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RESEARCH STRATEGY ON WASTEWATER REUSE IN THE UNITED STATES

Wastewater reuse in the United States is being specifically recognized by recent legislation, and a great deal of research is directed toward some facet of reuse. A number of issues must to be solved before planned reuse will be achieved to the maximum extent. Many wastewater reuse programmes have been initiated.

1. INTRODUCTION

Abundant supplies of clean surface and underground waters in the United States have been taken for granted until recent years. Severe contamination of many surface supplies has occurred and increasing instances of groundwater contamination are being found. Thus, the relatively fixed volume of water may become less and less usable. Adequate water pollution control measures must be taken and conservation and reclamation of water resources must become the rule.

The quality and quantity of wastewaters produced by the community depend upon such factors as the source of supply, population density, industrial practices, and even the attitudes of the local population. The quality of the environment can be improved by reducing pollution at the source, providing adequate treatment of the wastewaters, and recycling and reusing wastewater. Public support and some change in social behaviour will be required in most instances.

Water shortages and the recent recognition in the United States of the need to conserve water has focused attention upon the value of more intentional reuse. A strong legislative mandate exists for research development of cost-effective technology for reclaiming wastewater to make it usable again for any purpose. Planning of research to acheive this goal is needed.

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2. OFFICIAL SUPPORT FOR WASTEWATER REUSE

The role of the U.S. Environmental Protection Agency (U.S. EPA) and its predecessor organizations in wastewater reuse has been stated in various acts. Public Law 87-88 passed in 1961 amending the Federal Water Pollution Control Act directed the Secretary (at that time of Health, Education, and Welfare) "to develop and demonstrate practicable means of treating municipal sewage and other water-borne wastes to remove the maximum possible amounts of physical, chemical and biological pollutants in order to restore and maintain the maximum amount of the Nation's water at a quality suitable for repeated reuse".

This Act gave impetus to the Advanced Waste Treatment Research Programme, which began in 1960. The objective of this programme is to conduct research that will develop new and improve existing wastewater treatment processes and ultimate disposal technology, thus permitting maximum removal of contaminants and reuse of waters.

Wastewater reuse is being specifically recognized by recent legislation. Public Law 92-500, the "Federal Water Pollution Control Act Amendments of 1972", recognizes the potentially large benefit to be realized if wastewaters can be renovated for reuse applications.

Sections 201 b, 201 d, and 201 g, 2 B clearly require that: EPA provide for the application of best practicable waste treatment technology, including reclaiming and recycling of water; construction of revenue producing facilities providing for reclaiming and recycling be encouraged; and works proposed for grant assistance, to the extent practicable, allow for the application of technology at a later date which will provide for reclaiming and recycling of water. Section 105 a, 2 authorizes EPA to make grants for demonstrating advanced waste treatment and water purification methods, and Section 105 d, 2 requires that the Administrator conduct on a priority basis an accelerated effort to develop, refine, and achieve practical application of advanced waste treatment methods for reclaiming and recycling water and confining pollutants.

The Safe Drinking WATER Act of 1974 (Section 1444) also contains mandates of importance with regard to renovation and recycling of wastewaters. Section 1444 authorizes a development and demonstration programme to: demonstrate new or improved technology for providing safe water supply to the public; investigate and demonstrate health implications involved in the reclamation, recycling and reuse of wastewaters for the preparation of safe and acceptable drinking water.

There exists, therefore, a strong and clear legislative mandate for research development and demonstration of reliable, cost-effective technology for reclaiming and recycling wastewaters for beneficial uses. A major beneficial use is the supplementation of domestic water supplies.

The Water Pollution Control Federation (WPCF) and the American Water Works Association (AWWA) issued a joint resolution that urged the Federal Government to support a massive research effort to develop needed technology. These organizations underscored the "lack of adequate scientific information about possible acute and long--term effects on man's health from such reuse", and also noted that "the essential fail-safe technology to permit such direct reuse has not yet been demonstrated". The resolution recognize the need for an "immediate and sustained multidisciplinary, national effort to provide the scientific knowledge and technology relative to the reuse of water for drinking purposes in order to assure full protection of the public health".

The U.S. EPA in a policy statement on water reuse dated July 7, 1972, supports and encourages the development and practice of successive wastewater reuse. EPA does not currently support the interconnection of wastewater reclamation plants with potable water systems.

3. RESPONSIBILITIES TO PROMOTE REUSE

Water reuse has to be planned on a broad basis. The Federal role has been outlined earlier in this paper and the responsibilities of the local agency and industry to promote reuse are presented below. Local agencies role in water reuse is as follows:

— promote to the extent possible, consistent with water quality consideration, the renovation and reuse of wastewaters;

— determine the water reuse potential on area-wide basis.

Specific studies on reuse in sub-areas would follow, and examples of objectives include the following:

— determine a ranked order of water uses in the local area in accordance with the acceptability of different levels of water quality,

— demonstrate how water reclamation can supplement available water supply,

— demonstrate how wastewater reclamation can downstream collection and treatment systems,

— develop legislative, economic and planning procedures to implement water reuse,

— examine all available technology for reuse assess public acceptance, aesthetics, and cost-benefit ratios.

Industrial role in water reuse is as follows:

— examine all plant practices to obtain optimum water use and recycle with a minimum of waste effluents, and try to become a minimum discharge industry;

— consider the use of available waters of secondary quality (sewage plant effluents, brackish waters, sea water, etc.) for suitable plant purposes;

— examine chemicals and processes contributing to pollution and determine if changes in either will help abate pollution;

— consider product recovery from waste materials;

— be aware of the new developments in processes to control pollution;

— make all plant personnel water and pollution conscious.

4. ECONOMICS OF REUSE

A very useful report [10] has been prepared by the Water Planning Division of the U.S. EPA to assist regional water agencies in assessing the cost-effectiveness of alternative wastewater management systems, including wastewater reuse systems. The following information is derived largely from this report.

A list of information necessary for economic analysis of wastewater reuse systems has been presented as follows:

1. General background information:

a. Population data (present and projected).

b. Land use data (present and planned and/or zoned).

c. Topographical base map of study area.

d. Geological data for study area (types and characteristics of soil bedrock formations, groundwater depths and locations).

e. Climatological data for study area (precipitation, evapotranspiration rates, temperature ranges).

2. Water use and supply information (withdrawal and consumptive):

a. Fresh water volume use (present and projected).

b. Fresh water quality (present and desired).

c. Fresh water supplies (volume available from various sources throughout planning period, quality of available supplies, relability, existing and planned water prices).

d. costs of water supply system (present and projected).

3. Wastewater information:

a. Municipal wastewater volume (existing and projected).

b. Municipal wastewater quality.

c. Location of existing treatment facilities, outfalls, and receiving waters.

d. Treatment costs for existing system (capital, operating and maintenance, expected increases in cost to more stringent treatment requirements).

A simple preliminary test for determining the potential applicability of wastewater reuse systems to a given area has been proposed. The checklist factors are presented below:

1. Existing or future fresh water supply is limited relative to demand. If the quality of fresh water used is greater than the available supply the following courses of action (for a combination of actions) have been recommended:

a. Decrease fresh water use,

b. Increase water supplies by:

— further development of local ground and surface water sources,

— importation of fresh water from sources outside the local basin,

— desalination of brackish or salt water,

c. Reuse wastewater.

2. Existing or future fresh water supply is expensive.

3. The area presently includes or will include individual high-volume water users.

4. Municipal wastewater meeting high-quality standards is presently discharged for disposal.

5. Requirements for improved wastewater effluent are impending or are anticipated.

6. Wastewater disposal is expensive.

In the event that evaluation of above factors indicates the potential desirability of wastewater reuse possible market for reclaimed wastewater should be assessed. The basic tasks for the market survey are:

— the identification of potential users,

— preliminary estimate of the potential volume, quality and reliability of reclaimed water demanded (consideration should be given to health and legal requirements),

— preliminary determination of effluent treatment, transportation, and storage facilities required.

A cost-effectiveness analysis of wastewater reuse systems should be performed when preliminary tests suggest the potential practicality of wastewater reuse. The basic steps necessary in the evaluation process are as follows:

1. Determine the nature and extent of the water resource problem.

2. Define objectives. The two basic objectives are: to meet water demand and to treat wastewater to acceptable standards for disposal or for reuse. It has been proposed to establish at a minimum the following objectives:

— the quantity of water to be supplied,

— the water quality for all intended uses,

— the minimum quality standards to be met for reclaimed wastewater,

— the extent of the water distribution system.

3. Hypothesize technically feasible solutions that can satisfy objectives. One or more solutions which do not involve wastewater reuse should also be considered.

a) Alternative water sources and means of increasing an area's water supply:

— existing supply sources,

— other in-basin sources (surface waters, groundwater basins),

— imported water from various out-of-basin sources,

— wastewater reclamation,

— miscellaneous (water conservation measures, temporary, overdraft of groundwater basins, desalination of brackish or sea water).

Alternative programmes that will provide water of sufficient quantity and quality to meet the area's water resource objectives must be formulated.

b) Wastewater treatment and disposal. The specific treatment objectives which may not exceed minimum standards must be decided. Alternative treatment and disposal systems (with and without reclamation), alternative geographical locations for treatment plant siting and different construction phasing should be proposed.

c) Wastewater reuse systems. A technically feasible solution or solutions should be based on an analysis of various factors, such as:

— location of existing wastewater treatment facilities and of potential effluent customers,

— volume and quality requirements of potential effluent customers.

4. Estimate the cost of each solution. For each solution to be analyzed, cost estimates should be obtained for the following items:

— construction cost of new water resources facilities to be built both at the outset of the project period and various intervals during the planning period where applicable,

— operating and maintenance cost on an annual basis,

— interest costs during construction, as detailed in EPA's guidelines [5] for cost--effectiveness studies.

The basic requirements of EPA's cost-effectiveness guidelines [8] are:

— planning period for projects — 20 years,

— service lives for each component of a wastewater systems:

a. land — permanent,

b. structures — 30 to 50 years,

c. process equipment — 15 to 30 years,

d. auxiliary equipment — 10 to 15 years

— monetary costs shall be calculated in terms of present worth values or equivalent annual values,

— interest rate times the total capital expenditures times one half the construction period in years,

— the future inflation of wages and prices shall not be considered in the analysis.

5. Calculate the present value for each solution.

It has been proposed that the present value for each solutions's costs should be determined as follows:

$$P = T+C+M+R-S$$

where

P — the present value,

T — total capital cost for initial construction and equipment purchases,

C — the capital construction phase **times** the single payment present worth factors based on seven percent and the number of years from time of analysis,

M — average annual operation and maitenance cost **times** uniform series present worth factor based on seven percent and twenty years,

R — equipment replacement costs, if service life is less than twenty years based on seven percent interest and the expected service life value,

S — salvage values of equipment and structures **times** single payment present worth factor based on seven percent and twenty years, if service life for these items is greater than twenty years.

6. Compare the present values of the cost for each solution. The analysis indicates which solution has the lowest present value for cost over the 20-year period, and this lowest cost solution should be chosen. However, it is useful to recalculate the costs for each solution based on different assumptions and tests sensitivity of the results to possible changes in important factors.

The analysis is based upon economic considerations only. However, other factors as environmental impact, energy consumption, social effects, system reliability, and others can influence decision-makers.

Application of the analysis for reuse was conducted at Santa Barbara, California and Hampton Roads, Virginia. At both locations feasibility and cost effectiveness was shown for reuse, at least, of part of the municipal effluent.

Another EPA project [2] has also recently been completed which attempts to make an economic evaluation of renovated wastewater as an alternative source for municipal water supply. Eleven utilities were investigated, and detailed studies were made of the Dallas, Texas system and the San Diego, California system.

Both cities are in water-short areas and both will have to supplement their present water supplies in the future. Conclusions are that providing up to 50 % of renovated water for the two cities would cost from 25 to 50 % more than further development of natural supplies. Such a conclusion does not indicate that water renovation is not a viable method for supplementing water supplies or would not be different in other cities. The EPA project is valuable in demonstrating techniques of cost standardizing for making comparisons of natural and renovated waters. Reuse at the 50 % level in the two cities extends the water supplies significantly but even with reuse early in the next century, more water would be needed.

Water-short areas in the world may not have a choice — they will have to reuse wastewaters.

5. RESEARCH STRATEGY

A substantial basis of science and technology already exists for many wastewater reuse applications. Planning of research to achieve the highest quality water and assure its safety for any use is needed.

There are number of issues to be solved before planned wastewater reuse will be used to the maximum extent. Some of these issues are: adequacy of treatment technology and environmental effects of advanced wastewater treatment health effects, and socio-economic factors.

5.1. ADEQUACY OF TREATMENT TECHNOLOGY

In the past 15 years, significant advances have been made in wastewater treatment technology. An analysis of the status of wastewater treatment technology for preparing potable water conducted by DEAN and CONERY [3] has indicated that:

— wastewater treatment performance data is not available for all of the parameters included in existing drinking water standards,

— information that is available suggests that wastewater treatment technology is capable of meeting all the standards that have been measured,

— full-scale wastewater treatment facilities can be operated reliably over long periods of time;

— long-term reliability testing of a full-scale facility specially designed to produce potable quality water is needed.

The organic content of wastewater can be reduced to very low concentrations through application of chemicals, use of filters, and activated carbon. Membrane treatment offers another separation technique. Phosphorus and nitrogen removal technology is advancing, and bacterial and virus removal capabilities of the treatment processes are relatively high. However, some portion of the contamination remains after the best treatment.

On a particular basis, known treatment technology is adequate for non-potable reuses. Some reservations exist about reuse for potable purposes. These reservations usually refer to a direct treated wastewater to drinking water connection. While this type of direct interlock will seldom be needed it represents the most critical technological goal. Storage and dilution prior to use is more acceptable.

Present day Advanced Wastewater Treatment Systems (AWTS) can produce a water from municipal wastewater effluents that, by drinking water quality standards, is as good as the drinking water. The U.S. EPA work at the Blue Plains pilot plant has produced water very close in quality to the Washington, D.C. tap water. These highly treated waters may have small residues as follows: total organic carbon 1 to 2 mg/dm^3, total nitrogen 1 to 2 mg/dm^3, chlorinated organics 1 to 100 $\mu g/dm^3$. The meaning of these small residues is not known and is the subject of ongoing research. Proper disinfection of effluents from advanced treatment systems free of solids and of very low turbidity can assure safety from microbiological contaminants and viruses.

Final removal of all contaminants may require excessive processing and accompanying costs. Before programming large amounts of money and effort it is needed to know what residue limits are acceptable. Some specific goals in treatment technology are:

— continue the development and refinement of treatment technology to prepare water of any quality,

— collect performance, reliability, and cost data for alternative treatment systems.

5.2. ENVIRONMENTAL EFFECTS OF ADVANCED WASTEWATER TREATMENT

Recently Antonucci and Schaumburg [1] have evaluated the net impact of advance wastewater treatment technologies on the environment, using the U.S. wastewater treat ment plant at South Lake Tahoe, California as an example. It was found that advanced wastewater treatment processes requires a significant input of energy and treatment chemicals, and several types of contaminants are discharged to the environment as a result of the treatment operations. It was also noted that as the degree of sophistication of technology increases, energy consumption increases greatly.

The following inputs were considered:

1. Indirect inputs associated with support industries manufacturing treatment chemicals, and providing consumable energy, and with transport of materials and chemicals:

a. consumption of energy (electricity, fuel oil, natural gas),

b. consumption of raw materials,

c. discharges and emissions of contaminants during production and during transport to the air, water and land phases of the environment.

2. Direct inputs:

a. consumption of raw and manufactured materials and chemicals (lime, alum, chlorine, activated carbon) directly at the plant site,

b. consumption of energy directly at the plant site,

c. discharges and emissions of contaminants to all environmental phases by the plant itself.

Conclusions are that it is not yet possible to determine whether advanced waste treatment processes effectively reduce the net level of degradation in the total environment and that further research is needed to develop a common denominator by means of which various types and amounts of contaminants discharged to the environment may be quantitatively compared.

5.3. HEALTH EFFECTS

Full-scale reuse will be inhibited by questions concerning health effects. A fundamental problem which retards wide-scale application of wastewater reuse is the lack of suitable standards. There are, of course, more uncertainties in using wastewaters as a source for a potable water because of the wide differences from place to place and the lack of control of spills, additives, and miscellaneous discharges to sewer systems.

Adequate health effects data of trace contaminants in present drinking waters and reused waters is a major block to potable reuse. Chemicals are, generally, of greater concern than the microbiological contaminants. The concern for chemicals has been accentuated recently with the discovery of asbestos, chloroform (from disinfection with chlorine), vinyl chloride, and a very large number of organic chemicals present in the microgram per cubic centimeter range of concentrations. Carcinogenic properties are ascribed to many of these chemicals. These very low, but significant, concentrations of toxic chemicals and carcinogens appear in environment, and often it is only after many years of exposure that the deleterious effects are associated with the cause. Little has been done in the past on the health effects of water contaminants. This gap in information is now beginning to receive research attention. Improvement of the ability to screen and predict what is harmful and what concentrations of materials are tolerable in water is needed. In addition to safety for potable purpose, the information on health effects from body contact, stock watering, irrigation, and fish propagation is required. Following laboratory studies of pathogenic, toxic, carcinogenic, and teratogenic effects, and epidemiological studies will be a necessity. Development of a data base in the health field will be slow and costly.

Increasing attention has been given to the transmission of viral diseases through the water route. DRYDEN and ONGERTH [4] have proposed that four types of research need to be conducted concurrently:

— epidemiological and statistical studies of the health of populations presently subject to significant percentages of wastewater in their municipal water supplies,

— bioassays on a wide variety of mammals and a wide variety of wastewaters type, dilutions, and degrees of treatment,

— analytical procedures to more throughly identify specific organic components in minute concentrations and find suitable continuous monitoring devices for practical onstream application,

— pilot demonstration plants assembled and operated under fail-safe conditions provide a field laboratory for testing new developments.

It has been anticipated that the programme outlined above will require a minimum ten to fifteen years of extensive work at a cost of approximately \$ 50 to \$ 150 million.

5.4. SOCIO-ECONOMIC FACTORS

The socio-economic aspects of large-scale purposeful reuse of renovated waters has received only minor attention. Particular factors involved in socio-economic issues include: public acceptance, problems of cities pioneering reuse, conflicts between water and wastewater agencies, implications to downstream users, and energy considerations.

Milliken and Creighton [7] conclude that the principal question with regard to recycled water is whether it can be efficiently and equitably integrated into socio-economic and social framework of the existing systems. They recommend that where reused water can be made cost competitive it should be substituted for conventional water at levels furtherest from human contact. This will conserve present supplies and allow the lead time needed to resolve socio-economic problems.

The full facts about reuse need to be made known and the reliability of technology fully explored and explained. Public attitudes must be sought on reusing water for potable purposes. Accurate assessment of the alternatives and costs of water should determine where and when water reuse will occur.

5.5. RESEARCH OBJECTIVES

A valuable compendium of up-to-date information on wastewater reuse as well as a guide to research needs are proceedings of a workshop [9] sponsored by the U.S. EPA, along with the American Water Works Association and the Water Pollution Control Federation.

The general conclusions from the workshop are:

— the identified needs pertain to indirect wastewater reuse as the possible potable reuse,

— identification of contaminants present in drinking waters and the development of optimum control processes is urgent,

— develop rapid, sensitive, and accurate testing procedures for all types of contaminants and seek on line continuous monitoring where required,

— toxicological studies using in vitro and screening and testing are of high priority,

— long-term health effects of reuse involving retrospective and prospective epidemiologic surveys of populations exposed to indirect wastewater reuse should be undertaken as an international collaborative study,

— improved exchange of information relative to reuse is needed.

6. WASTEWATER REUSE RESEARCH PROGRAMMES

Research programmes in the past within the U.S. EPA, and predecessor agencies, have not often been directed toward wastewater reuse as such. However, many of the research projects conducted have developed data needed for assessing the various aspects of reuse. The former Advanced Waste Treatment Research Programme (now the Wastewater

Research Division) in seeking to remove the maximum amounts of contaminants from water contributed data needed for reuse consideration. Within the last two or three years more direct attention has been given to reuse. A variety of projects related to reuse in the Wastewater Research Division of the Municipal Environmental Research Laboratory, EPA at Cincinnati have been recently completed.

Several water reuse research programmes in the U.S. is performed outside of EPA. The U.S. Office of Water Resources Research has funded several studies to determine whether the public will accept the use of renovated water for various purposes, and this type of information ties directly to the U.S. EPA programme. A new programme on water reuse has been indicated by the Office of Water Research and Technology, U.S. Department of the Interior [6]. This reuse programme is coordinating with other federal agencies and is maintaining liaison with professional organizations. The objective of the programme is to support research and development efforts for reuse applications. Topics for FY1977 are as follows:

— evaluation of national and regional water reuse needs and potential,

— evaluation of existing and advanced technology and reuse applications,

— research and development support of selected municipal, industrial and agricultural reuse applications,

— treatment processes and systems,

— planning and management aspects of water reuse.

Studies have been made or are planned on using renovated water for potable purposes at the local level. The City of Dallas, Texas operated a pilot plant to study the feasibility of renovated water. The City of Denver, Colorado completed preliminary plants for its about four thousand cubic meter per day pilot plant for direct recycle of wastewater. With this facility, Denver will develop design data its four hundred thousand cubic meter per day plant. The U.S. EPA is cooperating with both cities. Reuse research in California is another example of a major activity.

Also the U.S. Army is carrying out research on using renovated water for potable purposes. The military unit, self-contained transportable hospital project is researching the limited reuse potential of all hospital liquid wastes. In addition, the Army is developing plans for pilot plant at Washington, D.C. to study treatment technology and related health effects when the Potomac River estuary and the Blue Plains sewage treatment plant effluent are recycled as a supplemental water supply. The U.S. EPA is serving in an advisory capacity to both projects.

The Research Foundation of the American Water Works Association is providing services as a coordinating and reporting agency for research being conducted in the area of water reclamation for potable use. The contract is with nine agencies including U.S. Environmental Protection Agency at Cincinnati, and distribution of information is to contractors.

The World Health Organization (WHO) sponsored a meeting in The Hague in 1975 on "Health Effects Relating to Direct and Indirect Reuse of Wastewater for Human Consumption". One of the recommendations of the meeting was to designate the WHO — sponsored International Reference Centre for Community Water Supply located at The Hague as International Coordinating Agency for the Study of Health Effects of Direct and Indirect of Wastewater for Human Consumption.

At the present the World Health Organization International Centre for Community Water Supply is one of the coordinating bodies in existence, and is initiating certain research studies relating to wastewaters reuse for potable purposes. The U.S. EPA has been asked to participate in these international programmes.

CONCLUSIONS

The reuse of wastewater is becoming more attractive because more stringent standards are imposed on treatment plant effluent, and population increases and/or industrial and agricultural developments are placing added burden on traditional water supplies. A great deal of research in the United States is directed toward some problems associated with wastewater reuse. The U.S. Environmental Protection Agency and other govermental agencies together with industry, as well as some states and major municipalities are working on a variety of reuse projects. A major effort is needed to embark upon a long term integrated programme to permit wastewater reuse for any purpose including the supply of drinking water. Combined programmes should lead to a sound base of science and technology that will gain the public confidence for full-scale water reuse. The technology for preparing water of any quality is well advanced. Needed is better knowledge on the level of residues that remain and their possible health effects. Social and economic factors will need additional research. Further development of methodology for assessing the cost-effectiveness of wastewater reuse systems and the net impact of advanced wastewater technology on the environment is also needed.

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STRATEGIA BADAŃ NAD WYKORZYSTANIEM ŚCIEKÓW W STANACH ZJEDNOCZONYCH AMERYKI PÓŁNOCNEJ

Wykorzystanie ścieków w Stanach Zjednoczonych zostało ostatnio objęte specjalnym ustawodawstwem. Problemowi temu poświęcono wiele badań. Zanim jednak będzie można planowo wykorzystać ścieki, należy rozwiązać jeszcze wiele problemów, chociaż wprowadzono już programy dotyczące tego zagadnienia.

STRATEGIEN DER ABWASSERNUTZUNG IN DEN VEREINIGTEN STAATEN VON NORDAMERIKA

Eine weitgehende Abwasserbewirtschaftung war in neuester Zeit in den USA Gegenstand einer speziellen Verfassung. Viele Untersuchungen sind schon diesem Problem gewidmet worden. Bis aber eine planmäßige, und maximale Bewirtschaftung der Abwässer möglich sein wird, müssen noch recht viele Fragen gelöst werden. Nichtdestoweniger sind einige Programme bereits praktisch eingesetzt worden.

СТРАТЕГИЯ ИССЛЕДОВАНИЙ ПО ИСПОЛЬЗОВАНИЮ СТОЧНЫХ ВОД В СОЕДИНЕННЫХ ШТАТАХ АМЕРИКИ

Использование сточных вод в Соединенных Штатах Америки стало предметом кодификационных работ, а сама проблема является объектом многочисленных исследований, без чего, конечно, планомерное хозяйство в этой области невозможно. Многие программы по использованию сточных вод находятся уже в стадии реализации.