soil in solution. This is shown by accumulations of phosphorus in the surface of fertilized soils where erosion does not occur, and extremely low concentrations of phosphorus in ground water, usually less than .01 part per million.

In contrast, nitrogen moves easily through the soil as nitrate. Concentrations ranging from 1 to 10 parts per million are common in ground water.

Nitrate is produced in soils by microbial action, which is greatest in warm, moist soils. Most of this nitrate can be taken up by plants growing on the soils. However, certain late-planted crops may not develop quickly enough to use the nitrate before some of it has leached from the soil.

Increasing use of fertilizers in agriculture has been blamed as a source of water pollution. Fertilizer use has been rising rapidly and this trend is likely to continue.

About twice as much fertilizer as is currently used would be required if all crops received the applications recommended by the State agricultural experiment stations. However, the current annual addition of about 7 million tons of nitrogen in fertilizers is less than the amount of nitrogen removed in crops, estimated at 9 million tons. The amount of phosphorus added in fertilizer is now about equal to that removed in crops. Additions of both nutrients are small compared with the amounts naturally present in soils.

In view of the mobility of nitrates, efficient use of nitrogen fertilizer is important for maintaining water quality. George Stanford, a U.S. Department of Agriculture soil scientist, estimated that an acre of corn recovered 50 pounds of nitrogen from the average application of 66 pounds in Iowa in 1964. Experiments in Nebraska showed that corn recovered 25 pounds of nitrogen from a summer sidedress application of 40 pounds per acre. The percentage of recovery was lower from spring or fall applications or with higher rates of application.

Many Federal, State, and industrial experiment stations are conducting research on increasing the recovery of nitrogen fertilizers by crops.

The fate of unrecovered nitrogen is not well known. Many experiments have shown little accumulation of nitrogen in fertilized soils. A portion leaches to ground water. An unknown portion is microbially reduced to nitrogen gas by the process called "denitrification." It is then indistinguishable from nitrogen of the air.

Although field estimation of the amount of denitrification is difficult, it is apparently very effective in some situations. The concentration of nitrate nitrogen in the soil solution leaching through an irrigated soil in southern California decreased from an average of 2.4 parts per million in the top 3 feet to .7 parts per million at the 6- or 8-foot depth of the tile drains.

Pesticides are used in agriculture to control insects, plant diseases, weeds, and rodents. Improved pest control will be essential for obtaining the increased agricultural production that will be required in the year 2000. There will be a need for improved pesticides as well as alternative methods of pest control.

Many pesticides are acutely toxic to fish and wildlife, directly killing them when sufficient amounts of pesticide are absorbed. However, this does not normally happen unless there is an accidental spill of pesticide or something unusual happens to cause a concentration of pesticide in the water to reach toxic levels. Persistent pesticides may have slow, cumulative effects on the reproduction or food value of fish and wildlife even though they enter water in minute amounts.

Monitoring studies by the U.S. Department of Agriculture indicate no progressive buildup of pesticide residues in soils in farming areas where pesticides are commonly used for crop production. However, in some orchards, the soil residues of certain pesticides are relatively high.

If orchards are taken out of production, the soil should be tested for pesticide residues and caution used in selecting crops to be planted on these soils. It is important to control movement of soil particles from such areas.

Most pesticides are strongly adsorbed on soils. In addition, many of the more persistent pesticides are not very soluble in water. Movement of these pesticides in water usually results from movement of soil or sediment that has adsorbed the pesticide. Good soil conservation practices will minimize this movement.

The disposal of pesticides should be

avoided in areas where they could enter ponds, streams, or ground water.

Much current research is aimed at developing very specific, short-lived pesticides and methods of controlling pests without chemicals. Many problems of water contamination would be avoided by using short-lived pesticides which degrade before entering bodies of water. However, applications might have to be repeated many times for control of persistent pests. In addition, short-lived pesticides such as parathion are highly toxic to man and animals.

Certain herbicides are used to control aquatic weeds in ponds and irrigation ditches. Many herbicides, such as diquat, simazine, sodium arsenite, silvex, and 2,4-D, do not injure fish at the concentrations required for aquatic weed control. At higher rates they may be toxic to fish, humans, livestock, and crops.

Alternative methods of pest control under active investigation include biological controls of insects and weeds, trapping of insects, release of sterile insects, breeding of disease-resistant crop varieties, and improved cultural practices. Many of these methods avoid the use of chemicals that could contaminate water.

Chemicals have been used to sterilize insects or to attract them to traps. In these uses there is little possibility of water contamination. Mixtures of baits and pesticides have been used successfully to control the fire ant and the Mediterranean fruit fly with greatly reduced amounts of pesticide.

Animal manure may create serious water quality problems. Runoff from feedlots contains much decomposable organic matter, many bacteria (possibly including pathogens), and sometimes high concentrations of salts. Instances of poisoning of fish or cattle have occurred downstream from large feedlots.

Concentration of thousands of cattle, swine, or poultry into single production units intensified the problem of manure disposal. The expense of hauling manure from such units is appreciable, and sometimes the manure accumulates to become a potential water pollution hazard. The growing catfish feeding industry poses a similar waste disposal problem with direct effects on water quality.

Disposal of manure on land has been practiced for centuries. Its value as a soil conditioner and source of plant nutrients is generally accepted. One ton of cattle manure contains about 20 pounds of nitrogen, 5 pounds of phosphorus, and 20 pounds of potassium, as well as other plant nutrients.

But it has become much easier and cheaper to spread the same quantities of plant nutrients from a bag of commercial fertilizer.

Water pollution could occur from manure spread on the land or directly from feedlots. Spring runoff from manure spread on frozen soils is thought to contribute a major part of the agricultural nitrogen and phosphorus reaching the lakes at Madison, Wis. On the other hand, allowing organic wastes from a cannery at Paris, Tex., to trickle over sloping grassed areas removed about 95 percent of the decomposable organic matter, 90 percent of the nitrogen, and 55 percent of the phosphorus.

If manure is spread on vegetated areas with good soil conservation practices, runoff should not be a problem.

One way to minimize manure distribution costs is by spreading the maximum amount in an area. However, excessive amounts may interfere with crop production. Studies at Bushland, Tex., show that good corn and sorghum yields are maintained when as much as 60 tons of feedlot manure is applied per acre. When 120 tons are applied per acre, the yields are limited by concentrations of salt or ammonium.

Other ways of handling manure that are being studied include drying to reduce weight, and developing liquid manure distribution systems.

One of the primary considerations in the use of irrigation water is its salt content. The salinity is considered low if water contains less than 150 parts per million and high if it contains more than 1,500 parts per million of dissolved salts.

Low salinity water can be used with most crops and soils. High salinity water can be used with very few crops and soils. With higher salinity water, soils must be better drained; more water must be used to leach salt accumulations from the soil; and crops that tolerate higher salt levels—such as barley, sugarbeets, or cotton—must be grown.

Irrigation agriculture necessarily increases the concentration of salts in water. Of the 130 million acre-feet of water used annually for irrigation, only 55 million acre-feet is returned to streams as drainage, the remainder evaporating in crop production. Yet the 55 million acre-feet must carry all the salt added in the original 130 million acre-feet. Otherwise the irrigated soils would soon be too salty for crop production.

Soil conservation practices can affect the movement of salt by increasing the amount of infiltration. When the soils or underlying materials contain soluble salts, more salt will be moved by the increased flow of water through the ground. The salt may appear in streams or in surface seepage areas. In parts of North Dakota, stubble mulching for moisture conservation has increased the number of salt seeps.

Streams and ponds in most agricultural areas are still relatively clean and pure. It may never be possible to control all potential polluting materials from agriculture. However, the major sources of sediment—plant nutrients, pesticides, animal wastes, and salt—can be limited through good soil conservation practices.

In addition, alternatives to some pesticide uses are being developed, as are new methods of handling animal wastes.

Widespread research will continue to help protect water quality and agricultural production.

New Approaches to Pest Control

H C COX

THE NEED to control insect pests and reduce or eliminate their depredations will be more critical in the year 2000 than it is in 1971—and certainly the need is an important one today.

An estimated 25 million or so additional new families by the turn of the century will be just as anxious to rear their children in the absence of insect-borne diseases as we are. They, too, will want to live in homes and enjoy recreation areas free from damaging or bothersome insects. And certainly our Nation must continue to provide an abundance of wholesome food, with a minimum of loss due to insects, if we are to maintain or exceed our present high standard of living.

How can research make this goal possible if our Nation does not continue to rely heavily upon conventional chemical insecticides for insect control? U.S. Department of Agriculture scientists are working today to develop selective methods to use against insects that cause the greatest amount of damage or account for the greatest use of insecticides in the United States.

We have already devised a variety of selective methods of control for some pest insects and have used them successfully. But we are only in the process of developing other—perhaps even more imaginative—methods for use against the many additional pest insects. As a result, conventional insecticides must be used to control most present-day insect problems.

Noninsecticidal methods of insect control are not new. For generations, man has used every conceivable method—from slapping mosquitoes to crop rotation—to combat insect