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Executive Summary of the Report "Surface Impoundments and Their Effects on Ground-Water Quality in the United States --A Preliminary Survey"

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EXECUTIVE SUMMARY OF THE REPORT "SURFACE IMPOUNDMENTS AND THEIR EFFECTS ON GROUND-WATER QUALITY IN THE UNITED STATES--A PRELIMINARY SURVEY"

PREPARED FOR THE

U.S. ENVIRONMENTAL PROTECTION AGENCY

OFFICE OF DRINKING WATER

STATE PROGRAMS DIVISION

GROUND WATER PROTECTION BRANCH

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INTRODUCTION

During the period October 1976 to April 1978, EPA (U.S. Environmental Protection Agency) completed an investigation of the potential impact on underground drinking water sources of a variety of surface impoundments that are used for the treatment, storage, or disposal of wastes. These impoundments are commonly referred to as "ponds, pools, lagoons, and pits." The investigation was made as part of EPA's responsibility for controlling subsurface emplacement of wastes as mandated by the Safe Drinking Water Act [P.L. 93-523, Section 1442(a)(8)(c)]. The principal objective of the investigation was to compile preliminary background information, on a State-by-State basis, on the number of surface impoundments, composition of the impounded wastes, mechanisms of ground-water contamination, selected case histories, remedial actions and costs, and existing State regulations. The information was obtained mainly through literature review and through visits, correspondence, and telephone contacts with Federal and State agencies; no field studies or field counts of impoundments were made. Among the limitations in conducting the study were the scantiness of readily available data from central sources and a lack of uniformity among the States in compiling information on impoundments.

The data contained herein have been summarized from the final report of the investigation entitled "Surface Impoundments and Their Effects on Ground-Water Quality in the United States--A Preliminary Survey." This report was prepared for the EPA, Office of Drinking Water (formerly Office of Water Supply), by Geraghty & Miller, Inc., Consulting Geologists and Hydrologists, with assistance from Arthur D. Little, Inc., Consultants, who supplied material on the chemical content of wastes and remedial actions and costs. The above report can be obtained from EPA, Office of Drinking Water, 401 M Street, S.W., Washington, D.C., 20460. In addition to this study, EPA has recently completed or is presently sponsoring a number of studies containing information on surface impoundments, including an evaluation of techniques for managing and monitoring hazardous-waste facilities, regional studies of ground-water contamination, effects of waste-disposal practices, and an assessment of the effects of surface impoundments by the States themselves.

PHYSICAL AND OPERATIONAL FEATURES OF IMPOUNDMENTS

TYPES, USES, AND CONSTRUCTION

Waste impoundments may be natural or man-made depressions, may be lined or unlined, and may range in area from a few tenths of an acre to hundreds of acres. Generally, impoundments are excavated to relatively shallow depths above the water table, and some may be built on the land surface by construction of dikes or revetments. Most impoundments are rectangular or square; some are circular or irregular. Impoundments may be operated individually or may be interconnected, with flow taking place from one impoundment to another in series or in parallel. Many impoundments discharge, either continuously or periodically, to streams, lakes, bays, or the ocean; these are called "discharging" impoundments. Others lose their fluid contents by evaporation or infiltration; these are called "non-discharging" impoundments.

Some impoundments are designed specifically to permit seepage of fluids into underlying earth materials and are commonly referred to as percolation, infiltration, or seepage ponds or lagoons. Others, designed to be watertight, are lined with clay, asphalt, metal, or synthetic membranes or are sited on clayey soils having a very low permeability. Some unlined impoundments are thought to be "self-sealing" as a result of deposition or precipitation of fine-grained materials. Treatment accomplished in impoundments includes reduction in temperature of cooling water, pH adjustment, chemical coagulation and precipitation, and biological oxidation.

The term "pit" is usually applied to a small impoundment that serves a special purpose. For example, pits may be used on farms as storage and curing facilities for animal wastes. In industry, they may be used to discharge highly treated wastewater into the ground. Most pits used for permanent storage of toxic wastes are lined. Many abandoned sand and gravel pits or rock-quarry pits are used to dispose of septic-tank wastes and municipal and industrial sludges.

Factors influencing the potential for ground-water contamination by seepage from unlined surface impoundments include soil permeability, depth to the water table, rates of precipitation and evaporation, nature and volume of wastes, and geochemical characteristics of the soils. The chemical composition of the wastes, especially those consisting of toxic or hazardous substances, is also an important factor in evaluating the potential for ground-water contamination.

SELECTED IMPOUNDMENT PRACTICES

Domestic Sewage Wastes

Domestic sewage wastes, generally defined as wastes of predominantly human origin, are commonly collected, treated, and disposed of by community waste-handling systems owned by municipalities, towns, and subdivisions; institutions such as schools, parks, hospitals, and jails; and commercial establishments such as motels, restaurants, gas stations, and mobile home parks. Treatment systems for domestic sewage range in size from small units handling about 20,000 gpd (gallons per day) to larger units handling about 200 mgd (million gallons per day) or more. Lagoons or ponds are used as minor or major components of such systems. For example, oxidation or waste-stablization ponds and lagoons are the principal waste-treatment units in over 4,000 communities, 90 percent of which have less than 5,000 residents.

Sludge from community waste-treatment systems is treated and disposed of by several methods, including drying in shallow rectangular impoundments that have permeable sand bottoms and are constructed with or without underdrains for leachate control. In some waste-treatment systems, the partly dehydrated sludge is disposed of in unlined storage lagoons; after being filled, these lagoons are covered and abandoned.

Industrial Wastes

Industry employs a wide variety of practices in treating and disposing of waste fluids and sludge, including discharge into ponds for storage, evaporation, recycling, or infiltration. Stabilization ponds are one of the major waste-treatment systems used by industries because industrial wastes are highly variable in composition and may require blending with other fluids. Industrial sludge with or without pretreatment and digestion may be stored in impoundments before disposal in landfills or spreading on the land.

Large volumes of cooling water, mainly from power plants, may be stored in very large cooling ponds and then ultimately discharged to streams or recycled through the plants. Air-scrubber wastes and cooling-tower blowdown may be discharged to streams with or without treatment or may be discharged to lagoons for treatment and retention. Settling ponds are commonly used to handle ash residues from coal-burning utilities. Filter backwash and sludge from municipal water-treatment plants are commonly classified as industrial wastes and generally require treatment before disposal to streams or ponds. The metal smelting and refining industry uses predominantly unlined settling pits and basins for handling waste and scrubber waters.

Oil and Gas Extraction Wastes

The oil and gas extraction industry is believed to be one of the largest, if not the largest, user of surface impoundments in the United States.

Oil and gas is produced commercially in 31 States; Texas, Oklahoma, Louisiana, California, Wyoming, and Alaska are among the leading producers. The number of impoundments differs from State to State, not only in proportion to the production of oil and gas, but also in relation to methods of extraction such as water flooding for secondary recovery.

"Evaporation" ponds formerly were used extensively in Oklahoma, Texas, and elsewhere for disposal of brine and salt water associated with oil and gas extraction. Most of these impoundments were unlined; consequently, large quantities of salty water were lost not only by evaporation but also by seepage into underlying permeable shallow aquifers. Numerous incidents of brine contamination of wells and streams resulted from the use of these disposal methods in Texas and other States. However, earthen ponds excavated in clay, or lined with clay or other material of low permeability, are permitted by a number of States for evaporation of brine and for emergency uses.

Animal Feedlot and Other Agricultural Wastes

The principal potential mechanism for contamination of ground water from feedlot operations is seepage of contaminated water from lagoons that compose parts of waste-disposal systems. Virtually every State has some concentrated animal-feeding facilities for cattle, sheep, hogs, or poultry. Several hundred thousand animal-feeding operations of all types and sizes generate on the order of several billion tons of wastes per year.

Among the types of impoundments used in agricultural waste-disposal systems are debris basins, disposal lagoons, aerated lagoons, holding ponds, and storage lagoons. Debris basins are used to collect solids in runoff from pens and lots; they commonly precede a holding pond. Holding ponds are used to store the liquid part of runoff and animal wastes; they are generally designed to be leakproof and to have sufficient capacity to prevent overflow except during severe storms or other emergencies. Lagoons are designed and operated to encourage biological decomposition of organic wastes; the effluent may be disposed of by evaporation or by land spreading. Lagoons are also used to store manure temporarily or permanently.

NUMBERS OF IMPOUNDMENT SITES AND FLOW DATA

SOURCES OF DATA

The principal regulatory agencies in all States were contacted either by mail or telephone for readily available data on municipal, industrial, agricultural, and oil and gas impoundments. Only 19 States provided computer printouts of industrial or other impoundments that included information on the name of the facility, Standard Industrial Classification (SIC) number, type of treatment, and flow. Some States provided copies of river basin reports that contained data only for impoundment facilities related to municipal and industrial point-source discharges to streams. Visits were made to 16 States to consult with State personnel on case histories of contamination and regulations, to identify impoundment users from NPDES (National Pollution Discharge Elimination System) permit lists, and to examine records of non-discharging impoundments. Because of time and budget limitations, no attempt was made to visit all States or to make a thorough review of the files of the States visited.

Impoundment inventory data from Federal sources consisted mainly of an EPA printout of municipal waste facilities on a State-by-State basis, showing type of treatment, flow data, and population served. EPA also supplied lists of NPDES permitted facilities by State, SIC code number, and permit number.

Inquiries were made by telephone and mail to all EPA Regional Offices for impoundment inventory and case-history data, and visits were made to several EPA Regional Offices to review NPDES lists and files. Other Federal sources of data on impoundments included the U.S. Bureau of Census, U.S. Department of Agriculture, the U.S. Department of Army, and the U.S. Geological Survey.

PRELIMINARY IMPOUNDMENT COUNT

Table 1 shows the total number of waste-impoundment sites of all types, by States, for which data were available or could be reasonably estimated. The minimum estimated total impoundment site count was 132,709*, of which about 75 percent consisted of industrial waste sites, 15 percent of agricultural waste sites, and 10 percent of municipal, institutional, and private/commercial (domestic or sanitary waste) sites. New Mexico led all other States in the number of waste impoundment sites, with a total of about 16,200; Rhode Island had the smallest count--an estimated total of 30.

The total number of municipal impoundment sites was about 6,300, and the minimum total flow from these sites was about 4.2 bgd (billion gallons per day). About 27,800 general industrial sites had a minimum total flow of about 27.3 bgd. The total industrial flow figure, which is heavily weighted by a large amount of cooling-pond water for power plants, is incomplete due to scanty data.

The number of impoundment sites at institutional facilities such as jails, hospitals, schools, and public buildings totalled about 1,500 with the highest number, 150, in Florida. Impoundment sites at private/

*The actual number of impoundments most likely is several times greater than the total site count; the national average is estimated to be 2 to 3 impoundments per site.

Table 1. SUMMARY OF THE NUMBERS OF IMPOUNDMENT SITES, BY MAJOR CATEGORIES AND STATES

State	Municipal	Private-Commercial	Institutional	Industrial	Oil & Gas Extraction	Agricultural	Total
Alabama	156	130	50	583	2	669	1,590
Alaska	6	-	-	100	9	15	130
Arizona	52	63	55	44	6	112	332
Arkansas	180	50	10	66	540	107	953
California	245	560	118	782	910	1,106	3,721
Colorado	137	125	10	103	4,617	245	5,237
Connecticut	11	-	-	48	-	37	96
Delaware	4	10	3	33	-	13	63
Florida	118	1,200	150	217	0	350	2,035
Georgia	195	225	79	205	-	734	1,438
Hawaii	5	5	5	29	-	34	78
Idaho	76	20	10	24	-	454	584
Illinois	413	100	50	445	2,000	659	3,667
Indiana	183	117	62	357	752	1,067	2,538
Iowa	257	245	54	210	-	700	1,466
Kansas	256	64	14	164	4,525	1,063	6,086
Kentucky	29	26	6	944	1,000	136	2,141
Louisiana	81	150	50	552	8,841	323	9,997
Maine	3	10	5	44	-	175	237
Maryland	53	20	18	321	-	111	523
Massachusetts	5	15	5	40	-	8	73
Michigan	142	93	3	279	2,020	692	3,229
Minnesota	235	54	14	52	-	1,185	1,540
Mississippi	283	129	49	266	363	586	1,676
Missouri	332	1,092	50	213	6	1,064	2,757
Montana	130	20	8	64	825	316	1,363
Nebraska	223	15	8	1,180	200	703	2,329
Nevada	23	50	10	110	15	53	261
New Hampshire	8	10	2	41	-	44	105
New Jersey	9	20	5	230	-	13	277
New Mexico	38	28	2	63	16,000	45	16,176
New York	33	100	50	308	265	204	960
North Carolina	147	81	25	282	-	503	1,038
North Dakota	250	10	5	76	1,900	543	2,784
Ohio	88	100	50	1,460	11,000	498	13,196
Oklahoma	260	50	15	354	989	338	2,006
Oregon	104	28	10	88	-	527	757
Pennsylvania	51	41	90	12,300	2,500	359	15,341
Rhode Island	2	10	5	12	-	1	30
South Carolina	255	191	58	81	-	326	911
South Dakota	192	10	5	34	30	379	650
Tennessee	58	30	34	215	100*	339	776
Texas	379	358	142	1,042	6,000	515	8,436
Utah	38	8*	4*	68	317	234	669
Vermont	12	9	2*	244	0	62	329
Virginia	90	51	77	1,409	100	389	2,116
Washington	91	16	11	255	-	672	1,045
West Virginia	48	83	6	1,631	1,000	35	2,803
Wisconsin	223	50	11	103	-	598	985
Wyoming	64	15	5	73	5,000	22	5,179
	6,273	5,887	1,510	27,844	71,832	19,363	132,709

*Probably incomplete.

commercial facilities, such as camps, hotels, motels, restaurants, gas stations, and mobile home sites, totalled about 5,900, with the highest number, 1,200, in Florida. Agricultural impoundment sites, mostly at feedlots, totalled about 19,400, with the highest number, 1,185, in Minnesota.

The total number of oil and gas impoundments is about 71,800; the highest estimated total by an individual State is 16,000 in New Mexico. Oil and gas impoundments are used principally for emergency purposes, such as temporary storage of salt water or petroleum. Other uses are brine disposal and separation of water, oil, and gas. Burn pits and cuttings or mud pits were not included in the count; if these had been included, the total number of oil and gas impoundments most likely would have been increased by some tens of thousands.

CHEMICAL CONTENTS OF IMPOUNDED WASTES

CHARACTER OF THE WASTES

Impounded wastes may be liquid, semi-solid, or solid and may range from harmless to highly toxic, depending on the nature and concentration of the constitutents. The wastes may be classified according to source as industrial and domestic (includes municipal, commercial, and institutional). From a chemical viewpoint, the wastes entering impoundments are composed of inorganic or organic substances or a combination of the two.

Inorganic industrial waste streams are generally characterized in terms of suspended solids, TDS (total dissolved solids), pH, acidity or alkalinity, and specific cations and anions, including heavy metals that form part of a chemical process or product. Treatment is generally physicochemical in nature with separation of suspended solids by the use of settling ponds, clarifiers and thickeners, filters, centrifuges, and coagulation tanks. Dissolved solids can be removed by precipitation, ion exchange, and reverse osmosis or can be neutralized or oxidized. The parameters that are commonly used to characterize organic industrial waste streams are BOD (biochemical oxygen demand), COD (chemical oxygen demand), TOC (total organic carbon), oil and grease, and suspended solids. Other potential contaminants in industrial waste streams are miscellaneous organic chemicals, including phenols, cyanide, and chlorinated hydrocarbons.

Domestic sewage effluent has a high TDS content, various nitrogen compounds, phosphate, sulfate, chloride, BOD, and coliform bacteria. Most of these are natural constituents of human wastes. Locally, detergents, phosphate, heavy metals, and other compounds derived from man's activities are also present in sewage. Some municipal sewage consists of a mixture of domestic and industrial wastes. Sludge from sewage-treatment plants commonly contains heavy metals as well as pathogenic organisms. Leaching of organic substances, nitrate, and other constituents from sewage sludge placed on unlined drying beds or in lagoons is a potential cause of ground-water contamination.

RELATION TO GROUND-WATER QUALITY

Except for a few constituents derived from or adsorbed on aquifer materials during movement of fluids into and through an aquifer, contaminated ground water beneath and near many impoundments, as shown by case-history studies, commonly reflects the approximate character of the source fluids in impoundments. Knowledge of the composition of the impounded waste fluids, therefore, can provide a basis for predicting or explaining the composition of ground water that may be contaminated by seepage of waste fluids from impoundments.

Most of the dissolved inorganic and organic constitutents in waste fluids can move readily into ground water by direct seepage of the fluids through the sides and bottoms of unlined impoundments. Similarly, solids in impoundments may be leached by precipitation or by inflow of other fluids, and following dissolution, the leachate may seep into ground water. Although such factors as pH, sorptive capacity, and the low permeability of some soils may slow down or impede the movement of selected ions, many waterborne contaminants, given an adequate source of supply, sufficient time, and a hydraulic gradient, have the potential for eventually reaching the water table and moving downgradient in an aquifer.

PATTERNS OF GROUND-WATER CONTAMINATION AND CASE HISTORIES

GENERAL NATURE OF THE CONTAMINATION THREAT

A large majority of the surface impoundments in the nation are unlined; consequently, waste fluids that seep down from them constitute a potential threat to the natural chemical quality of underground drinking-water sources, public supply and private water wells, and surface water. Only a very small percentage of these impoundments are monitored routinely or have been investigated in sufficient detail to show the full nature and extent of the contamination threat, but enough case histories have been compiled to indicate that the potential threat could be widespread.

Many impoundments are considered to be virtually watertight, either because of excavation in relatively impermeable natural materials such as clay and silt or the use of liners. Some impoundments are thought to be "self-sealing" and generally present no significant threat to water quality unless the watertight seal is ruptured accidentally or the impoundment overflows.

PATTERNS OF CONTAMINATION

Patterns of contamination of ground water resulting from seepage of wastes from surface impoundments have some common features. Contaminated fluid first seeps out through the bottom or sides of the impoundment under the influence of gravity or hydraulic head differences and then moves slowly downward until it reaches the water table. In beds of extremely low permeability, the fluid may move only a fraction of an inch over a long period of time, but in more permeable materials, the fluid may move at rates of up to several feet per day or more.

Although the concentrations of constituents in wastewater are altered by various physical, chemical, and biological reactions during passage through the unsaturated zone, most dissolved constituents have the potential for entering the underlying saturated zone of the aquifer, especially where the sorptive capacity of the soils is exhausted by continuous seepage of contaminated fluids. Upon reaching the water table, the pattern of flow and the chemical character of the contaminated fluids are influenced by various mechanisms, such as hydraulic head differences, vertical and horizontal permeabilities, attentuation processes, nature of the soils, precipitation, density differences, and other hydrogeologic or geochemical factors.

Generally, the contaminated water seeping into an aquifer from an impoundment assumes the form of a discrete body or plume of contamination. The plume is elongated in the direction of ground-water movement and is usually at least several times longer than it is wide. The boundaries of a plume, which are marked by a zone of dispersion or zone of mixed waters, may be relatively smooth or irregular. Figure 1 shows a plan view and a cross section of an actual plume of metal-plating wastes in Long Island, New York, that contains hexavalent chromium and other heavy metals. The plume, which is now about 1 mile long and 750 feet wide, began developing beneath a cluster of unlined leaky disposal basins in 1941 and is moving very slowly downgradient in a shallow unconfined aquifer. Chromium and cadmium determined in samples from a nearby stream indicate that the contaminated ground water is seeping laterally and upward into the stream.

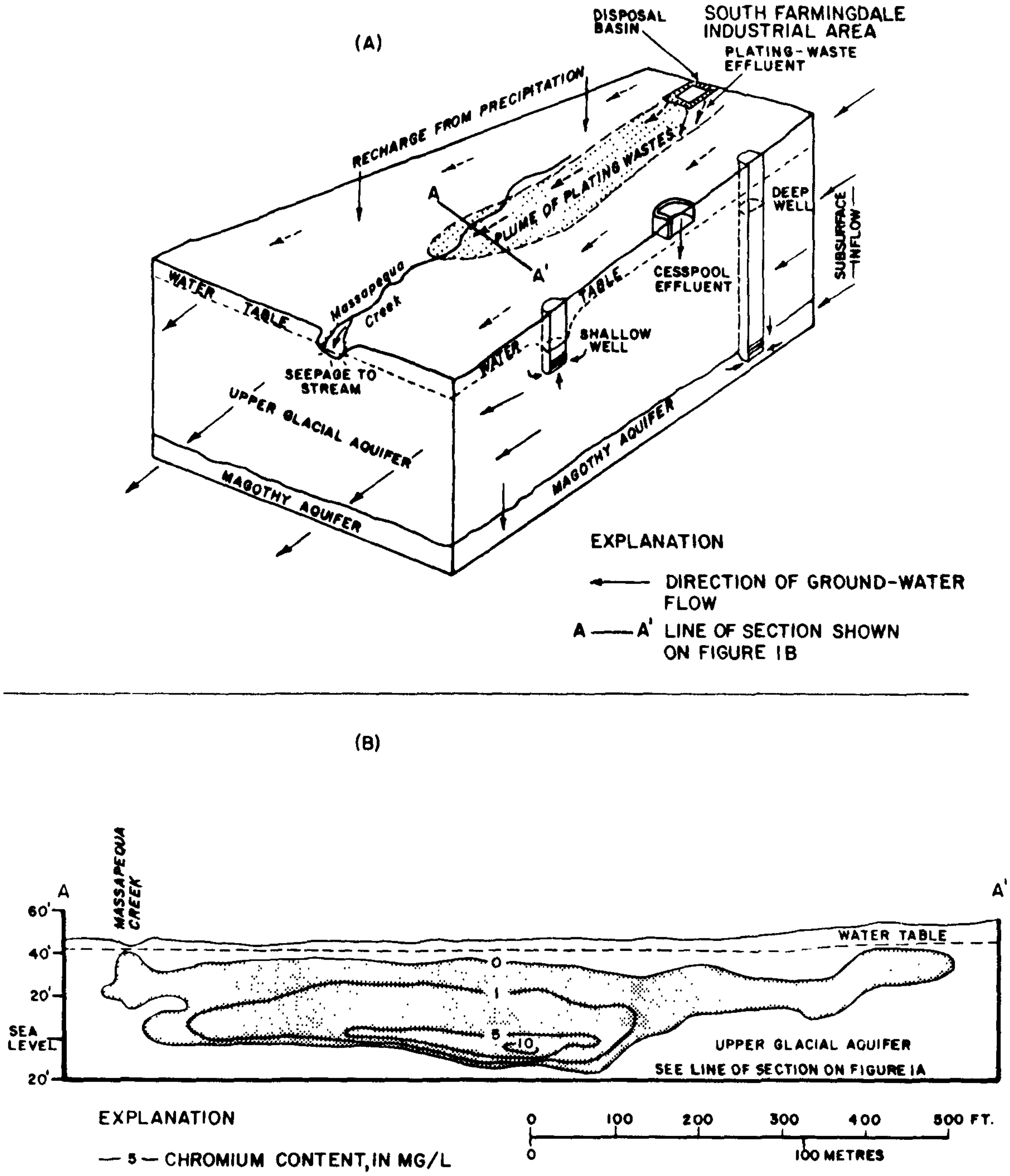

Figure 1. Block diagram (A) showing the aquifer system and areal extent of plume of plating wastes in South Farmingdale, Nassau County, N. Y., and downgradient section (B) showing vertical distribution of hexavalent chromium content in 1962. (After Perlmutter, N. M., and Lieber, M., 1970, U.S. Geological Survey Water Supply Paper 1879G)

Plumes tend to become longer, wider, and thicker as contaminated fluids continue to seep from source impoundments and move downgradient. In places, the leading edge of a plume may be stabilized at a discharge boundary such as a stream or a line of pumping wells.

Contaminants in ground water can be removed or reduced in concentration by attenuation. Attenuation mechanisms include sorption, ion exchange, dispersion, and radioactive decay. The rate of attenuation is a function of the types of contaminants and of the characteristics of the local hydrogeologic framework. Predicting the degree to which contaminants may become attenuated is extremely difficult because of wide differences in the chemical properties of contaminants, in soil properties, and in the hydrologic environment from place to place. Despite the potential for attenuation of wastes, case-history data show that plumes originating by seepage from impoundments can extend downgradient thousands of feet in highly permeable aquifers, especially those composed of sand, gravel, and limestone.

EVIDENCE OF CONTAMINATION FROM CASE HISTORIES

About 85 case histories in 29 States, selected from an estimated several hundred to potentially thousands of cases of ground-water and/or surface-water contamination associated with leaky impoundments, are summarized in the main report of this investigation. Most of the data were summarized from reports published by EPA and from various scientific, technical, and trade journals; data on a small number of cases were obtained directly from some State agencies by mail or during visits. The cases examined were selected at random and were not intended to indicate either the actual or relative magnitude of the contamination problem in any particular industry or State. A number of States such as California, Texas, and Pennsylvania, which have large staffs and stringent controls, have numerous case histories in their files; whereas other States, with small investigatory and enforcement programs, reported few or no contamination incidents from waste impoundments.

The case-history data indicate a general prevalence of contamination problems in the industrial eastern and north-central regions of the United States and also in other scattered areas, particularly in some western and southwestern States where mining and oil and gas extraction are major industries. In addition to these industries, the case histories cover a wide range of other industries, including: timber, pharmaceuticals, steel mills, paper mills, metal plating, meat processing, and one national research laboratory where impoundments are used to dispose of chemical and radioactive wastes. Among the contaminants reported in ground water and/or surface water near impoundments that seep are chloride, sulfate, phosphate, nitrate, ammonia, arsenic, chromium, cadmium, fluoride, zinc, nickel, selenium, molybdenum, pesticides, herbicides, phenols, tannic acid, other miscellaneous inorganic and organics, and radionuclides such as tritium, cobalt-60, and strontium-90.

TECHNOLOGICAL CONTROLS

CONTAMINATION-PREVENTION TECHNIQUES

Direct Methods

A number of direct methods are available that will prevent contaminated fluids in an impoundment from coming into contact with uncontaminated ground water. Some of these methods are applicable only during the construction of new impoundments, and others may be applied to new or existing impoundments. Although many variations and combinations of these techniques are potentially applicable, it is believed that the techniques summarized below cover the range of currently available technology for preventing or controlling ground-water contamination from impoundments.

Alternative 1 - Installation of Impermeable Membrane

One of the commonly used methods for preventing ground-water contamination from impoundments is the installation of an impermeable membrane on the bottom and sides of the impoundment. The membranes most commonly used are made from synthetic materials such as butyl rubber, polyvinyl chloride, polyethylene, polypropylene, and nylon.

Usually, an impermeable membrane must be installed during the construction of an impoundment. The only way to install an impermeable membrane in an existing impoundment is to remove the impounded material, install the membrane, and then replace the material on top of the membrane--a procedure that can be exceedingly difficult, costly, and environmentally risky. If the principal function of an impoundment is the treatment of wastewater, it may be possible to drain the impoundment and to install a membrane. If the installation delays production or if it requires unscheduled plant shutdowns, the resulting costs could make the use of this alternative economically prohibitive.

Alternative 2 - Installation of a Layer of Impermeable Material

Bentonite clay or local clay of suitable characteristics is used to form an impermeable layer on the bottom and sides of an impoundment. It is usually pumped in as a thick slurry and allowed to compact either by subsidence or by mechanical means. Although clay is not completely impermeable, it does have a significant advantage over other membrane liners in that it generally will not deteriorate with age. Also, because it is plastic, it tends to be self-sealing if punctured.

As in the case of impermeable membranes, bentonite and other slurry-like layers are usually installed during the initial construction of an impoundment; installation is not feasible in most operating waste impoundments because of high costs and physical difficulties.

Alternative 3 - Collection of Contaminated Water Seeping from an Impoundment

Where Alternatives 1 and 2 are not feasible, prevention or alleviation of ground-water contamination can be accomplished by collecting the contaminated water seeping from the impoundment and either returning it to the impoundment or treating it to remove the objectionable contaminants prior to reuse or discharge to a stream or lake.

A number of collection systems can be used to intercept contaminated ground water near the boundary of an impoundment. The three most commonly used systems are infiltration galleries, wellpoint systems, and conventional wells.

Infiltration Galleries. An infiltration gallery consists of a gravel-packed trench containing a horizontal perforated pipe along the trench bottom which connects to a vertical casing and pumping system. Infiltration galleries may be useful in places where hydrogeologic conditions make it difficult for standard wells to intercept all the contaminated ground water.

Wellpoint Systems. A standard wellpoint system is useful in dewatering part of an aquifer where the depth to the water table is less than the suction limit, about 25 feet below the land surface. The system consists of a line of screened wellpoints connected to riser pipes, a common header pipe, and a centrifugal pump. Under corrosive conditions, such as pumping acid ground water or water containing high concentrations of dissolved salts, polyvinyl chloride (PVC) wellpoints and headers are used.

Conventional Wells. A series of individual conventional wells can be used to dewater the ground-water reservoir to any depth, provided submersible pumps are installed. Each well is drilled at spacings dependent upon the soil conditions and the corresponding ground-water flow rates. A cone of depression is formed in the water table at each pumped well; the series of pumped wells is designed to have overlapping cones of depression in order to provide a uniform lowering of the water table. In employing this technique, the water drained from the assembly of collection points is combined into a single contaminated waste stream that can be returned to the impoundment or treated prior to discharge.

Alternative 4 - Return of the Collected Water Back to the Impoundment

After collection of contaminated water seeping from an impoundment, as described in Alternative 3 above, the treated water may be discharged to a surface stream, recharged into the aquifer, or simply returned to the impoundment. Although costly and difficult, returning collected water to an impoundment is an attractive alternative because it may not require extensive wastewater treatment; however, this technique is feasible only where it does not cause the level of fluids to rise and eventually overflow the impoundment.

Alternative 5 - Physicochemical Immobilization of Waste Material

A number of proprietary techniques are currently available that are intended to convert waste slurries, sludges, and other semiliquid materials into a solid and more chemically stable mass that is less conducive to leaching. All of these techniques involve some method of mixing the waste material with an immobilizing agent that can be composed of either an inorganic cementitious or an organic polymeric substance.

Inherent in the process is the problem of movement or transfer of material. If the immobilization is performed directly as the waste is generated, the task is merely one of mixing the waste stream with the immobilizing agent and depositing it in an appropriate impoundment. If, on the other hand, the intent is to immobilize the entire body of waste already deposited in a large impoundment, the overall task is far more difficult and costly.

Alternative 6 - Ground-Water Cutoff Wall

A ground-water cutoff wall can be a partial barrier, blocking off the upstream portion of an impoundment that is built in a narrow channel bounded by essentially impermeable materials, or it can encircle the entire impoundment, essentially forming a complete impermeable barrier. The feasibility of employing a ground-water cutoff wall is largely dependent on local hydrogeologic conditions, and it is unlikely that this alternative can be used for many existing impoundments.

Two general types of cutoff walls are: (a) slurry trench cutoffs and (b) grout cutoffs. Slurry trench cutoffs have been used in dam construction for about 40 years and in construction of underground walls. Wall depths of as much as 150 feet have been reported. The trench construction usually involves excavation, filling with bentonite clay slurry, and backfilling with soil. Grout cutoffs are less commonly used as impermeable barriers than slurry trench cutoffs because it is difficult to insure that a continuous grout curtain is formed. Grouting involves drilling holes at selected intervals and injecting the grout solution so that it flows laterally to form a continuous wall.

Alternative 7 - Capping of the Impoundment Surface

Capping an impoundment is intended to prevent precipitation from percolating down through the waste material and eventually reaching the water table. Capping involves placing an impermeable barrier on top of the wastes. Depending on the physical features of the impoundment, this type of barrier can either be an impermeable membrane or a layer of impermeable material such as bentonite clay. In some places it may be feasible to immobilize the upper surface of the waste materials in an impoundment by physicochemical methods.

Capping is not applicable to impoundments containing fluids because where a waste is already in a fluid form it is capable of seeping through the bottom and sides of an impoundment regardless of whether or not there is a cap over it. Capping is also ineffective in preventing a rising water table from coming in contact with and dissolving impounded waste material.

Alternative 8 - Treatment of Contaminated Water

Where it is not possible to prevent the generation of a contaminated waste stream, and where the wastes cannot be returned to the source impoundment, then normally the stream must be treated to remove objectionable contaminants before it can be disposed of into the environment. The type of treatment depends on the overall chemical composition of the waste, the specific contaminants to be removed, and the required composition of the treated effluent.

Although literally hundreds of configurations could be generated from the available types of standard wastewater-treatment and associated sludge-handling equipment, six basic process modules have been defined in this study. The modules, used in various combinations, represent by function the most commonly used types of treatment systems; these are described briefly as follows:

Equalization. Equalization is the use of a holding basin to damp out variations in wastewater flow and composition. An equalization basin is typically installed between the point of collection of the wastewater and the treatment system proper. Many equalization basins are mildly agitated to insure proper mixing of the incoming and stored wastewater.

Biological Treatment. Biological treatment refers to a whole family of treatment processes designed to remove organic material from wastewater by means of biochemical oxidation, using naturally occurring microorganisms. In biological treatment, the organic content of the wastes serves as the food source for the microorganisms, which covert the waste into carbon dioxide, water, and cell mass; these end products then are readily separated from the wastewater as a sludge.

Activated Carbon Adsorption. Adsorption is a complex surface phenomenon in which chemical species in solution or colloidal form preferentially migrate and become attached to the surface of the adsorptive material. Granular activated carbon is the most commonly used adsorbent in wastewater treatment, primarily due to its pore structure which provides a very large adsorptive surface. Activated carbon adsorption is generally used for the removal of organic matter that is partly or totally refractory to biological treatment and to effect further removal of organic matter.

Heavy-Metals Removal. Heavy metals in wastewater can either be in solution or in the form of solid particles. Because of the filtering action of the soil, the heavy metals of principal concern in ground-water contamination are those that are in the soluble phase.

A variety of processes are available for removing heavy metals from wastewater. The most widely used processes are precipitation and settling. Most heavy metals have very low solubility under alkaline conditions, and the addition of lime, soda ash, or other alkaline substances to a wastewater containing heavy metals will cause a large fraction of the metals to precipitate from solution as complex metal hydroxides and carbonates.

Conventional solids recirculation clarifiers are generally used for the settling of the metallic precipitates. The precipitated material is removed from the clarifier as a wet sludge and usually is subjected to dewatering prior to ultimate disposal. The disposal of metallic hydroxide and metallic carbonate sludges requires careful consideration because a significant amount of these materials can be resolubilized under mildly acidic conditions (pH 4 to 5) and may cause renewed contamination problems.

Dissolved-Solids Removal. Wastewater contains a wide range in type and concentration of TDS. Depending on the chemical composition of the wastewater, some of the dissolved-solids constituents are man-made contaminants, and others consist mainly of naturally occurring dissolved inorganic salts. The previously described biological treatment, carbon adsorption, and heavy-metals removal processes help reduce the overall TDS content, but generally the objective is to eliminate specific chemical constituents.

Removal of dissolved solids is usually directed toward wastewater containing high concentrations (more than 5,000 milligrams per litre) of inorganic dissolved solids and is exceedingly difficult and expensive for highly soluble species. Technology similar to desalination techniques must be employed, and the disposal of the salts eliminated from the wastewater can be a significant problem.

Indirect Methods

The following methods can be used in places where a ground-water supply is already extensively contaminated. These techniques would not be acceptable generally as a control strategy for the installation of a new impoundment.

Alternative 9 - Development of a New Source of Water Supply in an Uncontaminated Area

Even after the source of contamination is removed, it can take many years for contaminated ground water to be flushed out of an aquifer naturally. During that period, the users of the contaminated ground water may have no other choice than to obtain a supply of water elsewhere. Generally, this requires construction of an entirely new water-supply system consisting of a well field, a water-treatment plant (if needed), a water-storage reservoir, and water transmission lines.

Alternative 10 - Treatment of Contaminated Ground Water Prior to its Use

In places where the level of ground-water contamination is not prohibitively high, it may be possible to install additional treatment steps at a water-treatment plant that can make use of the contaminated ground water by reducing the concentrations of contaminants to acceptable levels. The type of treatment will, of course, depend on the specific contaminants that must be removed. It is usually not feasible to treat highly contaminated water supplies, partly because of the high cost and partly because of the inability of assuring a continuous supply of water that meets drinking water standards.

STATE REGULATORY CONTROLS

AGENCY ORGANIZATION AND OPERATION

Regulation of surface impoundments by the States is generally in the hands of one or more State agencies, depending on the types of impounded wastes and methods of discharge. In many States, for example, the Health Department has primary responsibility for the regulation of municipal waste discharges, whereas some other agency administers regulations to control industrial waste discharges. Interagency coordination is often through a policymaking commission or board, composed of representatives of agencies such as Oil and Gas Boards, Mining Departments, Water Resources Commissions, Parks Departments, and Agricultural Departments. Most State agencies responsible for the protection of ground-water quality have promulgated their regulations largely on the basis of liberal interpretations of the intent of State law rather than on specific statutory directives.

Waste impoundments may be permitted under Federal or State controls or a combination of both. Twenty-eight States have been authorized by EPA to administer NPDES permit programs for controlling waste discharges to navigable waters and their tributaries. States with and without NPDES authorization commonly operate a State Pollutant Discharge Elimination System (SPDES) similar to the Federal system. In addition, some type of permit or certificate of approval is required in many States for operating various types of non-discharging impoundments such as evaporation or seepage ponds.

Regulations differ somewhat from State to State with regard to reporting by operators, agency inspection of facilities, procedures involving violations of regulations, penalties, and public participation in such matters as the issuance or denial of permits and the promulgation or amendment of regulations. The legal procedures for dealing with violations include: a letter of warning or request to "show cause," usually following informal contact with the alleged violator, and invocation of regulatory requirements for remedial actions, usually in staged fashion, with a deadline set for final compliance. Violations may result in fines, or the courts may order imprisonment, a fine, or both.

Permit requirements for impoundments by State agencies range from highly detailed to very generalized. Although most States, for example, request general data such as the location, type of construction, and use of impoundments, only some States have very detailed requirements concerning information on the local hydrogeologic environment, complete chemical analyses and volumes of contaminated fluids entering and leaving impoundments, use of linings, monitoring systems including sampling wells, periodic field inspections, and other specific elements relating to ground-water quality protection.

Even in States where the rules and regulations appear to provide some measure of ground-water protection, the regulatory agencies may be confronted with workloads far beyond the capacities of their present staffs; therefore, many are unable to carry out the kinds of investigations that would be needed to properly enforce the regulations or to document suspected contamination incidents. Moreover, few State agencies are able to assign staff personnel to work exclusively on surface impoundments and thereby maintain adequate surveillance over these facilities.

TECHNICAL DESIGN CRITERIA

Municipal and Industrial Impoundments

Specific design guidelines or requirements for impoundments, by a few selected States, are summarized below. In many States, however, design requirements mainly emphasize construction and operational criteria that have little or no effect in preventing ground-water contamination.

Missouri. The "Guide for the Design of Municipal Waste Stabilization Lagoons in Missouri" stipulates that:

> "The ability to maintain a satisfactory water level in the lagoons is one of the most important aspects of design. Removal of coarse top soil and proper compaction of subsoil improves the water-holding characteristics of the bottom. Removal of porous areas, such as gravel or sand pockets, and replacement with well compacted clay or other suitable material may be indicated. Where excessive percolation is anticipated, sealing of the bottom with a clay blanket, bentonite, asphalt, or other similar material should be given consideration. A maximum percolation rate of 0.25 inches per day for the finished lagoon floor is included in the specifications for construction."

Tennessee. The "Outline of Engineering Requirements" of the Department of Public Health calls for: (a) location of wastewater oxidation ponds and lagoons 1,000 feet or more from homes, main roads, and business establishments; (b) prohibition against the entry of surface water into the impoundments; (c) a minimum top width of 8 feet for embankments; (d) preference for circular or square design; (e) 2 feet of freeboard for ponds of 3 acres or less, and at least 3 feet of freeboard for ponds over 3 acres; and (f) prefilling of the lagoon prior to operation, and installation of a gage to measure water levels daily for several days.

Washington. "Design Guidelines for Water Treatment Plant Solids Disposal" stipulates with regard to settling ponds that: (a) each impoundment must provide 1 1/2 hours of detention time at maximum backwash rate, plus storage space for solids; and (b) sludge entering dewatering ponds should not consist of more than 8 to 10 percent solids.

Minnesota. Minnesota's "Criteria for Sewage Stabilization Ponds" specifies that: (a) the permeability of the pond seal must be as low as possible and in no case should seepage loss through the seal exceed 500 gallons per acre per day; (b) specifications for siting and construction are based upon a testing program; (c) an approved system of ground-water monitoring wells or lysimeters is required around the perimeter of a pond site; and (d) monitoring is determined on a case-by-case basis depending on proximity to water supplies and on maximum ground-water levels.

Oil and Gas Impoundments

Regulation and surveillance of discharges to impoundments associated with the extraction of oil and gas on private and State lands are usually part of the responsibility of a State Oil and Gas Board. Generally, the degree to which these boards are required to cooperate with State water-pollution control agencies is dictated by the operational rules of the

State Water Resources Commission or other water-pollution control policy-making body. Commonly, the Oil and Gas Commission or Board is represented in the membership of the policymaking unit, which provides a means of coordination with other agencies in matters related to control of water pollution. Typical coordinating agencies are the Geological Survey, the Health Department, and the Department of Water Resources.

Nearly all oil- and gas-producing States allow earthen storage pits and ponds for handling produced water; requirements range from temporary or emergency use only to evaporation use only. Most States stipulate that the impoundments must be constructed in a clayey, impervious soil or have a lining of some type. Generally, however, the regulations are not specific with regard to the type of lining required. A permit or approval for the use of an impoundment is required in most States.

Feedlot Impoundments

State regulations governing animal feedlot operations may be more or less stringent than the NPDES requirements for a point-source discharge. State permits usually apply to both large and small operations and, in some States, is based upon considerations of the ratio of animals to land area. Retention impoundments are the principal form of waste treatment. Most States can require additional treatment as a condition of permit issuance or renewal.

Iowa's feedlot regulations exemplify those of States with detailed regulatory provisions. This State, for example, makes a regulatory differentiation between permit requirements for open feedlots and for fully or partly enclosed confined operations and requires that an open feedlot have a permit if beef cattle population exceeds 100 and lot area per animal is less than 600 square feet. Confined feeding facilities are classified by the number of different species whose wastes are discharged to a lagoon or holding basin, and a permit is necessary for beef cattle populations exceeding 20. The Iowa regulations also provide that, regardless of size, land-carrying capacity, or other specific provisions, all feedlots are subject to inspection if it is determined that a water-pollution problem exists. Permits are required for new operations and expansions of existing facilities. A separate permit must be granted prior to construction, installation, or modification of a waste-storage and disposal system for a permitted facility.

SUMMARY OF FINDINGS

1. There is a minimum estimated total of about 132,700 sites in the United States where municipal, industrial, or agricultural impoundments are used for the treatment, storage, or disposal of wastes. A large percentage of the sites contain more than one impoundment, and most likely, the total number of impoundments is several times greater than the total number of sites.

2. Industrial impoundments constitute about 75 percent of the total number of impoundments and are most numerous in the oil and gas extraction and mining industries. The mining, paper and pulp, and electrical utility industries operate some of the largest impoundments.

3. Municipal, commercial, and institutional impoundments comprise about 10 percent of the total number of impoundments and are used for processing and disposing of sanitary wastes. Agricultural impoundments constitute about 15 percent of the total number of impoundments and are used mainly in handling wastes from animal feedlot operations.

4. Billions of gallons of wastes are placed daily in surface impoundments. These wastes contain a wide variety of organic and inorganic substances, some of which are highly toxic.

5. Most impoundments are unlined, and because a large percentage of them are underlain by permeable soils, the potential for downward seepage of contaminated fluids into the ground water is high. However, only incomplete data are available on the comparative volumes of contaminated fluids that are lost by seepage into the ground water, by evaporation, and by discharge to surface-water bodies.

6. Some contaminants that seep from impoundments may be attenuated in the soil by ion exchange, adsorption, or other geochemical reactions. Others can move readily through soil and into shallow unconfined aquifers, especially where the sorptive capacity of the soil is exhausted by continuous seepage of contaminated fluids.

7. Incidents of ground-water contamination from impoundments have been reported in nearly all States. Although only 85 case histories of contamination involving industries are summarized in the main report, hundreds more of all types are believed to be in the files of State agencies.

8. Case-history studies generally show that the water in shallow unconfined aquifers is the first to be contaminated by seepage of wastes from impoundments. The contaminated ground water is generally in the form of a discrete plume that may be localized or that may extend as much as one mile or more downgradient from an impoundment.

9. Actions that can be taken to prevent or alleviate contamination of ground water from impoundments include: installing impermeable liners; constructing various collection and recycling systems, such as underdrains, infiltration galleries, and wells; pretreating wastes; and retarding or preventing the movement of contaminated ground water by means of hydraulic or physical barriers. Where

none of the foregoing techniques is feasible, it may be necessary to shut down the impoundment and to substitute other waste-disposal methods. Applicability of specific remedial actions at individual sites should be determined on a case-by-case basis. Some preventive measures are feasible only during the construction of new impoundments.

10. Costs of preventive or remedial actions at individual impoundment sites can range from tens of thousands of dollars to millions of dollars.

11. State pollution control or environmental control agencies commonly issue some form of approval for the use of many types of waste impoundments; these range from simple letters of authorization to very restrictive permits. Many States provide guidelines or have specific requirements for siting, construction, operation, and monitoring of impoundments. Many of these requirements, however, relate to construction and operational features that are not necessarily effective in preventing contamination of ground water.

12. There is a wide diversity in the degree of ground-water protection afforded presently by State rules and regulations relating to surface impoundments because of: (a) manpower and budget deficiencies, (b) inadequate knowledge of the scope and nature of the problem, and (c) the fact that many regulatory programs are not stringent enough to deal with the contamination threat.

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16. ABSTRACT

The data contained herein have been summarized from the final report of the investigation entitled "Surface Impoundments and Their Effects on Ground-Water Quality in the United States - A Preliminary Survey." The investigation was designed to provide broad background information on the use of municipal, industrial, and agricultural surface impoundments in the United States, with particular reference to the potential threats they may pose to the quality of underground drinking water resources and to methods of controlling or abating such threats. The study was made by EPA as part of that agency's responsibility for controlling subsurface emplacement of wastes, as mandated by Section 1422(a)(8)(c) of the Safe Drinking Water Act (P.L. 93-523). The principal subjects covered in the report are: (1) numbers, types and uses of impoundments, (2) chemical characteristics of the impounded wastes, (3) mechanisms by which wastes that seep from impoundments may contaminate ground water, (4) selected case-history data on ground-water contamination, (5) technical controls and costs for preventing and alleviating contamination, and (6) State regulatory controls over the use of impoundments.

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