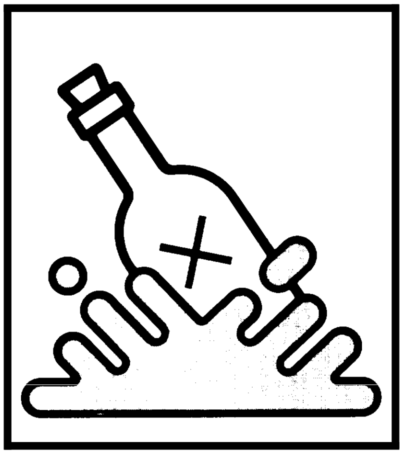

"Pollutions" Water Quality

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Chapter IV

Water Quality

Water-quality deterioration in the Western United States would have significant impacts on water use, Although agriculture is the primary user of water in the region, water-quality problems are associated with all uses,

This chapter presents an overview of two aspects of water quality of the Western United States: 1) the impacts that water quality has on agriculture and 2) the impacts that agriculture has on water quality. While the chapter is not an exhaustive consideration of all the water-quality implications for water supply and use in the Western United States, it does illustrate the broad nature of the problem and some of the more salient public health implications.

The discussions of this problem in the literature, on which this chapter is based, are fragmentary, and it is apparent that legitimate differences of opinion exist concerning the seriousness of the problem. Water planners and managers must be aware of these different interpretations but must also understand that, at least locally, water pollutants and their associated health problems have been detected in the region. With the increasing water usage indicated by present trends, these pollution and health problems can only worsen without concerted action on the local, State, and Federal level.

WATER QUALITY IN ARID AND SEMIARID REGIONS

Water quality defines the physical, chemical, and biological attributes that affect the suitability of water for agricultural, industrial, and domestic uses as well as for recreation and wildlife habitat. These attributes are closely linked to the physical availability of water, the extent to which the available resources are used, and the nature of the water-quality changes that use produces. Water quality is determined both by the nature of the pollutant and the concentration of that pollutant in the water.

No water problems are unique to the arid and semiarid portions of the Western United States. The more limited amount of water available in this environment, however, has the potential to increase the severity of any that do exist. For example, arid and semiarid environments are commonly characterized by high natural levels of salinity in the soil owing to the imbalance between precipitation and evaporation which decreases natural leaching, The sporadic runoff that characterizes these environments will often contain high concentrations of both suspended and dissolved solids which are added to the perennial river system. It is estimated, for example, that natural sources account for about two-thirds of the total annual dissolved salt carried by the Colorado River. For portions of this river, this represents values that may exceed 1,500 parts per million (ppm) total dissolved solids, or three times the recommended level for municipal drinking water.

The fact that there is less total water available in arid and semiarid environments means that each unit of water must be more fully used, resulting in the development of patterns of reuse in which each unit of water must be used consecutively as it moves through a river system. Thus, water may be withdrawn from the river and partially consumed by irrigation; the return flow may be stored in a reservoir where it will ultimately be used to generate hydroelectric energy; and then, following release, the water may be withdrawn by a municipality for domestic consumption. The return flows from each of these sequential uses have increasing levels of pollutants and may ultimately have little reuse potential without significant treatment (35). While continued reuse of streamflows for irrigation without treatment has become a necessity in many of the water-short areas of the Western United States, the gradual buildup of salts and agricultural chemicals in the soils and in the water itself could ultimately prove to be more detrimental to agriculture and other water users than will increasing water shortages.

Traditionally, the streams, lakes, rivers, and ground water of the Western United States have seemed a convenient and seemingly inexpensive and inexhaustible dumping area for human and animal wastes and residues from industry and municipalities. Many water-quality problems have been identified in the Western United States; most on a site-specific basis, depending on the type of pollutant and the nature of the ground and surface water system into which it is introduced. Experts disagree about the nature or extent of existing water-quality problems and about related public health aspects. Based on available evidence, however, concern is justified.

The kinds and amounts of impurities in water depend on a number of environmental factors, such as source of water and physiographic characteristics of the environment through which the water moves, and on the effects of human activity on water quality. In practice, it is difficult to separate water-quality from water-quantity problems in the Western United States. The development and use of the region's water resources have generally tended to decrease the volume of water in both surface and subsurface sources and to increase the concentration of both natural and human-caused contaminants. The ability of Western water resources to assimilate the increased levels of contaminants that might be produced by urban populations, industrial activities, and use of agricultural chemicals is more limited than in the humid Eastern United States because of lower total volumes of water. Because of the interconnected nature of ground and surface water supplies, contamination of one will eventually affect the quality of the other.

In discussing water quality in relation to agricultural development, two major issues arise. On the one hand, agricultural use requires certain standards of water quality. Under conditions of water scarcity, waste products concentrating in surface or ground water supplies can appreciably diminish the availability of suitable water for agricultural use. On the other hand, agriculture itself contributes waste products to the environment affecting water quality and its suitability for other uses.

THE EFFECTS OF WATER QUALITY ON AGRICULTURE

Technologically, water of any quality can be made suitable for any use. However, to neutralize or remove certain types of pollution from water is prohibitively difficult and expensive. The extent of improvement a water supply will require and the associated costs usually represent the rationale in assessing the comparative worth of alternative supplies.

"Water quality" in agriculture relates primarily to farmstead water supply, livestock, watering, and irrigation. Understanding the significance of a great variety of water constituents regarding tolerance limits for various uses is far from complete. However, the provisional threshold tolerance levels available for many water constituents may serve as guides in evaluating the suitability of water for particular uses. In 1963 the California State Water Resources Control Board published the first "Water Quality Criteria" for various uses, ineluding agriculture (33). In 1968 the Federal Water Pollution Control Administration published "Water Quality Criteria" in which considerable emphasis was given to water-quality requirements in agriculture, In 1976 the Environmental Protection Agency (EPA) contributed "Quality Criteria for Water. " In 1977 the

National Research Council of the National Academy of Sciences published "Drinking Water and Health," which summarized the state of knowledge on the effect of various drinking-water constituents on human health.

Domestic Use on Ranches and Farms

The requirements for water quality for domestic use by a human population in an agricultural setting should not be different from requirements for drinking-water quality elsewhere. However, water available on farms and ranches is usually in a raw state, while water in the cities is treated to make it suitable for human consumption. Thus, farm and ranch water must be of such quality that it can be consumed without, or with minimal, treatment. Because water used by individual households in rural areas is not subject to routine quality inspections as are public water supplies in the cities, there is very little information on the quality of drinking water available to rural populations. Some rural drinking-water supplies have become polluted. For example, analysis of water in California during 1979 revealed that some 100 water-supply wells contained trace amounts of DBCP (dibromochloropropane), formerly a widely used pesticide and a suspected carcinogenic compound (47)

Livestock

It is usually accepted that water that is safe for human consumption may be used safely by stock, but that some stock can tolerate water of a somewhat poorer quality. According to Heller (25,26), the maximum concentration of salts that can be tolerated by certain domestic animals is about 15,000 milligrams per liter (mg/l), but this limit is believed to be too high for food-producing animals. The maximum acceptable salinity level for livestock drinking water suggested by EPA (50) was 3,000 mg/l of soluble salts.

In general, the types of pollutants in water that are of potential significance to livestock are mineral salts, organic wastes and algae, microbiological pathogens and parasites, pesticides, herbicides, and radionuclides, Livestock water can be contaminated in many ways, either directly from natural sources or indirectly; e.g., agricultural fertilizers may stimulate algae "bloom" in the water so that it becomes unsuitable for animal watering. Various water pollutants may cause either loss of livestock by death or by reduced reproduction,

Irrigation: Salts and Ions

The quality of water used in irrigation is very important. It is known that water retained in soil (so-called "soil solution") tends with the passage of time to become progressively more saline. This process is believed to be responsible for the failure of many irrigation projects throughout the history of civilizations (7).

Using an inferior quality water for irrigation can affect soil by changing soil structure (permeability and aeration), and plants through the presence of phytotoxic substances in water or through the modification of processes that limit the water uptake by plants, Moreover, some constituents of irrigation water of no particular significance to plants themselves, but significant to animals and humans, can be accumulated by crops.

An evaluation of water suitability for irrigation based solely on water characteristics has limitations because more factors are involved. First, the "soil solution" is usually several times as concentrated as the water applied (in some cases it may be as much as 100 times more concentrated). Second, plants vary widely in their tolerance to salinity (see ch. IX, table 67). Third, soil types, climatic conditions, and irrigation practices and drainage conditions are of importance and vary widely. Well-drained soil can support growth of satisfactory crops even if the water applied to it is not of the best quality. However, poorly drained soils favor buildup of undesirable constituents, even if the constituents are present in rather small quantities in the water.

The characteristics of water most often considered in determining the suitability of water for irrigation use are: 1) the total concentration of salts in water (measured in mg/l or as the specific conductance, in micromhos); 2) the proportion of sodium to calcium and magnesium (often in percent); and 3) boron, chloride, and sulfate content in mg/l (table 17). Each of the characteristics varies relatively independently. Thus, water, adequate in all other respects, may not be suitable for irrigation because of a specific single adverse water-quality factor.

Soils in arid and semiarid regions have specific salt-accumulation problems. Such soils have been formed under limited precipitation conditions and scarce vegetation. Infrequent infiltration by rainwater causes the soils in such areas to be more shallow and saline. In order to maintain a steady state, salt accumulation in the process of irrigation should be balanced by equally effective salt removal, a difficult practice to accomplish. In most cases, salt removal may succeed only in moving the problem downstream to the next point at which water is withdrawn for irrigation application.

The proportion of sodium to other cations* in water is used to indicate the relative activity of sodium ions in exchange reaction with soil, Sodium hazard increases if water has a large concentration of bicarbonate ions. Alkaline water will act to dissolve the organic material in the soil, The effect is known under the general term of "black alkali," referring to the characteristic black-grayish color of the affected soil. Because of these considerations, the RSC* index (residual sodium carbonate) was suggested as an additional criterion for irrigation water. Water containing more than 2.5 mg/l of RSC is probably not suitable for irrigation; with RSC in 2.5 mg/l, water is marginal, and with RSC lower than 1.25 mg/l, water is probably safe (53).

While trace quantities of boron in water are essential for plants as a micronutrient, an excess of this element can cause plant injury. The information on tolerance of plants to boron as well as several other trace elements is presented in table 18,

Irrigation With Wastewater

In conditions of water scarcity, the reuse of wastewater in irrigation has been considered as a possible way to stretch available resources.

*Positively charged ions,

*RSC = $(CO_3^{--} + HCO_3^{-}) - (CA^{++} + Mg^{++})$, Ionic content in milliequivalents per liter.

Table 17.—Summary of Classifications of Irrigation Waters

Class	% Na = $\frac{Na \times 100}{Na + Ca + Mg + K}$ as meq per liter	Boron, in mg/l	Chlorides in meq/l	Sulfates in meq/l	EC x 10^6 at 25° C Specific conductivity (concentration of ions)	Total salts in mg/l
I	Less than 30-60°/0 (most recent work favors a 60°/0 limit)	Boron recommendation for water of this class is generally accepted as less than 0.5 mg/l; however, tolerant plants will not be injured by 1-1.5 mg/l	Less than 2-5.5	Less than 4-10	Earlier papers suggested limit of about 500, but more recently 1,000 has been accepted	Up to about 700
II	30-75%	0.5-2.0 mg/l although for tolerant plants water with boron up to *3.35* mg/l may be satisfactory	2-16	4-20	500-3,000	350-2,100
III	More than 70-75%	More than 2 mg/l although water with more than 1.0 may be highly unsuitable for sensitive plants	More than 6-16	More than 12-20	More than 2,500-3,000	More than 1,750-2,100

SOURCE J E McKee and H W Wolf, *Wafer Quality Criteria,* California State Water Resources Control Board, 1963

Table 18.—Trace Element Tolerances for Irrigation Waters

Element	For water used continuously on all soils (mg/l)	For short-term use on fine textured soils only (mg/l)
Aluminum	1.000	20.00
Arsenic	1.000	10.00
Beryllium	0.500	1.00
Boron	0.750	2.00
Cadmium	0.005	0.05
Chromium	5.00	20.00
Cobalt	0.200	10.00
Copper	0.200	5,00
Flourine	(')	(')
Iron	(')	(')
Lead	5.000	20,00
Lithium	5.000	5,00
Manganese	2.000	20.00
Molybdenum	0.005	0.05
Nickel	0.500	2.00
Selenium	0.050	0,05
Tin	(')	(')
Tungsten ., ...	(')	(')
Vanadium	10.000	10.00
Zinc	5.000	10.00

SOURCE J E McKee and H W Wolf, *Water Qualify* Criteria, California State Water Resources Control Board, 1963

However, the safety and desirability of land application of wastes has been a controversial issue, The divergence of opinion in this matter was reflected by participants of the Fourth National Groundwater Quality Symposium in 1978. At this symposium Wright and Rovey (both private sector water engineers) characterized such a practice as beneficial, arguing that "land application of treated wastewater can provide unique opportunities not only for a final high level of waste treatment, but for reasons of nutrients as well. " To support this conclusion, the authors presented several examples of land application of treated municipal and industrial wastewater with no detectable impact on ground water quality (57). In agreement, Sheaffer, the president of a company that works with wastewater reuse, suggested that "land treatment systems provide an opportunity to view sewage treatment as an investment in the production of food and fiber. " It "provides our nation with a positive program to deal with a negatively perceived material, sewage" (41).

On the other hand, Johnson, chairman of the National Drinking Water Advisory Council and vice president of an environmental engineering company, characterized land application of waste as "an accident waiting to happen. " He indicated that research has not been done to give assurance that natural interaction of wastewater and soils will remove to acceptable levels potentially harmful contaminants. He cited several examples where sewage effluents penetrated the ground to the water level, "There is a great deal to be learned, " he said, ''about the fate and transport of contaminants below the surface; the practices that represent the greatest threat to this national resource; and the economics of alternative ways of disposing of wastes in a manner more protective of the environment, " Johnson quoted California State studies in 1976 that concluded that "areas of uncertainties regarding health effects cannot be resolved because basic scientific knowledge is lacking" (29).

A 1979 report by the United Nations World Health Organization (WHO) warned that the application of wastewater to land, whether for agricultural irrigation or as a method of treatment for disposal, poses a possible risk of virus contamination of ground water. The report emphasized that "concern about hazard from viruses caused by this practice has only recently been raised, and available information remains limited. " Concentration of enteric viruses in human feces was reported to be as high as 10^5 to 10^8 PFU/g (plaque-forming units per gram) (56), Raw sewage and wastewater usually contain a large number of enteric viruses of human origin, Although sewage treatments reduce virus contamination to varying extents, significant numbers of viruses survive treatment.

Because viruses in wastewater that is applied to land can survive in the environment for a considerable period of time (27), the application of inadequately treated effluents and sludge to land poses the risk of potential public health problems, According to the 1979 WHO report, deposition of significant concentrations of viruses on the soil might be a health hazard via:

- direct virus infection of farmworkers and their contacts,
- virus contamination of crops destined for human consumption,

- virus contamination of the drinking-water source (surface contamination by runoff or ground water contamination by percolation),
- dissemination of viruses by insect vectors or animals in contact with contaminated soil, and
- virus dissemination by the air when sprinkler irrigation is u-seal.

An improved understanding of factors that influence virus retention and inactivation in soil and of factors controlling virus migration through soil is critical in managing wastewater land-treatment systems. According to studies by Gerba, et al. (19), virus retention in soil is believed to occur mainly by the mechanism of adsorption, * which, in turn, is controlled by a number of variables; e.g., soil composition and ionic content, pH, moisture content, temperature, rates of wastewater application, strength of sewage (19,27). Moreover, adsorptive behavior of viruses and their survival were also demonstrated to be strongly type- and strain-dependent. Hurst, et al. (27), reporting this observation in 1980, stated:

> The fact that [adsorptive capacity] significantly affected virus survival is of great importance. This finding indicates a dilemma insofar as virus inactivation during land treatments is concerned. On one hand, concern for public health would, of necessity, require that land treatment sites be developed on soils with high virus adsorptive capacity. This is required to minimize the possibility of viruses applied to soil reaching groundwater. On the other hand, virus survival is likely to be greatest in those soils that would be most effective in preventing groundwater contamination.

*Adherence of one particle, ion, or molecule to the surface of another.

Heat

Water-temperature increases can result from industrial water use and from water impoundment, Such increases have a direct effect on the efficiency of water as a coolant and an indirect influence on aquatic life and on water chemistry. A change in water temperatures, by itself, has little effect on the agricultural uses of water. However, changes in water temperature may produce associated water-quality changes which will render the water less desirable for a variety of agricultural uses. For example, an increased water temperature increases the volubility of all substances including those that may be harmful to agriculture. With higher water temperatures the dissolved oxygen content is lowered, increasing the possibility of eutrophication, including the production of anaerobic decomposition products and increased algae growth, when sufficient nutrients are present. Pathogenic organisms will survive for longer periods of time at higher water temperatures, thus increasing the risk of disease transmission both to and from agricultural areas.

Radioactive Substances

The possibility of the uptake and translocation by plants of the radioactive material from fallout—in particular strontium, cesium, barium, and iodine—has been identified in some literature (33). Radioactive material can be picked up by rivers as they cross areas of uranium mining (7)0 Uranium mining exists in several States—e. g., Utah, New Mexico, Arizona, and Texas. Some streams used for irrigation purposes either cross through uranium districts or originate within the uranium districts (9,55). Ground water can also be contaminated in the process of uranium exploration.

THE EFFECTS OF AGRICULTURE ON WATER QUALITY

Agriculture contributes its share of water pollution, both from point and nonpoint sources, * The impact of agricultural wastes such as sediments, dissolved salts, and bacteria on water quality has been given comparatively little attention until recently (14,51). Within the past

● Point pollution comes from sources that can be pinpointed; nonpoint pollution comes from diffuse sources. See app. E.

several decades the use of agricultural chemicals (pesticides and fertilizers) has become widespread in the West, and a sizable feedlot industry has been created with massive concentrations of livestock, poultry, and the resultant waste products. These kinds of activities raise serious concerns about Western water quality,

Suspended Sediments

The greatest mass of waste resulting from agricultural activity in terms of quantity is probably the material eroded from cultivated land. The total quantity of sediment production in the United States is appreciable, estimated to be as much as 6.4 billion tons per year (11). Waterborne sediments are solid particles of various sizes composed of inorganic and organic materials eroded from soil and rocks, products of plant and animal decomposition, and debris of human activity.

Much sediment and erosion results from poor agricultural management practices according to a report prepared by the Department of Agronomy at Cornell University (14). The problem is magnified by numerous individual farmers who, either for lack of knowledge, carelessness, or economic necessity, do not practice proper methods of erosion control, manure application, or agricultural chemical application.

Although there is no evidence that common suspended sediments or solids affect health directly, they can affect health indirectly. Specifically, clays are very adsorptive and can provide a transport mechanism for viruses, bacteria, and various toxic substances into drinking-water supplies. Pesticides and fertilizers bind to soil particles and are later mobilized by erosion and transported by runoff. Paraquat and Diquat (herbicides) and phosphorus (fertilizer) are examples of chemicals that can be transported by clay particles (36). Viruses and bacteria tend to concentrate in the bottom sediments of lakes, rivers, and estuaries (22,32,36],

Some organic pollutants that do not adsorb readily on pure clays adsorb on clay-organic complexes in the sediments. Water treat-merit is usually capable of removing most of the suspended material; in cases when it is not, such material may be ingested, Pollutants bound to clay particles may be released into the water or into the digestive tract of humans and animals.

Other problems commonly reported in association with waterborne sediments come from agriculture. These include impairment of drainage, reduction of reservoir storage capacity, and increased need for dredging of water-development projects. Waterborne sediments increase costs of water clarification for industrial use and potable water delivery. Coarse sediments cause abrasion of turbine blades in power-generation facilities and clogging of injection wells, Economic losses to commercial fisheries can result from the effects of sediment on spawning grounds.

Plant Nutrients and Fertilizers

Nutrient transport from cultivated land and feedlots is among the most frequent problems associated with agricultural activity. While elements such as phosphorus and nitrogen are essential nutrients for any terrestrial or aquatic ecosystem, the overenrichment of water bodies with these same chemicals may bring about an uncontrolled algae “bloom” and excessive growth of aquatic plants. This growth leads to problems in waterways and canals and interferes with water recreation and other beneficial uses of water. Decaying water plants reduce the quality and length of the useful life of farm ponds, lakes, and reservoirs.

Phosphorus

According to some experts, phosphorus may be one of the most limiting nutrients in aquatic habitats. Agricultural sources of phosphorus include fertilizer and runoff from animal feedlots. Phosphorus, unlike nitrogen, does not readily leach out of soil. Soil can hold large quantities of this nutrient in a fixed state. Erosion and sediment transport is the primary way in which phosphorus is introduced into water bodies. phosphorus commonly is present in greater concentration in the bottom sediments of a water body than in solution.

Some research has shown that algae "bloom" can exist at phosphorus concentrations in water as low as 0.1 ppm. However, such algae could not sustain itself for long at this initial concentration unless phosphorus were resupplied at least 15 times throughout the growing season (14). It is believed that the amounts of phosphorus moving off the land as fertilizer may not be sufficient to support the algae "bloom" experienced in farm ponds, lakes, and reservoirs, Runoff from barnyards, animal feedlots, and domestic sewage also contribute phosphorus to water.

Nitrogen

A second nutrient and potential water pollutant is nitrogen. Nitrate contamination is likely to be of importance where rural water supplies are concerned. Major sources of nitrogen-containing wastes are drainage from animal feedlots, irrigation reuse water, wastewater from municipalities and industries, solid waste dumps, and septic tanks. An important nonpoint source is runoff from fertilized land (chemical or manure) (36). It has also been suggested that some nitrates in ground water are of a natural origin—i.e, indigenous to some geological deposits—e.g., tertiary and quartenary sands (18). The origin of excessive nitrates in shallow wells is a subject of debate. Several recent reports from the United States and England have suggested trends of increased nitrates in water attributed principally to the increasing use of organic and inorganic fertilizers in areas of arable farming and to changes in methods of farming (16,24,58).

IMPACTS ON HUMAN HEALTH

An excessive intake of nitrate or nitrite leads to the development of methemoglobinemia. * The effect has been well documented in humans, and a similar effect has been observed in animals exposed to high doses of these chemicals (36).

*Presence of methemoglobin (a chemically altered hemoglobin which does not combine with oxygen) in the blood results in cyanosis (bluish discoloration due to deficient oxygenation of the blood].

Evidence implicating nitrate, nitrite, and N-nitroso compounds in the development of cancer in humans is circumstantial. Several epidemiological studies of certain geographical/nationality groups have provided data that are consistent with the hypothesis that exposure of humans to high levels of nitrate and nitrite may be associated with an increased incidence of cancers of the stomach and esophagus (see, e.g., 2,13,59), In none of these studies was there a direct attempt to investigate actual exposures of nitrate, nitrite, or N-nitroso in individuals who developed cancer, however. In most of the studies, several other plausible causative agents were also identified (36).

Many N-nitroso compounds are clearly carcinogenic in many species of laboratory animals, suggesting that they should be considered as possible human carcinogens. However, the value of these tests in making predictions of the nature or extent of risk to humans is unknown (36). It has been recommended that exposure to the precursors of N-nitroso compounds—especially nitrate and nitrite—and to preformed N-nitroso compounds be reduced (36), A thorough discussion of pathology associated with N-nitroso compounds is available in a publication of the International Agency for Research on Cancer (28).

IMPACTS ON ANIMALS

Cattle, sheep, goats, horses, swine, and birds are farm animals susceptible to nitrate poisoning which occurs when nitrate is ingested faster than it can be reduced and incorporated into proteins. In such a situation, nitrite is then absorbed into blood where it converts hemoglobin into methemoglobin, This reaction reduces the oxygen-carrying capacity of blood, and the animal then experiences oxygen deprivation and may die by asphyxiation. Other consequences are spontaneous abortion, reduced production of milk, and signs of vitamin A deprivation.

Dissolved Salts

A favorable mineral salt balance in the soil is essential for human survival and for successful functioning of agriculture. Water that evaporates from the soil surface or is transpired by the plants is salt-free, and thus salt residue tends to be left behind not only in the soil but also in any water flowing through the field. As a result, the irrigation return flow usually has a much higher salt burden than does the incoming water.

Wadleigh (51) has suggested that irrigation does not actually produce waste in the form of dissolved salts nor add much to this salt burden by the application of chemical fertilizers. He suggests that irrigation transfers the salt loads in a more concentrated form into return flows from irrigation. The increased salt burden of irrigation drainage water renders the water of receiving streams and rivers less suitable for downstream users. Progressively higher salt concentrations of irrigation return flows may render receiving waters unfit as a potable water supply or for other uses.

Sodium is one of the salts that may buildup in relatively high proportions in irrigation return flow as water on the field evaporates. The impact of sodium excess on nonagricultural uses of water—in particular, water designated for human consumption—has not received widespread recognition. Sodium is a life-essential element, and the amount that can be tolerated by healthy people is believed to be considerable. For people suffering from some illnesses, however, excessive intake of sodium (salt) is undesirable, and might be harmful. These illnesses include congestive heart failure, hypertension, liver cirrhosis, renal disorders, adrenal hyperfunction, and possibly certain complications of pregnancy.

The U.S. Public Health Service limits the total dissolved solids in water destined for human consumption to 500 mg/l and the chloride content to 250 mg/l. A report of the National Research Council (38) indicates that over 6 million people in the United States are on physician-prescribed salt-restricting diets. When drinking water contains sodium in a concentration greater than 20 mg/l, compliance with restricted diets of 1 g or less daily becomes difficult. In view of this fact, the American Heart Association (1) recommended that the amount of sodium in water for use in salt-limiting diets shall not be in excess of **20 mg/l. White, et al. (52), found that many municipal water supplies are unsuitable for patients on severely restricted sodium-salt diets. Drinking** water containing sufficient sodium to interfere with the aims of salt-limiting diets had been reported by Krishnaswami *(31),* Cech, et al. (10), and Gonzales, et al. (21).

Animal and Other Organic Wastes

The tendency in animal husbandry toward huge confinement-type operations with feedlots containing thousands of cattle and hogs and hundreds of thousands of poultry creates massive and serious waste problems. It has been estimated that domestic animals produce over 1 billion tons of fecal material a year and animal liquid sewage amounts annually to 400 million tons (51). Together with other wastes, such as animal carcasses, the total amount of waste products from animal husbandry is estimated to be around 2 billion tons per year; about half of this is generated in concentrated confinement-type operations.

One of the problems in coping with animal waste stems from its high biochemical-oxygen demand (BOD), the amount of oxygen necessary to decompose organic material present in water, A feedlot of 10,000 cattle may produce a sewage-disposal problem equal to that of a city of more than 160,000 people. The major differences are that sewage from a city of this size would be diluted in about 8 million gallons of water, while feedlot wastes are undiluted. Also, most cities are served by some form of sewage treatment facilities, while often feedlots are not. Table 19 provides estimated population equivalents of the fecal production by animals expressed in terms of BOD.

Other sectors of agricultural manufacturing are also known to contribute wastes with high BOD, These include fruit canning; sugar refining, fermenting, and distillation; animal slaughterhouses; meat processing; dairy cleaning; wool processing; and cotton manufacturing (51). Also, runoff of decaying products from

Table 19.—Population Equivalent of the Fecal Production by Animals in Terms of Biochemical Oxygen Demand (BOD)

Biotype	Fecal G./cap./day	Relative BOD per unit of waste (lb)	Population equivalent
Man	150	1.00	1.00
Horse	16,000	0.105	11.30
cow	23,600	0.105	16.40
Sheep	1,130	0.325	2.45
Hog	2,700	0.105	1.90
Hen	182	0.115	0.14

SOURCE E. H. Wadleigh, *Wastes in Relation to Agriculture and Forestry,* USDA Miscellaneous Publication No. 1085, 1988

plant residues on farms and ranches contributes organic materials to the receiving water bodies.

Oxygen-demanding wastes act to impair the quality of the receiving water. Common effects are depletion of oxygen in bacterial decomposition of organic wastes, changes of conditions in the water from aerobic to anaerobic (putrid), characteristic foul odor, and algae "bloom,"

Water-Treatment Problems

Undesirable effects on water supplies from the overload of oxygen-demanding organic wastes is comparatively well recognized. Recently, however, other problems related to high organic content in receiving water have been identified. When such water is subjected to chlorination at water-treatment plants, some exotic compounds are synthesized by chlorine interactions with organics (4,40). The compounds so formed are collectively known as trihalomethanes (chloroform, bromoform, bromodichloromethane, and dibromochloromethane). Some of these compounds are recognized animal carcinogens and suspected human carcinogens.

The cancer-causing potential of one of these trihalomethanes, chloroform, was suggested as early as 1945 by Eschenbrenner from studies with mice. These results were confirmed later by the National Cancer Institute (37) which reported that chloroform induces certain kinds of tumors in male and female rats. The carcinogenic properties of a related compound, carbon tetrachloride, were demonstrated also with rats and mice, and a possible accumulation of this compound in blood plasma was reported by Dowty and associates (15).

The mutagenic properties of two other trihalomethanes (bromoform and dibromochloromethane) were demonstrated by Simmon and Poole (43) and by Theiss, et al. (46). Brungs (5), in assessing the effect of chlorination of wastewater effluents on aquatic life, concluded that the end-product compounds created after chlorination of wastewater are often entirely different from the original material and are more toxic.

In 1974, EPA undertook the National Organic Reconnaissance Survey that included 80 U.S. cities (45). Chloroform was detected in the drinking water of 95 percent of those cities. It was concluded that trihalomethanes were probably present in almost all drinking water disinfected with chlorine. They are more likely to occur in higher concentrations when surface water is the source of raw water because the organic content of raw water is high, when prechlorination is used, and when the dose of chlorine required to disinfect water is high.

Several epidemiological studies have been carried out to address the association between chlorination and cancer mortality (see, e.g., 9,30,44). Comprehensive reviews have been written by Wilkins, et al. (54), Shy and Struba (42), and Crump and Guess (12), While differences of opinion with respect to existing evidence are still considerable, prudence dictates increased efforts to reduce the organic load in water destined for drinking. In February 1978, EPA amended the National Interim Primary Drinking Water Regulation by setting a maximum contaminant level (MCL) at 0.1 mg/l for trihalomethanes in community water systems serving populations greater than 75,000 persons and by specifying trihalomethane monitoring requirements for smaller communities. To meet these regulations, some cities have to remove or reduce the content of precursor-organics in raw water prior to its treatment with chlorine, which means that the burden of dealing with the high organic load falls on municipalities.

Waterborne Infectious Diseases

Agricultural wastes also are important potential sources of infection, Leachates from barnyards and feedlots carry animal-disease agents. Residues and litter from crops, orchards, and forestry operations are often sources of plant diseases and breeding places for insects.

Many animal diseases are infections shared by humans and other vertebrates. Table 20 shows selected diseases of worldwide distribution and / or relevance in the United States. The list is by no means all inclusive. It is, however, illustrative of a number of diseases shared by animals and humans for which water is known or suspected to be the route, or one of several routes, of transmission.

Agricultural Chemicals

According to a recent FDA report, more than 300 exotic chemical compounds are in use in the agricultural sector of the United States and other countries (39). The word ''pesticide" encompasses categories of chemicals such as:

- insecticides—agents designated to control insect pest infestations of plants, animals, and humans;
- herbicides or defoliants—chemicals designated to control undesirable plants in the vicinity of beneficial plants (including aquatic plants);
- fungicides–chemicals used for control of fungal growth;
- rodenticides—chemicals that control rodents that would otherwise consume farm products;
- fumigants—gases or aerosols used to control pest organisms in the soil or in buildings; and
- larvicides and molluscicides–agents that control undesirable larval or mollusk populations in terrestrial or aquatic environments,

Historically, the use of pesticides has been of great value to society. For example, pesticides have helped control insect carriers of various communicable diseases (typhus, malaria] and have increased the agricultural output of food, Tschirley (48) has pointed out that despite intensified and accelerated research on alternative methods of pest control, there will probably be some continuous need for chemical pesticides. He has stated that "agricultural scientists cannot conceive of producing an adequate supply of food, feed, and fiber on the acreage now used for agriculture without judicious use of pesticides. "

The unauthorized or careless use of pesticides may, and has been known to, cause harm. For some pesticides the margin of error is very small (48). Acute effects from unintended exposure to a large dose of toxic chemicals have been recognized. Quite another matter is the question of the impact of chronic human exposure to trace levels of pesticides distributed in the environment. This issue is much more complex, sensitive, and unsettled.

When pesticides are applied, it is very difficult to avoid an exposure of nontarget organisms in the vicinity. Some chemicals decompose readily and rapidly in the soil and thus are of little concern. Others, however, tend to persist for an appreciable length of time and become widely distributed in the environment, across land, water, and air.

Some resistant and fat-soluble pesticides tend to concentrate in animal tissues and to magnify biologically in the successive steps in the food chain. The concern over such persistence and accumulation in the environment and also in tissues of fish, birds, wild and domestic animals, and humans has brought notoriety to one group of insecticides, the chlorinated hydrocarbons. Other agricultural chemicals may be contaminated with a toxic byproduct of manufacture, dioxin, Many chemicals, currently banned, may continue to reside in the environment, being carried by and deposited in water which is then applied to other uses, The following discussion is illustrative of the concern in this complex and difficult area over past and

Table 20.—Selected Infections and Infestations Shared by Humans and Vertebrate Animals

Disease	Causative organism	Principal animals involved bacterial diseases	Known geographical distribution	Probable means of spread
Anthrax	Bacillus anthracis	Cattle, sheep, goats, horses, and wild herbivorous animals	Worldwide	Occupational exposure (hand dead animals) occasionally recreational exposure, from wounds or insect bites. Rarely airborne or food borne. Waterborne in animal to animal transfer
Brucellosis	Brucella abortus Brucella melitensis Brucella suis Brucella canis	Cattle Goats and sheep Swine, caribous Dogs	Worldwide	Occupational exposure. Foodborne. Waterborne in animal to animal transfer
Melioidosis	Pseudomonas pseudomallei	Rodents, sheep, goats, horses, swine, nonhuman primates, and kangaroos	Asia, Australia, East India, South America, and United States	Exposure and ingestion. Organism lives in soil and water
Salmonellosis	Salmonella spp. (2,000 serotypes)	Poultry, swine, cattle, horses, dogs, cats, wild animals and birds, reptiles, amphibia, and crustacea	Worldwide	Ingestion, occupational and recreational exposure. Wound infection
Staphylococcus	Staphylococcus spp.	Domestic animals	Worldwide	Ingestion and contact
Streptococcus infections	Streptococcus species. Some species host-specific and only accidentally are the cause of disease in humans	Domestic animals	Worldwide	Ingestion and contact
Tuberculosis	Mycobacterium bovia	Cattle, nonhuman primates	Worldwide, except for countries that have eliminated the disease in cattle	Ingestion, inhalation, and occupational exposure Organism is capable of surviving in water
Tularemia		Rabbits, dogs, cats, rodents, and sheep	Circumpolar in northern hemisphere of America, Europe and Asia	Occupational (hunters) and recreational exposure to water, insect bites, and ingestion

SOURCE Abstracted from Cech, 1983 Original source" U S Department of Health and Human Services, Public Health Service, Centers for Disease Control, Center for Infectious Diseases and the Off Ice of Biosafety Atlanta, Ga and the University of Texas School of Public Health, Health Science Center, Houston, Tex. Revised in 1982. Courtesy of Professor James Steele, D V M present uses. A number of new products enter the agricultural market every year.

Chlorinated Hydrocarbons

Chlorinated hydrocarbons include Aldrin, Dieldrin, Endrin, Chlordane, Heptachlor, Oxychlordane, and Heptachlor Epoxide. (These compounds are grouped under the common term "cyclodienes.") Tables 21 and 22 illustrate pesticide concentrations reported in animal milk and human milk. Cyclodiene insecticides have been recognized as animal carcinogens. NAS (36) has characterized this group as "the most hazardous of all pesticides because of their persistence, fat storage, and central nervous system target site. " In conclusions and recommendations on cyclodiene pesticides, the NAS report states:

> The cyclodiene insecticides—particularly the persistent expoxides, Dieldrin, Endrin, Heptachlor Epoxide, Oxychlordane—present the greatest hazards of all residual pesticides in water. At low dosages, they are highly active hepatocarcinogens and have a dangerous effect on the central nervous system of man and higher animals, leading to apparently irreversible changes in encephalographic and behavioral patterns , , . .

and further:

> In light of the above and taking into account the carcinogenic risk projections, it is suggested that very strict criteria be applied when limits for Dieldrin, Heptachlor, and Chlordane in drinking water are established.

Table 21 .—Organochlorine Insecticides in Illinois From Cow's Milk (ppm)

Insecticide	1971	1972	1973	Average
Chlordane	0.02	0.04	0.06	0.05
DDT	0.05	0.02	0.03	0.03
Dieldrin	0.08	0.04	0.08	0.07
Heptachlor .	0.03	0.03	0.05	0.05
Lindane	Trace	0.02	0.03	0.02

Note Of 200 Samples analyzed, 87% were positive for chlordane, 92% for dieldrin, 93% for heptachlor, and 81% for lindane

SOURCE A Curely and R Kimbrough, "Chlorinated Hydrocarbon Insecticides in Plasma and Milk of Pregnant and Lactating Women, *Arch Environ Health, vol* 18, 1969, pp 156.164

Table 22.–Pesticides in Human Milk

Insecticide	Concentration, ppm	
	Mean	Range
Dieldrin	0.0073	0.0029-0.0146
Heptachlor epoxide. ., ...	0.0027	<0.0001-0.0044
DDT-T	0.0027	0.0404-0.1563

SOURCE A Curley and R Kimbrough, "Chlorinated Hydrocarbon Insecticides in Plasma and MI I k of Pregnant and Lactating Women, ' *Arch. Environ.* Health, vol 18, 1969, pp 156-164

According to NAS (36), perhaps 600 million pounds of these compounds have been dispersed into the soil, air, water, and food of the United States during the last several decades, and little is truly known about the fate of these compounds. It is recognized, however, that they are very stable compounds and, because of certain properties, become widely distributed throughout the environment.

Traces of these insecticides and their stable byproducts have been found in water nearly everywhere in the United States. The following average concentrations were reported by Breidenback and coworkers in 1967 (5):

Aldrin, <O.001–O.006 parts per billion (ppb)
Dieldrin, 0.08-–0.122 ppb
Endrin, 0.008–0.2144 ppb
Heptachlor, 0–0.0031 ppb
Heptachlor Epoxide, 0.001–0.008 ppb.

Samples of finished drinking water taken in the late 1960's and early 1970's from the Mississippi and Missouri Rivers were positive for Dieldrin, Endrin, and Chlordane. Surveys of drinking water have identified traces of cyclodienes in public water supplies in Miami, Seattle, Cincinnati, New Orleans, and other cities. Water treatment apparently is incapable of totally removing these pesticides even with activated carbon filters (36).

pesticides are regulated under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). This act, as Tschirley (48) pointed out, is essentially a "labeling law, " It allows the registration of so-called "economic poisons" by the U.S. Department of Agriculture [USDA) in situations where products are designated for interstate commerce. It further allows the seizures of unregistered or insufficiently labeled pesticides. In 1972 an amendment to FIFRA

was passed, giving EPA the authority for control over end-uses of pesticides.

The cyclodiene insecticides Aldrin and Dieldrin were banned by EPA on October 1, 1974. Chlorodane and heptachlor registrations were suspended for use on agricultural crops on April 1, 1976. DDT was another chlorinated hydrocarbon insecticide in widespread use from World War II until its ban in 1972. * Because of its slow biodegradation and high-fat volubility, this chemical also became widespread in the environment. DDT has been detected in milk and many other food products. Table 23 shows daily dietary intake estimated for an average 16- to 19-year-old U.S. male in the period 1965-70. The significance of these residues in the environment is not adequately known.

Dioxin

Contamination of irrigation water with herbicides was reported by the Federal Water Pollution Control Administration in 1968. In recent years the herbicide of phenoxy-type 2,4,5-T and also 2,4,5-TP (Silvex) have received much attention, mainly in connection with their associated chlorinated dioxin, TCDD (or 2,3,6,8 -tetrachlorodibenzo-p-dioxin). By itself, 2,4,5-T (or 2,4,5 -trichlorophenozyacetic acid) herbicide is only moderately toxic. However, it is now known that manufacturing of **2,4,5-T** herbicide is accompanied by formation of an extremely toxic byproduct, TCDD, or dioxin, and that this dioxin may be present as a contaminant of technical grade herbicide 2,4,5-T and also Silvex.

*DDT and DDT-related products, DDD (2,2 -(p-chloropheny l)-1, 1-dichloroethane) and DDE (2,2 -bis-(p-chlorophen yl)-1, 1-dichloroethylene) are collectively known as DDT-T.

Table 23.—Pesticides in Diet

Pest icicle	Daily dietary intake, mg						
	1965	1966	1967	1968	1969	1970	6-yr average
DDT	0.031	0.041	0.026	0.019	0.016	0.015	0.025
DDE	0.018	0.028	0.017	0.015	0.011	0.010	0.017
DDD	0.013	0.018	0.013	0.011	0,005	0.004	0.011
DDT-T	0.062	0.087	0.056	0.045	0.032	0.029	0.053

SOURCE" National Academy of Sciences, National Research Council, *Drinking Wafer and Heallh* (Washington, D C U S Government Printing Office, 1977)

The President's Scientific Advisory Committee (Panel on Herbicides) moved in 1971 that, in the future, production of 2,4,5-T herbicide shall not contain more than 0.1 mg/kg of dioxin as a contaminant (it has not been feasible to produce 2,4,5-T herbicide totally free of dioxin), Existing stock manufactured before 1971 was allowed to be marketed only if dioxin was limited to 0.5 mg/kg,

According to the Council on Scientific Affairs of the American Medical Association Advisory Panel on Toxic Substances (3), at one time as much as 70 ppm of the dioxin TCDD was present in the commercial formulation of these herbicides. Since manufacturers have become aware of the problem, products contain dioxin impurities at levels normally below 0,01 ppm. Dioxin maybe generated during incineration of some chlorinated compounds in industrial and municipal wastes and by burning vegetation treated with phenoxy-type herbicides,

Dioxin is not particularly soluble in water, but it binds tightly to clay particles and thus can be carried into water by sediment transport. This compound is toxic at extremely low levels, much below the reliable limits of detection, Dioxin "may well be one of the most toxic substances known to man, " according to the Advisory Panel on Toxic Substances of the American Medical Association (3). Symptoms of exposure to dioxin have been reported as chloracne, impaired liver function, nephropathy, irritation of gastrointestinal tract, depression, and irritation of nervous system (36). Pathological changes in the liver, peripheral nerves, blood-forming organics, and the reticuloendothelial system (3) have also been noted,

In assessing the situation with regard to toxicity and the long-term health effects of dioxin, the Advisory Panel on Toxic Substances formed by the Council on Scientific Affairs reported that "although data from studies on experimental animals tend to support some of these claims, it is not certain that the animal data are extrapolatable to man" (3). The council therefore recommended a continuation and expansion of the studies of exposed or allegedly exposed persons to alert all physicians through American Medical Association publications to the possible adverse effects and signs of dioxin exposure and to enlist their cooperation in the collection of vitally needed information.

DBCP

Another example of recent concern over agricultural chemicals that may still be polluting the water supply and affecting humans is DBCP (dibromochloropropane)—an agricultural chemical widely in use prior to 1977. In 1977 it was reported that DBCP had caused infertility in male factory workers exposed to it. Studies initially conducted in the agricultural chemical plant in Lathrop, Calif., and later in three other DBCP manufacturing plants, found a total of 100 cases of abnormally low-sperm counts (49). In September 1977, DBCP was banned from manufacturing and agricultural application in the United States.

According to Glass and associates (20), workers who applied this chemical in the field situation were probably the largest group of people exposed to this nematocide. Glass pointed out that prior to the ban on DBCP in 1976, several thousand independent farmers and professional pesticide applicators in California alone applied more than 1 million pounds of this chemical to more than 50,000 acres of land.

Public Health Effects

In 1977, the NAS National Research Council reported that a large number of synthetic organic compounds had been detected in drinking water in the United States. From the compounds known to be present in water, a fraction were selected for detailed review of their health significance. Among compounds selected for scrutiny were 55 pesticides and 74 nonpesticide organic chemicals. It was indicated that some of the pesticides studied had not been observed in drinking water but were included because of their widespread and heavy use.

Of the pesticides studied, 23 compounds were identified for which positive data on carcinogenesis existed. These compounds are listed in table 24. The category of confirmed animal carcinogens included such well-known pesticides as Dieldrin, Heptachlor, Chlordane, DDT, Lindane, B-BHC, Aldrin, Kepone, and several others, The insecticides Endrin and Heptachlor Epoxide and the fumigant Bis (2-chlorethyl ether) **were** classified as "suspected animal carcinogens. "

In this NAS study, data to estimate risk from human exposure varied widely. For some compounds it was possible to estimate acceptable daily intake (table 25); for others it was not possible (table 26), As a result of its assessment, NAS (36) concluded that:

> The potential for existing concentrations of organic pesticides and other organic contaminants in drinking water to adversely affect

Table 24.—Categories of Known or Suspected Organic Chemical Carcinogens Found in Drinking Water

Compound	Highest observed concentrations in finished water, µ/liter
Human carcinogen:	
Vinyl chloride	**10**
Suspected human carcinogens:	
Benzene	10
Benzo (a) pyrene	D
Animal carcinogens:	
Dieldrin	**8**
Kepone	ND
Heptachlor	D
Chlordane	0.1
DDT	D
Lindane (γ-BHC)	0.01
ßBHC	D
PCB (Aroclor 1260)	3
ETU	
Chloroform	366
a-BHC	D
PCNB	ND
Carbontetrachloride	5
Trichloroethylene	0.5
Diphenylhydrazine	1
Aldrin	D
Suspected animal carcinogens:	
Bis (2-chloroethyl) ether	0.42
Endrin	*008*
Heptachlor eposide	D

D = Detected but not quantified, ND= Not detected

SOURCE National Academy of Sciences, National Research Council, Drinking *Water and Health* (Washington, D C U S Government Printing Office, 1 977)

Table 25.—Organic Pesticides and Other Organic Contaminants in Drinking Water, Concentration, Toxicity, ADI, and Suggested No-Adverse-Effect Levels

Compound	Maximum observed concentrations in H_2O, µg/liter	Maximum dose producing no observed adverse effect, mg/kg/day	Uncertainty factor[a]	ADI[b] mg/kg/day	Suggested no-adverse-effect level from H_2O, µg/liter assumption 1	2
2,4-D	0.04	12.5	1,000	0.0125	87.5	*4.4*
2,4,5-T		10.0	100	0.1	700	*35.0*
TCDD		10^{-5}	100	10^{-7}	7×10^{4}	3.5×10^{5}
2,4,5-TP	detected[d]	0.75	1,000	0.00075	5.25	**0.26**
MCPA		1,25	1,000	0.00125	8.75	**0.44**
Amiben		250	1,000	0.25	1,750.0	**87.5**
Dicamba		1.25	1,000	0.00125	8.75	**0.44**
Alachlor	2.9	100	1,000	0.1	700.0	**35.0**
Butachlor	0.06	10	1,000	0.01	70.0	**3.5**
Propachlor		100	1,000	0.1	700.0	**35.0**
Propanil		20	1,000	0.02	140.0	**7.0**
Aldicarb		0.1	100	0.001	7	**0.35**
Bromacil		12.5	1,000	0.0125	87.5	**4.4**
Paraquat		8.5	1,000	0.0085	59.5	**2.98**
Trifluralin (also for Nitralin and Benefin	detected	10	100	0.1	700.0	35.0
Methoxychlor		10	100	0.1	700.0	35.0
Toxaphene		1.25	1,000	0.00125	8.75	0.44
Azinphosmethyl		0.125	10	0.0125	87.5	4.4
Diazinon		0.02	10	0.002	14.0	0.7
Phorate (also for Disulfoton)		0.01	100	0.0001	0.7	0.035
Carbaryl		8.2	100	0.082	574	28.7
Ziram (and Ferbam)		12.5	1,000	0.0125	87.5	4.4
Captan		50	1,000	0.05	350	17.5
Folpet		160	1,000	0.16	1,120	56.0
HCB	6.0	1	1,000	0.001	7	0.35
PDB	1.0	13.4	1,000	0.0134	93.8	4.7
Parathion (and Methyl parathion)		0.043	10	0.0043	30	1.5
Malathion		0.2	10	0.02	140	7.0
Maneb (and Zineb)		5.0	1,000	0.005	35	1.75
Thiram		5.0	1,000	0.005	35	1.75
Atrazine	5.1	21.5	1,000	0.0215	150	7.5
Propazine	detected	46.4	1,000	0.0464	325	16.0
Simazine	detected	215.0	1,000	0.215	1,505	75.25
Di-n-butyl phthalate	5.0	110	1,000	0.11	770	38.5
Di (2-ethyl hexyl)	30.0	60	100	0.6	4,200	210.0
Hexachlorophene	0.01	1	1,000	0.001	7	0.35
Methyl methacrylate	1.0	100	1,000	0.1	800	35.0
Pentachlorophenol	1.4	3	1,000	0.003	21	1.05
Styrene	1.0	133	1,000	0.133	931	46.5

aUncertainty factor—the factor of 10 was used where good chronic human exposure data was available and supported by chronic oral toxicity data in other species, the factor of 100 was used where good chronic oral toxicity data were available in some animal species, and the factor 1,000 was used with limited chronic toxicity data.
bAcceptable Daily Intake (ADI)—Maximum dose producing no observed adverse effect divided by the uncertainty factor.
cAssumptions Average weight of human adult = 70 *kg, Average daily intake of water for man = 2* liters

1 *20%* of total ADI assignment to water, 80% from other sources.
2. 1% of total ADI assigned to water; 99% from other sources
dDetected but not quantified

SOURCE National Academy of Sciences, National Research Council, *Drinking Water and Health* (Washington, D C US Government Printing Office, 1977)

Table 26.—Organic Pesticides and Other Organic Contaminants Found in Drinking Water, With Insufficient Data on Chronic Toxicity to Calculate an Acceptable Daily Intake

Concentration	Highest concentration in finished water, µg/liter
Acetaldehyde	0.1
Acroleina	
Bromobenzene	detected[b]
Bromoform	detected
Carbon disulfide	detected
Chloral	5.0
Chlorobenzene	5.6
Cyanogen chloride	0.1
1, 2-Dichloroethane	21.0
2, 4-Dichlorophenol	36.0
2, 4-Dimethylphenol	detected
e-Caprolactam	detected
Hexachloroethane	4.4
o-Methoxyphenol	detected
Methyl chloride	detected
Methylene chloride	7,0
Phenylacetic acid	4.0
Phthalic anhydride	detected
Propylbenzene	<5.0
t-Butyl alcohol	0.01
Tetrachloroethane	4,0
Tetrachloroethylene	<5.0
Toluene	11.0
Trichlorobenzene	detected
1, 1, 2-Trichloroethane	1,0
Nicotine	3.0
Methomyla	
Cyanazine	detected
Xylene	<5.0

aNot detected in finished drinking water
bDetected detected but not quantified

SOURCE" National Academy of Sciences, National Research Council, Drinking Water *and Health* (Washington, D C U S Government Printing Office, 1 977)

health cannot be answered with certainty at this time. The key issue is whether or not certain organic chemicals found in very low concentrations can cause or increase the rate of cancer development in man. Even though several of these chemicals have demonstrated carcinogenicity in laboratory animals, the extrapolation of such results to man remains difficult for a number of reasons.

Among the reasons for uncertainty was the difference in dosage: the doses at which tests are conducted are many times greater than the concentrations of the **same** chemicals found in drinking water. Therefore, risk at low levels of exposure is derived, out of necessity, by extrapolation from high doses. "There is no real hard evidence," it was said, "that low-level exposure to the same chemical produces cancer," The 1977 report summarized NAS's position on pesticide use as follows:

> Demonstration that a pollutant is carcinogenic, and application of nonthreshold risk estimates to it, do not imply that its use must be prohibited. Such a prescription might itself give rise to even greater risks to health or other disadvantages. In some cases, a net risk must be estimated, and society must attempt to use the pollutant in such a way as to minimize risk and maximize benefit.

DATA COLLECTION

Water-Quality Monitoring

The only coherent nationwide information on water quality is provided by a monitoring system established by USGS in 1975. The National Stream Quality Accounting Network (NASQAN) is an assemblage of monitoring stations located in different river basins and subbasins, The size of the network is increasing and now numbers over 500 stations, of which approximately half are in the Western United States. The same data have been collected on the same pollutants since the inception of the network.

The stations included in the NASQAN network were established to measure the amount of surface water flowing out of a watershed. For this reason, they are not necessarily located where water is used. In some cases, the watersheds which the stations were established to monitor are located upstream from major pollution sources, In other cases, the station may be located substantially downstream of such sources, For those pollutants that do not degrade or otherwise change in the water, downstream monitoring locations may be adequate. However, some water pollution problems are quite localized. For example, the depletion of oxygen in a stream near the point where municipal sewage or agricultural organic wastes enter may produce serious problems near the point of discharge and be undetectable by the time the river reaches a NASQAN station. Moreover, NASQAN stations do not measure all pollutants. Most toxic organic chemicals, such as those used as pesticides, are not measured. In many cases, monitoring equipment may not be able to measure low concentrations of pollutants which nonetheless may have a significant effect on water quality and long-term implications for human and animal health.

Additional information on water quality is collected by State water pollution authorities. The usefulness of this information, however, is limited because of variations in State programs and monitoring procedures and because the data often cannot be easily obtained. One useful source of State-generated information is the set of reports that State authorities are required to submit to EPA every 2 years under section *305(b)* of the Clean Water Act.

No systematic, comprehensive monitoring of ground water quality exists, Federal legislation adopted subsequent to the Clean Water Act has addressed ground water contamination from selected sources, principally hazardous waste sites. But this legislation (the Resource Conservation and Recovery Act, or RCRA, and the Comprehensive Environmental Response, Compensation, and Liability Act, "Superfund" program) lacks clearly stated ground water-quality objectives.

The Safe Drinking Water Act contains a provision that allows the Federal Government to attempt to prevent pollution of specific aquifers designated as the sole source of drinking water supplies. Since its passage in *1975,* nine aquifers have been designated as sole-source aquifers. Approximately 12 additional aquifers are in various stages of investigation for inclusion,

In 1979, EPA began to integrate its various legislative authorities for ground water quality into a coherent ground-water protection strategy. In a draft published in 1979, the Agency has proposed water-quality goals for ground water and alternative means of achieving those goals. The success with which these goals are met is clearly related to the effectiveness of a ground-water quality-monitoring program, which has yet to be established,

CONCLUSIONS

To evaluate the relationship between water quality and agriculture in the Western United States, it is necessary to consider: *1)* the effects of agricultural uses on water quality for other uses, and 2) the effects of water quality on various agricultural uses. In some cases, these are linked in that an agricultural water use may create a quality problem that affects succeeding users, including agricultural users. In other cases, water-quality changes that are deleterious to agriculture may result from nonagricultural water uses or simply from the processes that determine natural water quality.

The types of possible water pollution are varied and can arise from different uses, They can be summarized in eight general categories:

1. municipal sewage and other oxygen-demanding wastes,
2. infectious agents,
3. synthetic organic chemicals,
4. inorganic chemicals and mineral substances,
5. sediments,
6. plant nutrients,
7. radioactive substances, and
8. heat.

The highest quality water required in agriculture is for domestic farm consumption. Almost all of the water used in this way is taken from water wells, The quality of this water is not routinely monitored, nor is it subject to any routine treatment prior to use, as is the case with municipal domestic water supplies. The quality of this water source is particularly susceptible to degradation because of the many potential sources of contaminants in the farm environment.

Water that is safe for human consumption can also be used by livestock, but some stock can tolerate water of a somewhat poorer quality. It is suspected that many animal diseases can be transmitted by contaminated water. Water for livestock use can either be polluted by natural sources, such as a high natural mineral content of the water or a deficiency of some necessary mineral, by algae "blooms" associated with the discharge of agricultural fertilizers into the water, or by the presence of diseased animals.

The quality of water used in irrigation is very important. Also important is the way in which this irrigation water is applied to the soil and the characteristics of the soil itself. As some water applied in irrigation is lost to evapotranspiration during the growth of plants, the salts contained in that water are left behind in the soil. If this situation is not eventually corrected by the application of additional water to leach the salts out of the soil and return them to the river, this salt buildup will ultimately restrict agricultural productivity. The return flows from this leaching process raise public health implications for downstream drinking-water users.

Present knowledge of water constituents and associated tolerance limits for various users is far from complete. Some tolerance levels are available, however, for evaluating the suitability of water for particular uses. Increased research efforts would contribute to improved information on water-quality aspects of agricultural water use.

The possibility of supplementing irrigation water supplies in some areas with municipal and industrial wastewater is receiving increased attention. The suitability of such water for agriculture depends on its level of contamination and the type of treatment it receives. The most serious reservations concerning this practice have to do with viruses and heavy metals, which are particularly difficult to remove by existing water treatment. There is concern that viruses may remain viable in the water or the soil for long periods of time and pose a significant health threat to both humans and animals.

Water contamination resulting from agricultural practices involves many natural and chemical nonpoint sources of pollution that are particularly difficult to detect and treat. The exact effect of any single practice will be largely determined by the nature of the substance introduced into the water, the concentration at which it is introduced, and the natural capacity of the soil-water system to deal with that substance, Effects may range from increased sedimentation to complicated chemical reactions from synthetic agricultural pesticides that are suspected of causing serious human health problems ranging from cancer to nervous disorders. In all cases, more efficient management of potential sources of water pollution from agriculture will do much to decrease the severity of the impacts.

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