
AGRICULTURAL POLLUTION OF WATER BODIES^{1, 2}

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ABSTRACT

Pollution of Ohio's water bodies is of growing public concern; industrial, urban, and rural sources are becoming the subject of critical examination. Rural sources are soil sediment, plant nutrients, animal waste, and pesticides. Pesticides and phosphorus are absorbed rapidly and strongly to soil particles. Therefore reductions in sediment, phosphorus, and pesticide pollution are achieved by soil-erosion-control farming practices. More acres need to be brought under erosion-control practices. Nitrates dissolve in water and are carried by surface flow to streams and lakes, and by percolating water to underground aquifers. Increases in the use of nitrogen fertilizer, in evidence almost everywhere, could result in serious contamination of water bodies, if soil enrichment greatly exceeds the crop demand. Areas where large-scale livestock and poultry production is concentrated are also potential sources of serious pollution. In Ohio, animal-waste pollution problems are being studied at The Ohio State University, and movement of pollutants in surface and subsurface waters on drainage plots near Castalia are being studied by the Ohio Agricultural Research and Development Center and on agricultural watersheds by USDA Agricultural Research Service at Coshocton, Ohio.

INTRODUCTION

The rapid increase in pollution of man's environment on earth is the concern of men and nations. Now that space travel appears to be a possibility, great care is being exercised to prevent earth's contamination from reaching other planets. Here at home, state and federal agencies are involved in rapidly expanding programs to determine the severity and extent of water and air pollution, their rates of change, sources, and control measures.

In Ohio, investigations and reports on the condition of Lake Erie state that man is destroying the lake (Chicago Tribune, 1968). Detroit was listed as the lake's prime polluter on the United States side, with Michigan's Wayne County, Cleveland, Toledo, Akron, and Euclid, Ohio, as other serious contaminants. A considerable amount of pollution is also coming from the Canadian side. The main cause of pollution was described (in the Tribune) as the dumping of untreated or only partly treated sewage into the lake. Pollution has been largely caused by man. Now pollution is affecting man's activities and he is disturbed about it.

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²Manuscript received March 12, 1969.

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A few hundred miles to the west, the Chicago Tribune (1968), a strong advocate for programs to save Lake Michigan from expiring like Lake Erie, reports a growing public outrage at finding water rendered unfit for human, game, industry, or agriculture use. Most people can't believe that such foul situations exist and, in many cases, are getting worse. There is now great public pressure for officials to do something. And do something they will. Their first acts for restrictive control are now being directed towards industry, urban, and lake activities. Concurrently, a critical examination is being given to agriculture's contribution to pollution. It is important that we in agriculture develop a greater understanding of our contribution to environmental pollution and relate it to climate, soil, land use, animal wastes, and use of chemicals. In this report, major sources of agricultural pollution to water bodies are cited, and information given on the present status of research activities in Ohio quantifying these sources, along with some preliminary results.

Sources of Agricultural Pollution

There are many potential farm sources of pollution in Ohio's water. The most important are:

1. *Sediment from soil erosion.*—This is not limited to agriculture, since huge loads of sediment in streams come from stream bed and bank; from raw roadside ditches, cuts, and fills; and from real estate developments in suburbia.
2. *Plant nutrients, especially nitrogen and phosphorus.*—These would come primarily from commercial fertilizer applied for efficient crop production.
3. *Animal waste.*—This would be washoff (material carried in surface runoff) directly into streams from barnyards or feedlots, washoff from cropland after manure application, or seepage into underground water reservoirs. This is almost entirely an agricultural source.
4. *Agricultural chemicals—pesticides and herbicides.*—These are carried in washoff from lands where the chemicals have been applied for control of insects and weeds which threaten agricultural crops. Other sources are centered around the chemical manufacturing sites and cities having insect-control programs. Home owners' usage of pesticides could contribute to the pollution of water bodies via storm sewers.

Those engaged in agricultural business need to know something about the source and fate of these pollutants in order to understand how their disposal is influenced by farming practices. A brief review of the state of present knowledge on this subject is presented below.

Sediment from soil erosion.—“Sediment derived from land erosion constitutes by far the greatest mass of all waste materials arising from agricultural and forestry operations” wrote Dr. C. H. Wadleigh, Director, Soil and Water Conservation Research Division of ARS, USDA (1968). Measurements of soil erosion from field plots and watersheds leave no doubt that cultivated farm land can be a major contributor to the sediment burden of rivers, reservoirs, and lakes.

Farmers are concerned about loss of productive topsoil from their lands, especially those working hill and rolling cropland. This loss is evident in reduced crop yields. Soil erosion is not so apparent in flat land like that in the lake-bed soil region of northwestern Ohio, yet the Maumee and Cuyahoga Rivers are transporting more tons of sediment per square mile of watershed into the harbors of Toledo and Cleveland than that carried by all the rivers of the hilly Muskingum basin (Hubble and Collier, 1960). A greater percentage of the area of the drainage basins of northwestern Ohio is cropland. In the Muskingum basin, flood-control reservoirs catch some sediment and reduce the total river-basin sediment yield. In addition soils in this area are more sandy.

Soil and water conservation research has shown that contour tillage in hill land can reduce erosion by 75 per cent over that of straight-row farming, and the reduction by contour strip cropping is even larger (McGuinness *et al.*, 1960). Farming procedures involving various minimum-tillage practices and, more recently, no tillage for corn (Harrold *et al.*, 1967) appear to give the necessary control of runoff and of erosion needed to sustain more intense cropping systems and even continuous corn production on hill lands. Erosion control is a big part of the Soil and Water Conservation District's program in this area. It is a notable factor in reducing this source of pollution of surface waters here.

In the past few years, newsprint, radio, and television media have vividly portrayed the fact that algal growth in our ponds and lakes is spreading much more rapidly than it would naturally, partly because of phosphorus washing off of farmland. As this is one of the important plant nutrients applied as chemical fertilizer on cropland, it must be considered as a possible source. There is evidence that its movement into streams and water bodies in large quantities is related to erosion of soil particles. Taylor (1967) reported that phosphorus applied as a plant nutrient attaches itself to fine soil particles and is not redissolved in sizable amounts. Therefore, soil-erosion-control measures on the farm reduce the amount of phosphorus pollution coming from agriculture. In this way, the enriched soil can be retained on the farm for crop production and the role of agriculture in phosphorus enrichment of surface waters can be minimized.

The importance of erosion control in pollution abatement cannot be over-emphasized. Research to define this relationship and to develop better farming practices so as to minimize pollution from agricultural sources is limited to isolated locations and to only a few years' study. Such research needs to be intensified and extended to different conditions. Renewed efforts to establish and maintain better soil and water conservation farming practices are also needed. Furthermore, there is a need for more knowledge of the factors relating to the eutrophication, or aging processes of water bodies. It is generally concluded that the role of phosphorus adsorbed on sediment deposited in streams, ponds, or lakes in supplying the needs of algae is not clearly understood.

Plant nutrients.—In Ohio's agricultural use of plant nutrients, the compounds of greatest concern in pollution are nitrate and phosphorus. The first is highly soluble and is transported readily to surface and underground water bodies. Phosphorus is not readily soluble, is adsorbed rapidly on the surface of fine soil particles, and is transported off the farm along with the sediment (as described above).

Phosphorus, because of its low solubility, does not move downward through the soil in sizable quantities (Taylor 1967). Phosphorus enrichment of underground-water supplies by leaching from cropland topsoil is so small that it is not considered a pollution problem. However, phosphorus seepage from septic tanks or from barnyards may be serious.

Nitrate fertilizer has sometimes been blamed for the contamination of well and spring water bodies. The use of nitrogen fertilizer is increasing rapidly. Application rates have more than doubled in the past decade. In some places they may double again in the next 10 years.

Agricultural research is recognizing its responsibility to quantify the movement of plant nutrients into water bodies. Stewart, Viets, and Hutchinson (1968), reporting on research in Colorado, showed that, in irrigated cropland, 25 to 30 pounds of nitrate per acre moved to the ground-water table annually. Such dangerous situations may be local or widespread. They are indeed *hot spots* in agricultural pollution. On the other hand, there are areas where the increased use of fertilizer did not result in contamination of underground water. In Ohio, Harrold and Dreibelbis (1958) showed that the amount of nitrate percolating through an eight-foot cropped lysimeter under natural rainfall conditions averaged

about four pounds per acre annually. However, reasonable increases in application of fertilizer nitrogen for corn in a four-year rotation, from a low of 6 to a high of 18 pounds per acre, did not increase the amount of nitrate percolating through an eight-foot profile. Greater crop production used much of the increased nitrogen application. To apply no more fertilizer on the land than can be used in crop production is sound wisdom and economy in farming. In addition, it certainly helps to minimize agriculture's role in the national pollution problem.

Animal waste.—"Time was when animal waste was considered a tremendous asset in providing fertility to the nation's soils. How times do change!" (Wadleigh, 1968). Now in areas where livestock and poultry production are concentrated in large scale, the disposal of animal waste is a problem of great concern. It can be a potential source of serious pollution. Here is another *hot spot* in agricultural pollution. The source may be a barnyard of 30 head of dairy cattle, a feedlot of several thousand head of beef or hogs, or a small area for thousands of chickens or turkeys. Stewart *et al.* (1968), reporting on observations in the Great Plains, showed that nitrate in 20 feet of soil beneath a feedlot reached a high of over 5,000 pounds per acre, with an average of 1,436 pounds per acre. A single feedlot in this area may carry over 75,000 head of beef cattle. The disposal of animal waste in such *hot spots* is a real problem.

In pointing out the seriousness of the contribution of farm-animal waste to pollution, the volume of waste from animals is often compared to that of humans. On the basis of the Ohio farm-animal and human populations, if all the animal wastes were to be discharged *untreated* into public waterways, the pollutional damage would be equivalent to discharging the *untreated* sewage from 25 million people—two and one-half times Ohio's 1968 population (Taiganides 1968). The fact is, however, that very little animal waste goes directly into Ohio's streams and lakes. Most of it is spread on the land, providing fertility to the soil. The disposal problem is indeed serious, however, where large-scale concentrations of animals are located. Here waste-disposal systems are urgently needed.

Agricultural chemicals.—Herbicides and pesticides are widely used in, but certainly not restricted to, agriculture. Control of mosquitoes and the Dutch elm disease in cities are examples of large-scale nonagricultural pesticide usage which may contribute to the environmental pollution problem. However, widely publicized incidents, such as fish kills, usually result from accidental or careless usage. Early investigation traced the origin of pesticide concentrations in the Lower Mississippi River to the discharge of waste products from pesticide manufacturing and formulating plants (Barthel *et al.*, 1966).

Dieldrin and other long-lived chlorinated hydrocarbon pesticides are adsorbed on the surface of fine soil particles and do not wash off in the liquid phase of runoff into the stream in sizable quantities—a preliminary finding at the Coshocton, Ohio, Research Station, and explained later in this paper. In this respect, they move like phosphorus. Dieldrin concentration in soil eroded from fields may be quite high if the runoff-producing storm closely follows application, but again, like phosphorus, this material becomes part of the sediment in the bottom of surface water bodies and will not go into solution in sizable quantities.

Research Activities in Ohio

Dr. Taiganides, of the Agricultural Engineering Department, Ohio Agricultural Research and Development Center (OARDC), initiated research in 1966 on the engineering aspects of animal waste management (1968). His studies have been involved primarily with the development of techniques for measuring the pollutional properties of animal waste. One vexing problem facing the animal industry is odor nuisance from concentrated animal-production units. Research on methods of controlling malodors through management schemes and deodorants is being conducted at The Ohio State University.

Dr. Schwab, of the Agricultural Engineering Department, OARDC, initiated research in 1957 to measure the surface and subsurface movement of fertilizer nutrients and pesticides under various drainage systems. This research is being carried out at the North Central Branch Farm of OARDC, near Castalia, Ohio, where drainage treatments include surface drainage only, tile drainage only, and a combination of both (Schwab and Fouss, 1967).

More pollution studies were started in 1966 at the North Appalachian Experimental Watershed near Coshocton to determine the transport mechanisms of dieldrin, nitrogen, and phosphorus from small cropped watersheds—one having low fertility and no dieldrin, and another with high fertility and 5 pounds of dieldrin per acre mixed into the top 3 inches of soil (equivalent to 5 ppm). Watershed areas were less than 8 acres. Special automatic sampling equipment was designed, assembled, and installed (Edwards *et al.* 1969). A careful sampling program was laid out in detail so that laboratory analytical work on these samples would be reliable and so that the results could be related to runoff rates at various times throughout storms and at different times following application of agricultural chemicals. Results needed to be interpreted in light of historic record of treatment and hydrologic performance of the study watersheds.

The research program also included sampling runoff from 43 acres of woodland, where there had been no fertilizer or agricultural chemicals applied for over 35 years, to provide background comparison. Another 303-acre watershed of mixed cropland was sampled to relate the quantity of dieldrin in the stream at the watershed outlet to applications on small fields in its headwaters.

In March, 1968, research on pollution from a beef-cattle barnyard was started. Runoff immediately below the 0.4-acre barnyard and at a point downstream, where the drainage area was 76 acres, was sampled automatically. This experimental situation was designed to represent normal dairy or beef barnyards in Appalachia, where 30 to 50 head are fed during the winter-spring season.

Preliminary Results

Surface-water pollution from farm land resulting from washoff—agricultural chemicals attached to soil particles and transported by soil erosion—was very small the first two years of the study, due to lack of high rainfall rates. In the third year, there was more rainfall, so erosion occurred and concentration of phosphorus and dieldrin pesticide attached to sediment was significant, especially for a short period after application of the chemicals on the land. Concentration of pollutants on solids and in liquid runoff reduced as the period after application increased. Concentration data for solids are currently being multiplied by corresponding values of total sediment yield, and values for concentration in water runoff are being multiplied by corresponding flow rates and integrated with time to derive values of total amounts of agricultural chemicals removed from the farm land. Although these results are not yet available, it is evident that phosphorus and pesticide pollution in surface runoff comes mostly by soil erosion and that erosion-control measures on farm land will play an important role in minimizing pollution from agricultural sources.

Erosion from well-managed grass and wooded areas at the Coshocton station has been negligible. It is greatest in row-crop land. Contour tillage of row crop, small grain, and meadow-rotation systems provide a measure of erosion reduction. Mulch-culture and no-tillage corn management reduced erosion to less than 0.5 ton per acre (Harrold, Triplett, and Youker, 1967). As soil erosion has been low, sediment-borne pollution would be a minimum in such cases (table 1).

Natural sources of pollution—wooded areas where no agricultural chemical has been applied for over 35 years—are being observed at the Coshocton Station. Herbage growth has been found in pools of water along the stream system. In this situation, far from man's activities, agricultural phosphorus is definitely not the cause of this growth, and this eutrophication pollution is not man-made.

Underground water pollution has been studied at Coshocton on monolith lysimeters of unglaciated silt loam of sandstone and shale origin (Harrold and Dreibelbis, 1958). Phosphorus movement to ground-water bodies was negligible and was not reported. Nitrate movement downward beyond the plant roots was measurable, and averaged less than five pounds per acre—not serious. In fact, leaching of nitrates to the eight-foot depth was less on the lysimeter receiving the greater amounts of nitrogen fertilizer. In producing greater crop yields on this lysimeter, there were lesser amounts of percolation and nitrate leaching, as was presented in more detail earlier.

TABLE 1

Average annual soil loss from watersheds in corn in a 4-year rotation of corn, wheat, meadow, meadow under different tillage practices at the North Appalachian Experimental Watershed, Coshocton, Ohio

Practice ¹	Soil loss	Length of record
	Tons/acre	Years
Prevailing	5.16	28
Improved	1.44	22
Minimum tillage	.39	10
No tillage ²	.01	5

¹*Prevailing practice* is fairly low fertility and straight, sloping rows.

Improved practice is that recommended in the Soil and Water Conservation District programs—moderately high fertility and contour rows.

Minimum tillage is plow, plant, and harvest.

No-tillage is chemical kill of grass, legumes, and weeds; planting; harvesting; chopping of corn stover; and manure application.

²Continuous corn.

Plant nutrients, pesticides, and herbicides were applied to the surface of a lysimeter in March, 1967. Runoff and percolation (water intercepted eight feet below the surface) have been monitored since that time. Another lysimeter, which received no treatment, served as a check. Laboratory and hydrologic analyses have not been completed. However, preliminary results indicate that only a trace amount of the heavy application appeared in the water reaching the eight-foot depth.

SUMMARY

Agriculture is facing a formidable challenge. It must produce crops with the most efficient use of water, land, and plant nutrients, and at the same time minimize the agricultural contribution to water pollution, as well as to that of soil and air. Research to identify the role of agriculture in the pollution of our environment, and to identify the causes and develop alleviation measures is of high priority. This research is progressing as rapidly as funds and personnel become available.

Those in agricultural research have a responsibility to see that facts regarding nutrient enrichment of our environment are reported as accurately as possible. Frequently overlooked is the fact that aging, or eutrophication—one phase of pollution often said to result from phosphorus from urban and agricultural sources—is a natural process in the life cycle of a lake. We may not find ways of reversing it, but we must do all we can to minimize any acceleration of the process that might be attributable to agricultural practices.

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