LAND APPLICATION OF WASTEWATER

by

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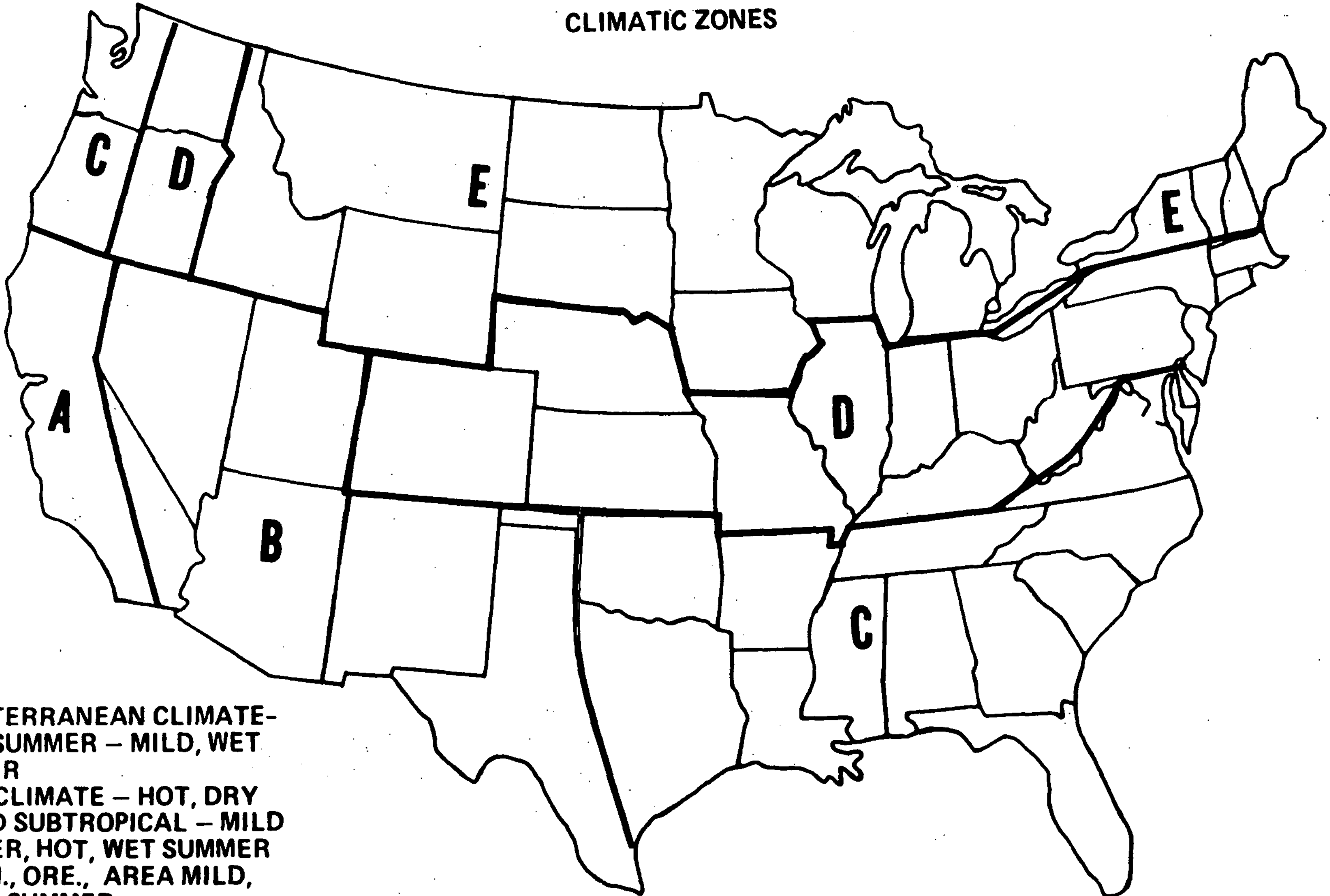
CLIMATIC ZONES



A–MEDITERRANEAN CLIMATE- DRY SUMMER – MILD, WET WINTER
B–ARID CLIMATE – HOT, DRY
C–HUMID SUBTROPICAL – MILD WINTER, HOT, WET SUMMER (WASH., ORE., AREA MILD, MOIST SUMMER
D–HUMID CONTINENTAL – SHORT WINTER, HOT SUMMER
E–HUMID CONTINENTAL – LONG WINTER, WARM SUMMER

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SUMMARY

The American Public Works Association Research Foundation, in 1972, conducted an on-site field survey of approximately 100 facilities in all climatic zones where community or industrial wastewaters are being applied to the land, as contrasted to the conventional method of treating such wastes and discharging them into receiving waters.

Additional data were gathered from many existing land application facilities across the country by means of a mail survey addressed to responsible officials. Another survey was carried out to ascertain the nature and extent of State health and water pollution control regulations governing the use and control of land application systems. To augment information on U.S. practices, a survey was made of experiences gained in certain foreign countries. In addition, an extensive bibliography was compiled of literature on all pertinent phases of land application practices.

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The facilities surveyed were relatively large long-established operations. These were selected to obtain as much information as possible on the operating experience of those using this technique. The surveyed facilities whose municipal wastes were applied on land were predominately located in western and southwestern portions of the U.S., while industrial facilities were generally sited in the northeastern section, because this is where the majority of such installations are in service. This method of handling waste water has been used to meet definable needs and is technically feasible in most areas.

Land application of effluent has been employed for a variety of reasons. Those most frequently mentioned were:

1. to provide supplemental irrigation water,
2. to give economical alternative solutions for treating wastes and discharging them into receiving waters, without causing degradation of rivers, lakes and coastal waters,
3. to overcome the lack of suitable receiving waters and eliminate excessive costs of long outfall lines to reach suitable points of disposal into large surface bodies of water.

Among the major means of accomplishing land application of wastewaters are:

1. irrigation of land areas by spraying, with high-pressure or low-pressure devices, using either stationary or moveable types of distribution systems;
2. ridge and furrow irrigation systems;
3. use of overland flow or flooding methods; and
4. use of infiltration lagoon or evaporation ponds.

Although facilities of all types were surveyed, this report is primarily concerned with irrigation-type facilities for supplying supplemental water to crop areas, forest areas and unharvested soil cover acreages. The other types are not as widely used, because the climate or soil conditions in some locations have an adverse impact on these alternative methods of applying wastewater to land.

Irrigation-type facilities were found to be used in many instances under a wide variety of climate and soil conditions, with various degrees of prior treatment of the applied wastewater and various types of ground cover utilized.

Each method of application has inherent advantages and disadvantages which must be evaluated for their feasibility and efficacy.

Land application of wastewaters has been practiced extensively in various parts of the world for many years, long before the turn of the century. The majority of earlier facilities applied untreated domestic wastewaters with varying degrees of control and success.

As knowledge of wastewater treatment processes improved, and techniques were developed, confining, in a relatively small area, the entire process needed to produce a "treated" effluent for disposal into receiving waters, land application was relegated, in most states, to being an undesirable and unacceptable process.

New concerns about preserving the quality and re-use of the nation's water resources have resulted in a reawakening of interest in land application as a viable alternative to conventional wastewater treatment and disposal into receiving waters. Increasing volumes of sewage and industrial wastes, growing complexity of such raw wastes, and mounting needs for water to serve growing urban and industrial processing needs, have created doubts about the ability of receiving waters to assimilate effluents which do not meet high-quality standards. In addition, increasing evidence of eutrophication of non-flowing receiving waters has focused attention on the need to eliminate the presence of nutrients in wastewater effluents. Further, the presence of toxic trace elements in effluents is sometimes considered a threat to the safety of receiving waters. Thus, advanced treatment methods have been developed and utilized to avoid discharge of such objectionable components. Inasmuch as land application appears to offer comparable or superior degrees of treatment by augmenting waste treatment with the "natural" purification offered by soil contact, land application is again being considered as one of the acceptable means of achieving full treatment of wastewaters.

However, a most important factor of the current land application concept is that it be limited to the use of treated wastes. Generally, effluents are being conventionally treated to meet secondary treatment quality criteria. In at least three observed facilities, applied effluents have received tertiary treatment, to the point where the effluent would fully meet the generally prescribed, as well as proposed, criteria for discharge to receiving waters. Thus, land application is being used to give a degree of advanced waste treatment, including high degrees of nutrient and bacterial removal. In this context, land application can be viewed as an alternative to physical-chemical processes and other methods of ultra-treatment which are designed to achieve a high quality effluent.

Economics of construction cost, operating costs, energy requirements, and efficiencies of performance of land application systems must be balanced with the ability to acquire the right to apply wastewater upon the required land areas. The cost of advanced waste treatment by conventional means must be weighed in the light of the cost and complexities of land application systems.

Two informative reports were published on the subject of land application in 1972. Green Lands - Clean Streams, a report by Temple University Center for the Study of Federalism, is a frankly written advocacy of the land application of wastewaters and sludges.

Wastewater Management by Disposal on the Land by the U.S. Army Corps of Engineers is a thorough review of the physical, chemical, and biological interactions involved in the technique of land application. The Consulting Engineering firm of Metcalf and Eddy has also prepared a companion report for the U.S. Environmental Protection Agency, concerned with engineering considerations of land application systems, entitled Wastewater Treatment and Reuse by Land Application. The M&E report will be printed by the U.S. Government Prining Office in 1973. These three reports, together with this report on the study conducted by the AWPA Research Foundation, should be considered in evaluating land application systems, because they deal with somewhat different aspects of the common problem.

The report on the AWPA studies has made no special effort to examine the specific aspects covered in detail in the other reports. Rather, it is concerned with reporting upon the policies, practices and performances of a representative group of the relatively larger land application systems within the U.S.; policies, or lack of policies, of State regulatory agencies; and the experience with land application in certain foreign installations.

Systems which were under construction, such as Muskegon County, Michigan, and several major domestic and industrial systems which were intimately known to Metcalf and Eddy project personnel were not investigated for this report. However, the firm of Metcalf and Eddy has supplied copies of its field interviews at such sites to APWA evaluators and data on many of these installations have been incorporated in this report. Conversely, all field information obtained during the APWA investigations was supplied directly to the firm of Metcalf and Eddy for its use in analyzing its own study results.

HIGHLIGHTS

The following highlights from the field survey are presented to give a composite picture of the observations made during the land application site visits:

1. Communities generally use their land application system on a continuous basis. Food processing plants, the predominant industrial users of the system, generally use discharge-to-land systems for three to eight months per year.
2. Ground cover utilized for municipal systems is divided between grass and crops. Industries generally use grass cover.
3. Land application systems are generally used on a daily basis, seven days per week.
4. Application rates for crop irrigation are very low in terms of inches of water per week. Two inches or less was commonly used. (Two inches per week equals 48,000 gallons per acre per week.)

5. Many types of soils were used, although sand, loam and silt were the most common classification given. Two systems using applications over many feet of sand were applying up to 8 inches per day once a week, and one system on clay was applying a daily rate of 0.1 inch.
6. Most operating agencies, municipal and industrial, are planning to either expand or continue their land application installations. The few examples of systems which had been abandoned were due to either the desire to make a higher use of the land, or because of reported overloading and incompetent operation of the land application facilities.
7. Industries surveyed generally treat their total waste flow(s) by land application. Practices of municipalities varied from less than 25 percent, to all the wastewaters discharged.
8. Secondary treatment is generally, but not always, provided by municipalities prior to land application, often times accompanied by lagooning. Industries, using this technique frequently treated their process wastes by screening only.
9. Spray irrigation is the most frequently used (57 facilities) method of application, although most municipalities use more than one method. Ridge-and-furrow irrigation is used at 23 facilities and flooding irrigation by 34 systems. Industry generally used spray irrigation.

10. Land use zoning for land application sites is predominantly classified as farming, with some residential zoning in contiguous areas.

11. Wastewater generally is transported to the application site by pressure lines, although a number of municipalities are able to utilize ditches or gravity flow pipelines.

12. Many municipal land application facilities have been in use for several years -- more than half for over 15 years. Industrial systems generally have been in use for a lesser period of time.

13. Renovated wastewater is seldom collected by under-drains; rather, evaporation, plant transpiration, and groundwater recharge take up the flow.

14. Land application facilities generally do not make appreciable efforts to preclude public access. Residences are frequently located adjacent to land application sites. No special effort is made to seclude land application areas from recreational facilities and from those who use these leisure sites.

15. Monitoring of groundwater quality, soil uptake of contaminants, crop uptake of wastewater components, and surface water impacts is not carried out with any consistency.

OVERVIEW

In order to present all of the details and data relating to the conduct of the studies, and to explore the influence of possible factors influencing the handling of sewage from many sources, at many sites, and with many and diverse methods of application, the APWA report has resulted in a rather large document.

Among other things, the report has been compiled to answer the inquiries of the U.S. Environmental Protection Agency from other U.S. Government agencies, municipalities, industries and engineering consultants. The total report is valuable, not because of its size but due to its contents. This is the first time some of this data has ever been assembled, evaluated and reported. It will become available from the U.S. Government Printing Office in the autumn of 1973 and from the National Technical Information Service (NTIS) of the U.S. Department of Commerce.

This overview is for those who require a brief summary of the contents of the American Public Works Association report, entitled, Survey of Facilities Using Land Application of Wastewaters, and an equally concise evaluation of the principles, practices and performances of the land application systems now in service in the United States and in certain foreign countries. Summaries of the basic intent and information contained in each Section of the report are presented as well as a demographic evaluation and a discussion of the fate of materials applied to the land.

The conclusions drawn from the study serve to verify the relative success of present land application systems for supplementing groundwater sources; providing economical means of effluent utilization where discharge to surface waters would be excessively difficult and costly; affording augmented effluent quality improvement by soil uptake of constituents which would adversely affect receiving water quality; offering opportunities to enhance crop growths and silviculture; and augmenting indigenous water supplies for recreational and aesthetic purposes.

Successful application of effluent wastewaters to land areas is not without its problems. This management technique is not a universal panacea.

The need for public acceptance of land application methods is strongly advocated, particularly for proposed installations covering large volumes of flow to extensive acreage in relatively densely populated regions. Over and above the problem of neutralizing the aesthetic and psychological objections to any direct or indirect contacts with wastewaters or wastes residues, unfounded fears of virological or pathological infections must be overcome by carefully planned and effectively executed public education programs.

This public relations problem emphasizes the recommendation that irrefutable findings on the presence or absence of health hazards in land application practices must be defined and reported before guidelines for this method of wastewater effluent management are promulgated. Guidelines are soon interpreted as "the law" rather than suggested criteria. This gives credence to the sound suggestion that formalization of "guidelines" be deferred until "interim evaluation procedures" are published and given the opportunity to bridge the gap between today's rather limited use of land application systems and any greatly expanded utilization of this treatment-disposal procedure in the future.

THE STUDY - SECTION II

The studies conducted by the American Public Works Research Foundation on behalf of the U.S. Environmental Protection Agency were planned and consummated to produce the fundamental information needed to give validity to the intent of Section 201 of the 1972 Amendments to the Water Pollution Control Act such as:

∘Affirmation of design and operational data for a large number of U.S. installations in various climatic regions, handling waste-waters of various types and volumes; by various methods of application; for different purposes; on various types of soil, ground cover and cropping; and demonstrating different local environmental conditions and monitoring practices.

∘Collection and interpretation of similar data on foreign installations where land application has been in effect for longer periods and under varying conditions.

∘Collation of bibliographic records and references on every conceivable facet of land application, including design, operation, physical, chemical, pathological, virological, parasitic, aesthetic, hydrologic, agricultrual, herbicultural, silvicultural benefits and detriments, and other related matters.

◦Evaluation of all data in terms of practical interpretation of their meaningful answers and guidelines to land application practices.

The studies, in great measure, achieved these goals.

SURVEY INVESTIGATIONS - SECTION III

On-site, in-depth investigations of more than 67 community and 20 industrial land application systems were carried out by trained engineering specialists. The 87 installations designated provided data of significance. These sites were chosen to be representative of national experiences with varying types of wastewaters, applied to varying types of soils, ground cover and other indigenous conditions under diverse climatic conditions.

To augment the findings of the on-site surveys, a mail investigation of similar land application sites was carried out, covering the same study subjects explored by the field study team. Significant data were obtained for approximately the same number of municipal and industrial installations covered by the field studies. Five climatic zones, each with their own temperature, precipitation, humidity and seasonal characteristics, were designated. Evaluation of survey findings was interpreted on the basis of the impact of climatic conditions on wastewater application to land areas and other factors influenced by meteorological phenomenon.

The demographic, geographic, geologic, hydrologic and other factors and impacts of land application practices, procedures and performance are discussed in this section.

The findings of the survey offer evidence of acceptable operating experiences, which should be useful in guiding future land application decisions. An important finding, among all of the diverse conclusions that can be drawn from field and mail survey data, is the fact that 90 percent of communities and 95 percent of industries making use of land application methods plan to continue their use; nearly 50 percent of communities and one-fifth of the industries contemplate increasing or expanding their systems. If the "proof of the pudding" is in the performance, the approval of users is the final appraisal of the land application technique.

The study indicated that existing land application systems are serving, predominantly, in relatively small communities and industrial sites, in terms of population and flow loadings. Future applications may involve larger loadings, greater irrigation areas and greater land values, but the expansion of facilities may represent an orderly enlargement of scope and a manageable increase in costs. It is significant that the costs involved in existing land application systems apparently lie within the capabilities of smaller communities and industry installations. Choice of this means of wastewater disposal has been based on various factors: Need for supplemental irrigation water; augmentation of ground water resources; simplicity and economy of providing required degrees of treatment; problems of excessive cost of providing treatment and outfall lines to distant points of effluent discharge into suitable receiving waters; and merely "to get rid of the sewage" in a convenient, trouble-free manner that is acceptable to the community.

The findings of the survey are so manifold and technological that any attempt to capsulate them would hinder their value and endanger their interpretation. The following points are borne out by the report: Existing practice stresses land application of treated effluents, not raw wastewaters; the percentage of land application acreage frequently represents only a portion of the land reserved by the owners for their systems; application periods may vary from one month to twelve months a year, and from one to seven days a week, depending on climatic conditions, need for land application for surplusage flows, seasonal industrial processing, such as in the food industry, and other local factors; land values are relatively low, zoned for either agriculture or residential uses, often in undeveloped areas, and subject to minimal degradation of value due to use for irrigation purposes; all types of soil are utilized, with sand, clay and silt most favored; groundwater interference problems influence choice of sites and, after choice of unaffected sites, cause minimal difficulties with land application methods; predominant wastewater distribution methods are spray irrigation, overland flooding irrigation and ridge-and-furrow irrigation.

Use of the irrigated land varies with the owner's needs and dictates, from no ground cover to grass cover, cultivated crops and forested areas. Grass is the most common ground cover in community systems. It is evident that the cropping value of supplemental irrigation with wastewaters and their nutrient components is not universally utilized.

Rates of application of sewage effluents to the land, and duration of uninterrupted application vary from 0.1 inch per day to over 1 inch per day, with varying periods of irrigation and resting. The most commonly used application rate is two inches per week. Few systems are over-stressed by such loadings; it is apparent that increased rates of application could be practiced without jeopardy to the system or the environment, and with more effective and economical utilization of assigned acreages. The follow-the-leader trend in application rates is apparent; proposed guidelines--either tentative or final--would do much to establish more rational application rates, based on facts rather than blind adherence to the accidental or arbitrary rates used by other researchers.

Little concern and protective measures have been shown for the deterioration of the environment in application areas, or to the impact on contiguous lands and their occupants. Security provisions are not universally used to protect against intrusion of trespassers or against the dispersal of on-site conditions to surrounding land areas. Fencing and patrolling is not universally practiced; buffer zones to isolate land application areas and impede dispersal of aerosol sprays are used but no common practice is in effect; monitoring of groundwater, surface water sources, soils, crops, animals and insects is practiced in some locations and minimally used in others, often dependent solely on the requirements of public health authorities.

It is hazardous to characterize the above thumbnail findings as truly representative of the practices and experiences disclosed by the survey. Similarly, these factors do not represent all of the disclosures of the study. They do however, give indication for those who will not study the full text and details of the comprehensive investigations explored in the full report, that land application methods have been found to be workable and relatively amenable to the local environment, even under control and regulatory procedures which must be improved in all future land application practices. The future will require more complete supervision of land application sites, supported by definitive proof of the capabilities of such systems to serve as wastes handling facilities worthy of the term "alternative" techniques.

OPINIONS AND REGULATIONS OF STATE HEALTH AND WATER POLLUTION CONTROL AGENCIES - SECTION IV

The survey conducted by APWA with State health and water pollution control agencies indicated that most State agencies have no set policies on this phase of wastewater handling or attendant environmental impacts, do not impose specific conditions on installations, seldom inspect existing systems, and seldom require monitoring procedures and the filing of official reports on operation.

Only four States reported rules governing the types of crops that can be grown on sewage-irrigated lands. The few agencies which invoke restrictions of this nature specify the quality of effluents applied to land areas. Of 27 State control agencies which participated in the data-gathering program, a maximum of 25 percent involved themselves with any single item of the 11 guideline criteria covered by the opinion survey.

In defense of this record of irrelevance with the land application practice, it must be said that some States have few such installations and even fewer have installations of any major significance. In addition, States contend that they have been deeply involved with the control and regulation of conventional sewage treatment facilities and stream quality protection. Shortage of qualified personnel has been offered as the reason for absence of attention to the installation, operation and monitoring of land application installations.

In the absence of formal State regulations, some agencies have used unofficial staff opinions as the basis for land application decisions. Similarly, each-case-for-itself decisions on health hazards have been invoked or expressed by State health agencies but a minimum of translation of such policies into specific regulatory actions was disclosed by the survey.

SUMMARY OF FOREIGN EXPERIENCE - SECTION V

Data from such widely located countries as Argentina, Australia, Belgium, India, Israel, Hungary, and Mexico confirm the use and value of the land application technique for various purposes, for a variety of growing crops, under diversified conditions, and with different results. Enhancement of soil productivity, through the mechanics of supplemental irrigation with waste water and the enrichment of soil with the organic constituents of sewage and industrial processing waters are widely acknowledged.

Health hazards have been studied in various countries and protective measures have been invoked. Some countries, such as water-short Israel, utilize wastewaters for irrigation purposes --where over 100 systems are in service, but they tend to avoid the use of raw, untreated sewage and contact with crops that are eaten raw by humans or domesticated animals.

On the North American continent, the most dramatic land application system on record is in Tula Hidalgo, Mexico, where lands operated by the Mexican Federal Department of Agriculture are assigned to Ejidos, heads of families, in units of limited hectares. On 47,000 hectares, equivalent to 115,000 acres, some 1,476,000 metric tons of food products were grown in 1971. Approximately the same tonnage was produced in 1972. Additional arid land is available for cultivation when additional wastewater from Mexico City becomes available. Currently some 570 million gallons per day of raw untreated sewage flows by canal to this area, 95 percent of which reach the cropland. During the rainy season there is an additional storm water flow through the same canal, most of which is impounded in a series of dams for use during the dry season for cropland irrigation.

In England the Hertfordshire facility has had over 20 years experience irrigating liquid digested sludge containing about 3 per cent solids. Technically this land application system is more related to sludge than to sewage effluents, but its long and successful experience confirms the feasibility of that method of land application of wastewaters.

There is a non-technical 16 mm color film, entitled, Wealth from Waste, which shows the Herfordshire operations.

GUIDELINES FOR IMPLEMENTATION OF LAND APPLICATION SYSTEMS - SECTION VI

The survey provided many guidelines that could be translated into "do's" and "don'ts" in land application procedures. In addition the literature searches brought added criteria to light, confirming the basic facts evolved from the survey. From these information sources and others, the report suggests guidelines for the implementation of land application systems.

For the guidance of the regulatory administrator staffs, decision-makers, designers and owners of future land application installations, some tenative procedures have been presented as they may be affected by climatic conditions and applicability of the process to specific meterological phenomenon; availability and location of land areas suitable for wastewater application; rates of application; types of soils, crops and ground cover; methods of application and their relationship with geological, topographical and hydrological conditions; types of wastewater pretreatment to assure proper and safe land application; capital and operating costs; monitoring and health protective measures; and other related aspects of system planning and execution.

References have been drawn from all possible sources to support the tenative parametric procedures outlined in the guidelines. The listed criteria are not presented as "standards"; this would be improperly anticipatory of the next official step which must be taken to distill from this study and the other parallel investigations sponsored by the U.S. Environmental Protection Agency on land application techniques. Rather the guidelines are offered as suggested criteria, a necessary input into the overall fund of information upon which eventual official guidelines must be based. As mentioned in the Overview this gives credence to the suggestion that formalization of guidelines be deferred until "interim evaluation procedures" are published.

PLACING LAND APPLICATION OF EFFLUENTS IN PERSPECTIVE: AN INTERPRETATION - SECTION VII

This section stresses the importance of placing land application techniques in their proper perspective, and interpreting the alternative "pluses" and "minuses" on the basis of local factors and local needs.

It is evident that an "alternative" must be compared with something for which it is an alternative. Thus, the determination of the choice of wastewater utilization process must be based on a full-dimensional decision; and that decision must stem from placing the land application process into the proper perspective with itself and with other means of managing wastewaters.

When viewed in this light, land application technology is not a panacea for all wastes, in all areas, under all circumstances. It is not a "quick and easy" means of getting rid of unwanted wastewaters. It involves adequate pretreatment, effective operational procedures, rigid monitoring controls and rational cost evaluations. As a substitute for the return of waters into the drainage basins from whence it originally came, it can affect the "cycle of water" and create an imbalance in the water resources of a region. Land application can no longer be compared with disposal of wastes by dilution; just as conventional wastewater treatment now involves high degrees of treatment, so land application must assure that the soil will receive highly treated influent water or that the soil will provide the equivalent of tertiary treatment and removal of deleterious components by biological-chemical-physical phenomenon. The effectiveness of land application must be judged by what it accomplishes--not merely as a means of eliminating the direct discharge of comparably well treated effluents into receiving waters.

To fulfill its full possibilities and benefits, land application must be examined from the standpoint of what has become known as the "4-R cycle" -- return of waste water to the local land rather than being lost by stream flowage to downstream areas; renovation of the wastewater by soil and vegetative actions; recharge of the groundwater resources which then become the reservoir aquifer which feeds surface water sources; and the reuse of wastewater either directly off the land or via the tapping of the groundwater reservoir. Practical examples of these land application benefits are available; they must be placed in proper perspective with the needs and potentialities of the area in which a proposed land application project will be constructed as an alternative to conventional wastewater treatment works.

DEMOGRAPHIC EVALUATION OF LAND APPLICATION TECHNIQUES

Demography is the science of social statistics. Wastewaters are the product of people and of industrial production in an urban industrial society. The nature of wastes produced by community life and industrial processing and the amounts of such wastewaters are affected by regional conditions and their impact on life and living processes. Automatically then, the manner in which wastewaters are handled and disposed of is influenced by demography, or regional, environmental needs. For example, the degree of sewage and industrial treatment in the past was influenced by the water resources needs of regional areas and how regulatory bodies interpreted these needs to protect the natural environment and preserve public health and safety. Over and above the natural setting for any region, policies were and will continue to be, affected by population densities, water needs, public desires and antipathies, and other factors. This represents demography in action.

If it were possible to relate the applicability of wastewater management on land areas to such factors as climatic conditions, population and population densities, economic-social patterns, and similar demographic parameters, these would serve as important guides for the choice of this alternative method of wastewater treatment and utilization vis-a-vis today's conventional treatment standards and the advanced degrees of effluent quality that will be required in the future. If such relationships could be established, based on the findings of the APWA Report, or by parallel investigations now sponsored by EPA, the viability of the land application technique could be verified or clinically questioned.

The factors involved in a full demographic evaluation of land application practices appear to be too numerous, too complex and too interwoven to be capable of clarification by the current APWA study. Many of the factors are too intangible to be explained by basic survey data; the type of study parameters used in the current study could not include such incomprehensible implications. But the study did involve the relationships between land application and climatic conditions, and concurrent relationships involving urban populations and densities, industrial operations, local ecological conditions and other indigenous factors.

Climate is a major factor in the applicability of land application procedures, on the purpose and continuity of operation, and on the performance of this alternative technique. In recognition of the importance of climatic conditions, the study was based on the choice of site investigations in five climatic regions of the United States and evaluations were aimed at determining the impact of the specific zonal meteorological characteristics on every phase of the study.

Broadly characterized, Zone A (mid and south Pacific coast) is an area of dry summers and mild wet winters; Zone B (the southwest) is an arid region, with hot, dry climate; Zone C (southeast-Gulf coast-Atlantic coast and Pacific northwest) experiences hot wet summers and mild winters; Zone D (east-continent and northeast Atlantic coast) is subject to humid weather, with short winters and hot summers; Zone E (mid-continent and far northeast) is a humid area, with long winters and warm summers.

While climatic conditions have the most significant impact on the land application principle, other factors have potential bearing: size of the community and the industry; the volume of wastes flow; the population contributing sanitary wastes plus the population equivalent of the industrial wastes contributed to the municipal sewer system; the availability of open land for irrigation use; the land-use zoning of the region; the cost of land; the type of crops to be grown with supplemental irrigation and the market needs and demands for such crops; the groundwater depth and quantities, and their use for water supply purposes, protection against salt water intrusion into aquifers and other functions; the nature of the soil; the proximity of surface waters which can become recipients of conventionally treated effluents; and other correlated circumstances of local or indigenous nature.

It is not difficult to rationalize the effects of these climatic-demographic conditions on land applicaiton practices, and conversely, the impacts of land application on these environmental conditions. It is difficult, however, to translate the findings of the subject into these relationships. Efforts have been made to draw every possible relationship between these various factors but the findings are often too indeterminate to warrant such translations.

The following highlights can provide valuable guidance for decision-makers and designers of land application systems, even though they are not always affirmed and confirmed by study findings.

CLIMATIC CONDITIONS: The 67 community systems and 20 industrial land application sites covered by the on-site visits, and the comparable numbers of such installations covered by the mail inquiry, were representative of the actual total projects in each of the five climatic zones. The major number of community systems surveyed was located in Zones A and B, with California sites predominating. These two zones represent dry and arid conditions which make supplemental water resources--reused water in the form of effluents--a precious commodity. No industrial sites in these zones were surveyed by on-site investigators because minimal use of land application techniques is made by local industrial installations. In lieu of such industrial irrigation projects, communities in Zones A and B accept industrial wastes into public sewers and onto publicly owned application sites in the form of population equivalent loadings.

In Zones C, D, and E, industrial sites were surveyed because the use of land application is practiced more generally in these parts of the nation. The industries involved are primarily food canning-processing factories, dairy processing plants, pulp and paper mills, and organic chemical manufacturing firms.

The differentiation between the zonal incidences of community systems and industry sites is explained, at least in part, by the needs for supplemental water and the uses for such water. Thus, climatic water-short and water-rich areas dictate the retention of sanitary wastewaters in the areas which produce them, or whether to permit them to flow away downstream into other receiving watersheds and water basins.

In regions A and B, water is in relatively short supply, due to dry summers and year-round aridity, and wastewaters are often times considered by communities as a valuable commodity for land irrigation, for groundwater augmentation, and for use for such ancillary purposes as golf course and highway median watering and the creation of recreational water facilities. Industries in these areas however, as in other areas, are less concerned with such beneficial uses of wastewater and may not practice land application; they may use this management procedure primarily for the purpose of "getting rid" of such effluents in the cheapest and simplest manner without adversely affecting the environment.

This brings the matter of wastewater, or used water, economic and ecologic value and utilization into focus as the determining factors in the practice of land application. In arid regions, land application offers strong incentives. In wet, humid regions water-husbanding is not a vital motivating reason for land application installations; but such motivation can be found in the economies of producing high-quality effluent by means of the "free" purification capabilities of soil. Whether planned as a water resource conservation procedure or not, the ultimate fate of wastewaters applied to land areas by spray irrigation and surface application, such as, ridge-and-furrow methods is a means of enhancement of the local groundwater reservoir. The fact that 85 percent of the water stored in the United States is contained in subsurface aquifers adds significance to this wastewater fate.

Climatic, geographic and geologic conditions have other influences on the choice of wastewater disposal systems. Inland areas that have no convenient receiving waters may find it cheaper to apply wastewaters to the land rather than constructing long, expensive outfall lines from their treatment plants to suitable discharge points. On the other hand, the water-cycle imbalance which may occur in local waters by taking water supplies from them and not returning wastewater back to the same rivers and lakes may place a negative aspect on land application procedures. This type of water resource imbalance does not apply to coastal waters.

The relationship between hard winters and land application systems is obvious. In areas where full-year irrigation can be practiced, land application would have greater applicability than where adverse winter conditions would make irrigation inappropriate or inefficient. While land application is practiced in some ice, snow and sub-freezing conditions, optimum conditions are represented by year-round mild weather such as is experienced in Zones A, parts of B, and in C.

Similarly, the relationship between climatic conditions and holding pond capacities is equally understandable. Where seasonal cessation of land application is necessary, the principle of "not one drop of wastes into water resources" impells the construction and use of adequate holding facilities. "Adequacy" is a relative term; 31 percent of community and industrial systems use ponds with capacities of five days or less. In Zones A, B and C, 75 percent of the sites have holding capacities of less than 30 days, or less than needed for a full winter season. One installation in a cold zone provides a 50 million gallon pond for a daily flow loading of 0.5 mgd.

Of some significance, if not as perinent as other seasonal conditions, is the amount of rainfall in humid areas which may impede soil absorption of applied wastewaters and require the use of flow-equalization or flow-holding of excess waters until required rates of application can be reinstated. As stated, where rainfall is generally adequate, if not always predictable, land application for enhancement of crop growths, forest growths and groundwater augmentation is not the dominant reason for the choice of this wastewater management technique.

While the survey studies brought these climatic relationships into focus, they did not alsways provide postitive proof of these effects and impacts. This does not detract from the validity of the above observations. No attempt has been made to draw all possible climatic-environmental relationships with land application principles and practices; however, the rationale is adequate to demonstrate that there is a direct correlation which must be considered before choice of wastewater management is made for each individual project. No set standards can be established; each case will require its own relationship evaluation.

SIZE OF WASTEWATER FACILITY: In the case of publicly owned systems, the population served is translatable into volumetric and qualitative loadings. For industries, the flow loading is a factor of volume and population equivalency of the organic constituents, as measured by BOD, COD, suspended solids and other significant parameters.

The survey indicated that some outstanding large community land application installations have been in service in the United States and foreign countries. However, the major percentage of current operating installations are in the smaller-size range.

The on-site survey disclosed that 73 percent of communities studied have land application capacities of under 5 mgd; the mail survey covered no community systems with over 10-mgd capacity. Industry installations covered by the on-site survey were all under 5-mgd capacities; the mail-surveyed installations were all under 10-mgd size. It is conjectured that the small cities and industries have found land application within their economic range and that adequate conventional treatment would have been more costly.

Size factors are numerous but few showed definitive relationships with other land application site acreage parameters. The area used for irrigation application varied without basic reason from the total acreage owned by the community or industry. In some cases the major extent of the area is used for distribution; in other instances only a portion is so used, the rest of the acreage being devoted to holding ponds, buffer zone and general isolation of sites.

The size of the area varies, naturally, with the volume of flow applied, the nature of the soil and its absorptive character. The effect of climatic conditions, such as rainfall, humidity and temperature, on irrigation area acquired by communities and industries is minimal, despite any impression that such a direct relationship should exist. No specific trend was found in buffer zone regulations and usage. The open land available for such buffering or isolation facilities is undoubtedly influenced by State regulatory agency requirements and the type of distribution systems used (Spray irrigation tends to be associated with buffering acres and plantings to impede the off-site dissemination of aerosol mists and particulates.)

CONTINUITY OF OPERATION: The relationship between continuity of wastewater application, on a days-per-week or a months-per-year basis, and land acreages used for land application was found to be indeterminate. Continuity of operation appeared to be dictated by other factors than availability of site acreage. It is obvious that rates of application should have a bearing on the land areas required, particularly on sites that are limited in size and not over-generous in dimensions. While the analysis of study data does not disclose this relationship, it is undebatable since the failure of irrigated land to handle distributed wastewaters for planned periods will necessitate the resting of such areas and the immediate utilization of other equivalent acreages to replace the overloaded or ponded soil plots.

If wastewater production is in effect for longer weekly or monthly periods and pond storage capacity is not available to retain excess flows, irrigation areas may be affected by the requirement that direct application of produced flows must be provided. Similarly, the land-need requirements for any site will be influenced by whether the system will function on a twelve-month basis or shorter yearly periods.

Communities tend to maintain yearly continuity of land application more completely than industries; broadly interpreted, communities operate full-year at 60 percent of installations, and industries at 40 percent of sites. The relationship between climate and continuity of irrigation was partially clarified by the study, despite the fact that positive patterns were not confirmed. The on-site survey-interview procedures used in the study disclosed that twelve-month continuity of community operation for Zones A, B, C, D and E was practiced in 76, 63, 56, 71 and 67 percent of sites, respectively, while industrial systems showed similar year-round irrigation service in Zones C, D and E of 50, 56 and 30 percent of sites, respectively.

The mail survey showed that industries in Zones A and B (not surveyed in the on-site program) operated on a 12-month basis at 100 percent of the sites of the sites involved, with 100 percent of the Zone C community installations functioning on a full-year basis. Thus, the zonal factors showed little effect of widely divergent climatic conditions on whether systems functioned without cessation.

Full-week service seemed to be dictated more by the actual purpose of land application than by other factors. Full-week irrigation was found to be more common than when crop irrigation was practiced than when wastewater disposal onto grass-cover lands was utilized for groundwater augmentation or for the simple purpose of effluent disposal. Application rates and continuity of irrigation were, surprisingly, unaffected by soil types.

METHODS OF DISTRIBUTION: The relationship between the method of application and climatic conditions was brought into focus by the study. In general, spray irrigation is more commonly used in humid areas than in arid sectors; and surface application techniques, such as ridge-and-furrow irrigation and overland irrigation, are more frequently utilized in arid regions. Zones A and B were characterized by surface application sites.

The relationship between size of site and type of distribution used showed a trend of more or less specificity. Smaller sites were served by twice as many spray systems as surface application facilities. Larger sites, over 1,000 acres in size, were usually equipped with surface application systems; intermediate-sized sites, from about 100 acres to 1,000 acres, utilized spray and surface application systems about equally. In surface application installations, so-called overland flooding which depends on sheet-flow action has been used more frequently than ridge-and-furrow distribution.

No specific correlation was found between distribution methods and soil types, but some generalized patterns were evaluated: Spray irrigation is more commonly used on loam, silt and clay lands; spray and surface application methods are generally used equally on more granular soils. Surface application methods were found more frequently on crop lands or on unplanted, non-cover areas. Spray irrigation was found more frequently on crop lands and forested acreages. Community sites handling under 1-mgd flows were most commonly grass-covered, while larger areas of over 1-mgd capacity generally stressed crop growth. Forest irrigation was practiced more frequently in humid areas than arid regions, probably because tree growth is more common in the humid climatic regions. Cropping on arid region lands is relatively common, indicating the value of wastewater for supplemental irrigation.

Groundwater depths are a dominant factor in choice of sites but, once acquired, these application lands experience minimal impacts on choice of application methods and on operation performance. Obviously groundwater depths are greater in arid regions and are less of a factor in choice of land application sites. Application rates, while not consistently influenced by climatic conditions or soil character, and while varying minimally from the almost traditional level of one-half inch per day and two inches per week, are influenced by aridity and high humidity-precipitation conditions.

LAND AVAILABILITY, LAND USE AND LAND VALUE: A direct relationship between demographic criteria and land availability, zoning use and acreage price is unavoidable. The first requirement of a land application system is land. It must be available in reasonably close proximity to the source of community or industrial wastes; the land must be useable for wastewater application by zoning and other use regulations; the price must not be prohibitive.

These conditions are most commonly met in areas of low population density where open lands are available, and where undeveloped and properly zoned properties can be acquired at relatively low cost. This is why the survey showed the predominance of land systems in use by small communities and relatively small industries, and land prices ranging basically in the under-$500 per acre price level. Areas of the nation will become progressively more densely populated because over a million acres of rural lands are absorbed annually in urbanization and related facets of community growth. The availability of nearby lands, zoned for agriculture or residential purposes, and priced at low enough levels, will become a greater problem for users of land application systems. The cost of long-distance wastewater transmission will become an important factor in determining the economic feasibility of land application for wastewaters.

The impact of land application installations on neighboring areas and their residents can be in direct ratio to population density. While existing systems have demonstrated their ability to be "good neighbors" to residents living as close as 500 feet of application site, this close proximity may not be good practice in all cases. Reported complaints have been minimal against present installations despite the fact that, for example, 20 percent of community systems in Zone A are located less than 500 feet from the nearest neighbors and 22 percent are similarly located in Zone B. Industrial sites are located in Zones C, D and E within 500 feet of residences in 10, 10 and 21 percent of the cases investigated, respectively.

The relationship between local demographic conditions and land application system monitoring is obvious. The degree of monitoring was found to be less related to zone climatological conditions than to

State health and water pollution control regulations in the limited cases where such governmental stipulations are imposed. It is understandable that increasing population intrusions in an area, and the density of the residential population, will dictate that closer attention should be given to the impacts of land application on land and water resources and on persons exposed to actual wastewater, sludge residues, spray mists and animals and insects which come in contact with irrigation liquids and vegetative growths. The frequency and location of monitoring points, such as test wells and other sampling facilities, and the extent of monitoring parameters will be intensified in the future to satisfy actual hazards or the psychological impressions of local residents.

Site security measures, such as fencing may be required and buffer zones may be specified. Operation and maintenance costs will react to all such monitoring and security requirements but the reasonable cost levels for present systems could be increased without seriously affecting the feasibility and economy of land application techniques. Future wastewater treatment works, particularly those requiring full secondary treatment and processing to remove such components as phosphorous, nitrogen, trace metals and organic pesticides, will require similar augmentation of present specific laboratory control and site safety and security measures.

FATE OF MATERIALS APPLIED TO THE LAND

To complete this extended summary of the land application of wastewaters a review of the fate of applied materials is presented to round out the information which has been presented. Reference is made to two papers entitled, Experiences with Land Spreading of Municipal Effluents, and Fate of Materials Applied, prepared by Richard E. Thomas, Soil Scientist, Robert S. Kerr Water Research Center, Environmental Protection Agency, Ada, Oklahoma. For the future applicability of land utilization of wastewaters, it is important to know with some measure of certainty what the fate of wastewater components will be.

The materials contained in wastewaters are reminiscent of the origin of these flows--either sanitary, sanitary and combined storm water, industrial process water, or combinations of sanitary and industrial wastes. Since the application of raw wastewaters onto land areas is not contemplated under the definition of this alternative waste management technique, all such wastes have been subject to some degree of pretreatment before they are applied to land. The purpose of monitoring of influent flows onto land areas is to ascertain the composition of the wastewater after the stages of pretreatment provided.

A classification of wastewater materials could be: Suspended materials; major plant nutrients; and other constituents. Another delineation of the wastewater components, based on the actual physical nature of the substances is: Suspended solids; colloidal solids; dissolved organic materials; and dissolved inorganic substances.

The fate of these substances during the process of land application will vary with the type of distribution system, the nature of the soil, the rate of application, the climate, the resting periods, and the location and proximity of the groundwater aquifier and the surface water source which receives runoff from the site. The phenomena involved include: The physical condition of entrapment or mechanical filtration; the biological, biochemical, electrochemical and other manifestations in and in contact with the soil; evaporative factors; atmospheric oxidation; bacteriological, germicidal, and bacteriophage or anti-contamination reactions, and others which are not totally understood even by highly trained and experienced scientists.

Suspended solids entrapped in the interstices of the soil or adhering to soil particles by electrochemical entrainment can experience biological oxidation and decomposition into stabilized substances. The fate of this suspended material can vary; it can remain in the soil to form humus soil conditioning or nutritive material or, in course media, it may be sloughed off and percolated into lower soil depths or into the groundwater.

Colloidal materials--solids of minute size which may be able to filter through soil media--can be coalesced or coagulated by electrochemical agglomeration and then adsorbed onto soil particles. The fate of this material, normally considered to possess electrical charge, may parallel that of true suspended solids, by oxidation-digestion phenomena. Accumulations in the soil may affect the rate of application of subsequent wastewater loadings.

Organic dissolved solids may be utilized by plant crops, retained in the body of the soil by chemical fixation or other bonding phenomena or may be oxidized by atmospheric reactions, in the course of air contact with sprays or sheets of wastewater flowing over the land.

A major concern is centered on the nitrogen and phosphorous in wastewaters. The presence of these dissolved constituents can influence the use of land application systems in lieu of advanced treatment and discharge into surface receiving water, primarily because they can act as "triggers" in the eutrophication of surface waters. Similarly, if these materials can adversely "fertilize" lakes, why cannot they be used to fertilize land?

The fate of nitrogen and phosphorous will be influenced by many factors, including the type of wastewater distribution system utilized, and the type of ground cover and crops grown. The factors involved in the different land application methods are covered in excellent details in the above-referenced papers, and it is not the intent here to explore these manifestations beyond brief reference to the fact that the fate of these two basic elements can be regulated by proper practices to avoid serious effects on groundwater or surface water sources. The ability of soil to retain and fix phosphorous is more important than its capacity to handle nitrogen because phosphorous delivery to the soil may be greater than the crop uptake ability to utilize it. Fortunately, soil retention is able to prevent phosphorous intrusion into groundwaters that are adequately deep for any effective land application site.

Nitrogen could enter the groundwater in concentrations that might exceed the safe levels of this material in water for human consumption. However, the ability of land application techniques to complete a nitrification-denitrification cycle can be utilized to prevent this fate, as in the spray-runoff technique. A substantial proportion of the phosphorous contained in applied wastewaters in the same spray runoff process could reach surface water sources unless steps are taken to improve phosphorous removal by land contact.

Other constituents of land-applied wastewaters have fates that may influence the use of land methods, either in favor of this alternative process or opposed to its utilization. These include heavy metals, even in trace amounts, pesticides and other organo-compounds, and various salts. Evaporation and evapotranspiration of liquids from soil, vegetative surfaces or water surfaces will not change the fate of these dissolved materials; the evaporative process parallels the distillation phenomenon, in that the water is converted to vapor or gaseous form and the solids are thus concentrated in the soil or vegetation. Salts may thus reach the groundwater by percolation and leaching action. Heavy metals and pesticides can undergo physical, chemical and biochemical interactions with the soil, making land application an auxiliary means of providing so-called "tertiary" treatment for wastewaters, in lieu of more complex and more costly artificial wastes treatment processes.

To repeat the statement made above, the intent of this dissertation on the fate of materials applied to land areas is to point out that the soil and vegetative forms do offer a "bonus" factor that must be given consideration in determining the future of the land application process.

Current concern about the impacts of nitrates, phosphorous, trace metals, pesticides and other organic compounds on receiving waters is sufficient reason for knowing more about the fate of these objectionable materials in the land application process. More remains to be known about them, and about the way various methods of wastewater distribution, various types of soil and topographic and climatic conditions, and other factors and combinations of factors, influence their fate.

The fate of wastewater contaminants during the land application process, in short, offers opportunities for beneficial use for soil and crop enhancement which must be considered as a "plus" for this alternative technique. In addition, the capability of the land application system to remove, modify and stabilize pollutants which would require augmented processing in conventional sewage treatment systems offers another advantage for this alternative management procedure. But, these benefits must be evaluated in the light of whether the applied materials will in any way adversely affect the water and soil environment of the region where land application systems will be utilized. Only through a weighing of the benefits and hazards can the feasibility and applicability of land application processes be properly judged for each specific installation and each specific wastes problem.

CONCLUSIONS

1. Land application of wastewaters from community and industrial processing sources is practiced successfully and extensively in the United States and in many countries throughout the world. Facilities investigated handled from less than 0.5 mgd, providing service for sixty days per year, to over 570 mgd applied on a year-around basis.

2. Land application of wastewaters is practiced for several specific reasons. Among the major reasons were: to provide for supplemental irrigation water; the desirability of augmenting groundwater sources; excessive distances to suitable bodies of receiving waters or extraordinary cost to construct facilities to reach suitable disposal sites; economic feasibility, as contrasted with the cost of construction and operation of advanced or tertiary treatment facilities; and inability of conventional treatment facilities to handle difficult-to-treat wastes.

3. Present land application facilities generally are not "stressing" the system. Many facilities were found to be using effluent on a crop-need basis. Even where efforts were being made to use land as the only point of disposal, application rates were generally conservative and the soil-plant components of the system were not stressed to limits of assimilation or used to their optimum capacities, thus providing a large factor of safety.

4. A variety of beneficial uses are being made of wastewater effluents. Uses include irrigation of parks, golf courses, cemeteries, college grounds, street trees, highway median strips, sports grounds,

ornamental fountains and artificial lakes. Wastewater effluents are also used to irrigate many types of crops, including grasses, alfalfa, corn, sorghum, citrus trees, grapes, and cotton. Forest lands are also being irrigated in many areas. Groundwater augmentation to prevent salt water intrusion is being practiced. In Mexico, a wide variety of truck garden crops has long been irrigated with effluent. Crops appeared to benefit from both the nutrients and the increased amount of water which is applied.

5. A large variety of potential opportunities for land application of wastewater exist in many communities. Wastewaters that are given a high degree of treatment could well be considered for irrigating large public and private facilities to relieve the demand for irrigation with potable water supplies. Golf courses, cemeteries, parkways, school grounds, parks, airports, planned unit developments, green belts, forest preserves, and marginal land all offer the useful application of effluents to the land.

6. Sale of effluent for beneficial use has been generally unsuccessful. Few examples were found where a public agency had been able to obtain more than a token payment for supplying treated effluent. In several cases it was reported that land for the treatment plant had been given in consideration of a right to all or a portion of the effluent. Where an agency received a tangible dollar return, it was generally based upon use of both land and the effluent.

7. Successful operation of a land application system requires the inputs from a variety of disciplines. For many systems, the services of a geologist and environmental engineer are required. For system

designed to augment the indigenous crop water requirements by supplemental irrigation, the advice and guidance of soils specialist will be needed. For larger systems, social and behavioral scientists, as well as medical-health personnel may be required to assist in evaluating and securing acceptance of this alternative means of disposal.

8. Operation of land application facilities can be accomplished without creating a nuisance or downgrading the adjacent environment. The survey indicated that a majority of the facilities were conducted by well-trained personnel, aware of the need for careful operation of the systems. Training, supervision, and adequate monitoring of pertinent factors are necessary to ensure that systems will not be over-stressed. If ponding on the land is not allowed, odors will not be a problem. The hazard of creating other adverse effects on the environment by discharging treated effluent on land is minimal.

9. Monitoring of land application facilities and effects has been minimal and mostly inadequate. Few states appear to have taken an active role in requiring use of monitoring facilities, apparently because there was no direct discharge of effluents to receiving waters. Many of the municipal systems surveyed had little or no monitoring, inasmuch as the effluent was being used only for supplemental irrigation. Industrial systems were generally better monitored, but control in most cases cannot be characterized as being adequate.

10. Environmental analysis of the effects of land application facilities reflects a general improvement of the environment rather

than impairment of the indigenous ecology. Many facilities were observed where the effluent provided the only irrigation water available. Land values for sites with a right to such waste waters were greater than that of adjacent land because crop and forest growth was enhanced, and use of potable water supplies reduced. No instances of health hazards were reported from any existing facilities, although the State of Delaware indicated concern over potential virus transmission. Farming and recreation potentials exist, as well as improved habitat for wild life.

Treatment of wastewater prior to land application has generally been dictated by the desire to use the best practical means consistent with available technology and to minimize any adverse effects upon the environment. Land application of wastewater, by eliminating direct discharges of effluent into receiving waters, could be regarded as satisfying the ultimate national policy goal of "zero discharge" of pollutants.

11. Energy requirements for land application systems may be an important consideration. Reported energy requirements for most advanced tertiary treatment proposals are very high, as compared to conventional treatment. Depending upon the location and availability of land, energy requirements associated with land application techniques may be substantially less than other means of treatment and effluent management. This factor deserves further evaluation.

12. The nature and quantity of receiving waters must be carefully evaluated prior to diverting effluent to land application. Few existing systems were found that used underdrains to collect the renovated effluent. Rather, the groundwater aquifers received the flow. If a

land application area is adjacent to the receiving water, much of the groundwater may serve to augment the flow into the receiving waters by a gradual seepage into the drainage basin. Elimination of direct wastewater discharges to a stream could unbalance the flow regimen associated with downstream beneficial uses, inhibit desirable dilution of waste discharge, interfere with the tempering of thermal water discharges. Land application can prevent the intrusion of saline waters into normally fresh water zones. The impact of effluent diversion onto land areas with respect to the basic principle of riparian water rights must be considered where irrigation is planned as an alternate to discharge into surface waters.

13. When wastewater is discharged to land and this method is used as a means of advanced treatment by natural means, the land must receive priority for this use over other optional land uses. The needs of crop production, recreation and other benefits can be in conflict with the utilization of a land application system for the treatment of wastewater. For instance, the planting, cultivation and harvesting of crops and the use of recreation facilities may interfere with continuous application of wastewater onto land areas. The need for the system to either utilize all of the flow or provide sufficient retention storage for needed periods of non-operation must be provided. The objective of providing adequate treatment of the effluent can not be sacrificed for other needs and uses of the land; proper handling of the wastewater must be the first priority.

14. Choice of ground cover can play an important role in the success of a land application system. On other than sandy soil, it appears that forested or minimally wooded or cultivated areas will accept greater rates of application of effluent without ponding than will cultivated agricultural areas. Many existing facilities utilize forest areas and grassed areas for application. Forested areas appear particularly useful for winter applications when fixed spray systems are used. Reed Canary grass appears to be particularly well suited for producing mulched ground cover which can enhance soil assimilation and absorption characteristics.

15. Land application facilities that have been used for many years are available for the study of long-term effects of such use. They offer the opportunity to study effects on soils and groundwaters. Thus, it appears unnecessary to support separate demonstration facilities in each of several states and regions. During the course of the study project, several small-scale research and demonstration projects involving land application were disclosed. Some of these projects appeared to have been instituted simply for the purpose of convincing local and state officials of the safety of this alternative method of treatment and disposal. Specific evaluation at established systems in the various climatic zones would appear to be more fruitful than new research installations for determining long-term effects upon soil, vegetation, groundwater, and the indigenous ecology, or on the

health of site workers and adjacent residents.

16. Observations in the field and the survey of land application systems which handle municipal wastewater flows and industry-owned systems which handle process waters did not reveal the existence of specific health hazards and disclosed very little concern over threats to the health of on-site workers, residents of neighboring areas, domestic animals or wildlife, or of those who consume or come in contact with land-applied wastewaters. The mail survey of other representative municipal and industrial land application systems similarly provided no evidence of any health problems associated with this method of utilization.

Some concern over potential health hazards was, however, expressed or inferred by officials of some state agencies, who supplied information about their policies on land application of effluents as an alternative means of wastewater management. Whether this concern was based on specific information or mere suspicions, founded or unfounded, could not be determined from their response.

Inquiries have been made with inconclusive results about the health implications of land application systems by several Federal, state and local agencies, and by other quasi-governmental and public service organizations. Concern over "the unknown" was expressed for such factors as potential viral and pathogenic hazards resulting from dissemination of aerosol sprays or mists and contacts with sanitary and industrial sludge residues.

While the study did not disclose the cause for such concerns, the bibliographic abstracts*** prepared as an integral part of this investigative project to include references describing possible health hazards which warrant further study and these potential problem areas should certainly not be ignored. A balanced consideration of the concerns, and of the absence of any study evidence to support these questions, would be of great value at this time.

(***The bibliogaphy for the APWA report is being published separately, entitled, Land Application of Sewage Effluents and Sludges: Selected Abstracts.)

The APWA report and the foregoing conclusions lead to additional conclusions:

17. Emphasis in the future should be on wastewater utilization, reuse, and renovation, the 4-R cycle, and not on disposal.

18. Public acceptability is the primary factor limiting land treatment of effluents and land utilization of sludges.

19. Land application of wastewater is not an alternative to secondary treatment if secondary treatment is required as a pretreatment.

20. Land application of sewage effluents is an alternative to tertiary treatment for the removal of nutrients, suspended solids and certain pollutants. It is not effective for the removal of soluble salts.

21. In water-short areas land treatment of effluents may be considered as part of the reuse cycle.

22. Small communities will probably continue to be the principal users of land treatment of effluents for the near future, but stringent discharge restrictions will make land treatment more attractive to large communities.

23. Admirable as it may be to obtain drinking water quality from the land treatment of sewage effluents, since the goal of Public Health Service Drinking Water Standards is not required for secondary treatment, and it does not appear to be practical at present for land treatment either, it therefore should not be used to unduly limit the benefits to be derived from the land application technique.

RECOMMENDATIONS

1. Guidelines for land application of wastewaters should be prepared by the U.S. Environmental Protection Agency to provide full consideration of the wide choices of available methods and procedures. Guidelines should be prepared in a manner which will not restrict unduly the ability of local officials to make full use of this alternative method of treating and managing wastewater.

2. Land application must not be considered as a panacea or universal method of treatment. Suitability of each land application system can only be determined as a result of an interdisciplinary study for the particular site. Soils, climate, degree of pretreatment, ground water conditions and availability of suitable land acreages are important considerations.

3. Preparation of a suitable publication to inform the public about the practice of sewage effluent on land should be sponsored by the U.S. Environmental Protection Agency. Public relations problems are usually encountered by agencies attempting to implement any large public wastewater project. Recent efforts to consider land application as an alternative in planning for regional approaches to wastewater management have highlighted the need for such publication.

4. Training opportunities should be provided to bring to the attention of all disciplines involved in the consideration and evaluation of a land application facility the technical information which is available. Widespread consideration and utilization of land application can not be made until such time as adequate information concerning the technique

involved is made available. The experience gained by those who have successfully utilized this wastewater management method should be publicized.

5. Guidelines for the increased use of land application methods, which could result from the implementation of Section 201 of the 1972 Amendments to the Federal Water Pollution Control Law and its emphasis on alternate wastes management techniques and systems, should clarify the question of whether health hazards are a factor in the use of this system of treatment and disposal. Definitive findings are essential to the acceptance of land application systems, or to their adoption for municipal or industrial effluent management. Such findings should be provided with promptness and clarity, either through evaluation of existing data or any additional necessary research. Without such positive information, published guidelines might either be inadequate or tend to be too restrictive. If they are too stringent, this could endanger the proper utilization of land application systems as effective and economical solutions to water pollution control problems and the rational use of wastewater for crop and groundwater enhancement and other environmental-ecological benefits.