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ENGINEERING EXPERIMENT STATION
OREGON STATE UNIVERSITY
CORVALLIS, OREGON

**Proceedings of the Eleventh
PACIFIC NORTHWEST
INDUSTRIAL WASTE
CONFERENCE
1963**

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(1) To stimulate and elevate engineering education by developing the research spirit in faculty and students.

(2) To serve the industries, utilities, professional engineers, public departments, and engineering teachers by making investigations of interest to them.

(3) To publish and distribute by bulletins, circulars, and technical articles in periodicals the results of such studies, surveys, tests, investigations, and research as will be of greatest benefit to the people of Oregon, and particularly to the State's industries, utilities, and professional engineers.

To make available the results of the investigations conducted by the Station, three types of publications are issued. These are:

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OREGON STATE ENGINEERING EXPERIMENT STATION,
CORVALLIS, OREGON

Proceedings of the
ELEVENTH PACIFIC NORTHWEST
INDUSTRIAL WASTE CONFERENCE - 1963

Corvallis, Oregon
May 9-10, 1963

CIRCULAR NO. 29

Engineering Experiment Station
Oregon State University
Corvallis, Oregon

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PREFACE

The 1963 Pacific Northwest Industrial Waste Conference was conducted at Oregon State University on May 9-10. This was the eleventh meeting of a conference series which has been held on odd-numbered years and alternated among Oregon State University, Washington State University, and the University of Washington in cooperation with industries of the Pacific Northwest. The next conference will be held at the University of Washington in the spring of 1965.

The program of the conference is planned and conducted by an executive board, with industrial divisions representing wood-pulp-paper, mining-metallurgy, chemical-petroleum, and food-agriculture. Representatives from water management agencies serve on this board as ex-officio members.

Throughout the years the conference has grown in popularity and become increasingly productive as a meeting where industry, water management agencies, and universities may mutually share the findings of industrial waste research and operational experiences that are useful for the protection of our valuable water resources.

Proceedings of the
ELEVENTH PACIFIC NORTHWEST
INDUSTRIAL WASTE CONFERENCE - 1963

PROGRAM

GENERAL SESSION

May 9, 1963

Morning

JUDSON H. HOLLOWAY
Olympic Research Division
Rayonier Incorporated
Shelton, Washington
Chairman

- 9:15 INTRODUCTORY REMARKS. Dr. Judson H. Holloway.
WELCOME. Dr. J.H. Jensen, President, Oregon State
University.
- 9:30 ON PRESCRIPTIONS AND PARALYSIS, FACT-FINDING
AND THE FUTURE. C. Montgomery Johnson, Wash-
ington Manager, Public Affairs, Weyerhaeuser Company,
Tacoma, Washington.
- 10:30 PROGRESS ON RECENT BY-PRODUCT DEVELOPMENTS
FROM SPENT SULFITE LIQUOR. L.M. Whitmore,
Director, Research Division, Scott Paper Co., Everett,
Washington.
- 11:15 WATER SUPPLY AND WASTE DISPOSAL PROBLEMS
OF THE FOOD INDUSTRIES. Walter A. Mercer,
Associate Director, National Cannery Association,
Berkeley, California.
- 12:00 WATER RESOURCES PLANNING IN THE PACIFIC NORTH-
WEST. W.W. Towne, Director, Columbia River Basin
Project, Water Supply and Pollution Control Program,
Pacific Northwest, Public Health Service, Portland,
Oregon.

Afternoon

Three Concurrent Technical Division Sessions

FOOD INDUSTRIES AND AGRICULTURE DIVISION

Robert F. Cain and Roy E. Moser

Co- Chairmen

- 1:30 COMPOSTING FRUIT WASTE SOLIDS. Walter W. Rose, Research Chemist, National Canners' Association, Berkeley, California; Jay Chapman; and Walter A. Mercer.
- 2:05 CHANGES IN WATER QUALITY DUE TO IRRIGATION. Gilbert H. Dunstan, Donald E. Proctor, and Ervin Hindin, Division of Industrial Research, Washington State University, Pullman, Washington.
- 2:40 WASTES MANAGEMENT IN THE FOOD PRODUCING AND PROCESSING INDUSTRIES. S. A. Hart, Associate Professor of Agricultural Engineering in the Experiment Station, Davis, California; P.H. McGauhey, Professor of Sanitary and Public Health Engineering and Director of Sanitary Engineering Research Laboratory, Berkeley, California.
- 3:35 POTATO WASTE TREATMENT. Robert E. Pailthorp, Industrial Waste Engineer, Cornell, Howland, Hayes, and Merryfield, Corvallis, Oregon.
- 4:10 WASTE TREATMENT PROBLEMS - SOLUTIONS. Panel discussion. W.W. Rose, G.H. Dunstan, P.H. McGauhey, R.E. Pailthorp.

MINING-METALLURGY, CHEMICAL-PETROLEUM DIVISION

W.H. Haney and J.G. Craig

Co-Chairman

- 1:30 TREATMENT OF RADIOACTIVE CONDENSATE WASTE. J.M. Skarpelos, Engineer, Process Demonstration Analysis Labs, General Electric Co., Richland, Washington.

- 2:05 THERMODYNAMIC ASPECTS OF GROWTH AND OXIDATION DURING BIOLOGICAL WASTE TREATMENT. J. A. Servizi, Graduate Student, Department of Civil Engineering, University of Washington; R.H. Bogan, Associate Professor, Department of Civil Engineering, University of Washington, Seattle, Washington.
- 2:40 RECOVERY OF CHLORINE FROM CHLORINE PLANT VENT GASES. Harry W. Bryson, Hooker Chemical Corporation, Tacoma, Washington.
- 3:35 CONTROL OF WASTE SOLIDS AT MOUNT VERNON SAND AND GRAVEL PLANT. A. R. Kinney, President, Mt. Vernon Sand and Gravel Co., Mt. Vernon, Washington.
- 4:10 STANDARDS BY GOVERNMENT FOR AIR AND WATER POLLUTION AS RELATED TO THE SMELTING AND REFINING INDUSTRY. Louis V. Olson, Director, Department of Agricultural Research, American Smelting and Refining Company, Salt Lake City, Utah.

WOOD, PULP, AND PAPER DIVISION

Norman S. Lea
 Technical Control Manager
 Scott Paper Company
 Everett, Washington
 Chairman

- 1:30 A PROGRAM TO REDUCE THE KRAFT EFFLUENT ODORS IN RECEIVING WATERS. C. Edward Taylor, Technical Director, Georgia-Pacific Corp., Toledo, Oregon.
- 2:05 WATER QUALITY MEASUREMENT WITH THE MICROSCOPE. Roger Tollefson, Consulting Biologist, Georgia-Pacific Paper Co., Toledo, Oregon.
- 2:40 HYDRAULIC BARKER EFFLUENT CLARIFIER AT WOOD PRODUCTS DIVISION, WEYERHAEUSER CO., EVERETT, WASHINGTON. R.E. Draper, Senior Project Chemical Engineer; F.S. Mercier, Plant Engineer, Weyerhaeuser Company, Everett, Washington.

- 3:35 AN OCEANOGRAPHIC SURVEY OF PORT ANGELES HARBOR. Jerome E. Stein, Research Supervisor, Olympic Research Division, Rayonier Inc., Shelton, Washington.
- 4:10 LAND DISPOSAL OF PULP AND PAPERMILL EFFLUENTS. Russell O. Blosser, West Coast Regional Engineer; Eben L. Owens, Development Engineer, National Council for Stream Improvement, Inc.

GENERAL SESSION

May 10, 1963

Morning

- 8:30 SYNTHETIC ORGANIC PESTICIDES - AN EVALUATION OF THEIR PERSISTENCE IN NATURAL WATERS. Robert W. Okey, Chief Metabolic Support Systems Group, Bioastronautics, Boeing Company, Seattle, Washington; Richard H. Bogan, Associate Professor, Department of Civil Engineering, University of Washington, Seattle, Washington.
- 9:15 PROPOSED SYSTEM FOR POLLUTION CONTROL IN THE COEUR D'ALENE RIVER VALLEY. LeVern M. Griffith, Manager of Plant Services Division, The Bunker Hill Co., Kellogg, Idaho.
- 10:20 LAND DISPOSAL OF INDUSTRIAL WASTES. Ralph H. Scott, Industrial Wastes Engineer, U.S. Public Health Service, Portland, Oregon.
- 11:05 PRE-PLANT LOCATION BACKGROUND STUDIES. Robert O. Sylvester, Professor of Sanitary Engineering, Department of Civil Engineering, University of Washington, Seattle, Washington.

INTRODUCTORY REMARKS

J. H. Holloway

In the foreword of the published Proceedings of the First Pacific Northwest Industrial Waste Conference held in 1949, Mr. Richard G. Tyler, professor of sanitary engineering at the University of Washington, spelled out the problems facing industries and municipalities in the Pacific Northwest in the fields of water and air quality conservation and control. These problems had multiplied as a result of the rapid influx of population during World War II and the augmented industrial growth of the area.

This situation prompted the University of Washington, with the cooperation of technical personnel from the state and regional governmental regulatory agencies, to invite all interested parties from industry, university, and government to meet and discuss these waste disposal problems through the presentation of scientific information and engineering data.

Since that time, nine additional conferences have been held, the sponsorship of which has been assumed periodically by the University of Washington, Oregon State University, and Washington State University. During this 14-year period much of the research and engineering information that first saw the light of day in these conferences has grown to full maturity in the form of commercial installations involving the expenditure of many millions of dollars by the industries represented here today.

The problems are complex and solutions often come slowly. The complete solution, of course, would enable us to eliminate the term "Industrial Waste Conference," and change it to "Industrial By-Products Conference."

Meanwhile, true progress in the abatement of industrial and municipal pollution will come only through, (1) acquisition of factual information by industrial, university, and governmental scientists and engineers, (2) objective appraisal of this factual information by trained scientists and engineers of the regulatory agencies who are thoroughly familiar with the unique problems and characteristics of the area under study, including the assimilative capacity of the local atmosphere and receiving waters for the effluents of industries and municipalities, and (3) impartial administration of the statutes in the granting of operating permits and licenses.

We trust that the information presented at this Eleventh Pacific Northwest Industrial Waste Conference will help us to take one more step toward final solution of these problems.

ON PRESCRIPTIONS AND PARALYSIS, FACT-FINDING AND THE FUTURE

C. Montgomery Johnson

I am a practitioner in public relations and public affairs. I am neither a natural resource manager nor a water quality technician. I bring no direct answers to specific questions in watershed management. I have no direct solutions to technical problems.

My company is vitally interested in most, if not actually all, aspects of watershed management, particularly as they bear on relationships between forest production and the production of satisfactory quantities and qualities of water. It is affected by practically all watershed decisions. So is industry generally. So is the community. My family's future is affected. So are you and yours.

In this field great written and oral eloquence has been expressed on:

1. Increasing people demands and decreasing watershed acreages.
2. Using chemicals to increase tree and wildlife growth and to decrease forest pests and disease—to eliminate some fish species and to stimulate others; on the lowering of water tables and the raising of water standards.
3. The need to close municipal water supply areas for protection of city water and to open these same areas for fishing and hunting grounds.

In this field, both casual reader and careful student are exposed not just to profusion, but also to confusion. One day we are told by the Secretary of the Interior that man and nature already have paid a heavy price for widespread use of pesticides. The next, we are told by the Surgeon General that pesticides have contributed greatly to health—by the Secretary of Agriculture that without some of these pesticides and some of these chemicals we would have insect equality where food and agricultural production is concerned, if not insect ascendancy.

We read in a summary of a 1960 U.S. Forest Service study that modern logging practices affect the hydrological characteristics and behavior of watersheds from "lightly" to "severely." We read in another Forest Service report that following the November 1959 floods on the Snoqualmie National Forest numerous

cutting areas were examined and no indication was found that runoff was any heavier on cutover areas than on timbered lands.

We are told by municipal water supply officials that allowing fishermen and hunters into watershed areas will endanger water purity, and simultaneously told by a professor of clinical medicine that there is no greater prevalence of waterborne diseases in open watersheds than those which are closed to public entrance.

We have been told that the fish farm program was and is "the answer" to replenishing our fisheries, but we have just read that the Washington Department of Fisheries evaluated its own fish farm program with results ranging from "very promising" to "failure"—and more expensive than anticipated.

We read in a recent U.S. Public Health Service symposium on siltation that one California fisheries biologist thought it "pretty obvious" that an increase in stream or lake turbidity affects photosynthesis. We read in another presentation in the same symposium that another expert from Oregon State University concluded that 99.9 percent of the so-called research in the area of turbidity and sedimentation problems today results in data that allow, for the most part, inaccurate conclusions.

We cannot imply that any of these statements (most are direct quotes) express the full, unequivocal position of any man or agency. This is to suggest, however, that "all the hay isn't in the barn" so far as watershed research is concerned. Further, to repeat an old saying,

It ain't the things you don't know
what gets you into trouble; it's the things you
know for sure what ain't so.

So where do we stand today in watershed management? Where should we be going? How should we be planning to get there?

Even to a non-technician in watershed management, the most important fact seems to me to be the need for more facts. You cannot read a report, attend a conference, talk to technicians, or even scan a newspaper or television, without concluding this.

Here are several examples of what I mean:

Millions of people watching television last month heard a Public Health Service toxicologist say there is no evidence that the small doses of pesticides we get are causing harm. The same millions watching the same program heard a staff member of the President's Science Committee and the Federal Council of Science and Technology say there is a great deal that we do not know about the biological effects of pesticides as they relate to soil, water, and animals in our country, as well as man himself.

Millions last month also read a nation-wide wire service account in which the director of the Bureau of Commercial Fisheries was quoted as saying that fisheries research and development programs are inadequate, information is mainly limited to a few species that are heavily fished, and a step-up in research is needed to fill gaps in knowledge if the domestic industry is to develop.

We read in a recent University of Washington Fisheries Research Institute circular that in the case of upstream salmon spawning, our biologists know what salmon eggs and fry require for survival but know almost nothing about the gravel, the life of the plants and animals that are in it, or the interrelationships which determine whether the final resting place of the eggs is favorable.

We hear the managing forester for a large forest products firm with an advanced forestry research program admonish that we don't yet understand the physiological inner workings of a tree—the plant on which our entire forest products industry is based.

We read recent Congressional testimony of the chief hydraulics engineer for the U.S. Geological Survey in which he observes that while the nation spends \$10 billion annually on water control activities, very little is spent on basic water research.

We read in the proceedings of a recent Public Health Service symposium that fisheries managers want to know, and do not know for certain, how much sand or silt is permissible in the bottom of a lake or stream; how turbid the water can be and for how long. We read in the same proceedings that fisheries managers do not know for certain what sort of research they need on the subject of siltation (which Bertrand Russell partly would solve with his observation that the stupid are cocksure and the intelligent full of doubt).

The volumes accounting the blind spots, voids, vacuums, and needs for watershed management facts seem almost as thick as the data developed to date. There seem to be so many problems, and some of them seem so large and complicated they obviously cannot be attacked all at once. At the same time, to concentrate on just one would probably leave 99 or 199 others standing in the way of progress.

The situation seems to call for a systematic weighing of problems, a thorough analysis of the research and fact finding already conducted, and an evaluation of priorities to guide in setting future effort.

A systematic approach should probably include the following considerations:

1. Favor those areas of research and fact finding which can be seen to lead toward affirmative results. Find which combination of practices, conditions, or uses produce more water or better water, or fish, or game, or trees. Expend effort where the potential is greatest; where it will produce the most beneficial and worthwhile results in relation to investment of money or manpower in the shortest period of time.

For example, we are told that mortality of salmon is by far the greatest in fresh water, that probably 90 percent of their eggs die under conditions unmolested by predators, unaffected by man. Yet for some time now we have been tilting at pulp mills on the estuaries, forcing the installation of millions of dollars of control and recovery equipment. Much of this effort is questionably marginal or unknown in its effect on water quality. Why wouldn't it be more sensible at this date to direct our estuarial effort toward finding out what water conditions actually are required to correct identifiable problems? More important, instead of spending millions more on downstream mills, why wouldn't it be more productive to spend thousands more on determining how to improve upstream egg survival?

2. Remember that watershed management research and fact finding always costs somebody money. In the quest for answers never forget that these are not solely biological ventures. Economic factors are part of every watershed management problem. They are not separate problems to be resolved after biological answers are revealed.

The cost of growing trees and of forest management has been reckoned with and borne by the forest industry for years. The cost of providing game and game fish is shared by hunters and fishermen, to the extent that hunting and fishing licenses pay the bill. The cost of outdoor recreation is just beginning to be recognized.

The cost of water, in relation to its worth, has largely been taken for granted. Only recently have people begun to appreciate that we have acquired water at bargain prices. A real dilemma confronts private forest land owners in the matter of protecting water quality on a watershed they own or control.

If the landowner on whose land the water is developed really determines to go all the way to maintain the water at its highest practical quality, who pays the bill? How much should the landowner be expected to do without finding a way to charge the user for the quality of water he has protected, or being otherwise reimbursed?

These are critical questions when recognizing that tree growing as a business venture returns the owner no more on his investment than he can realize by sitting at home and investing in relatively risk-free investments such as government bonds.

3. Involve to the fullest practical extent the principal qualified and affected parties in setting priorities on research and fact finding to be initiated or issues to be resolved.

This seems fundamental. Priorities on projects can hardly be set rationally without having some predetermined course or policy for watershed use. How can an equitable settlement of "cities vs. sportsmen" for example be reached for city, sportsman, and landowner if all parties, including the appropriate public agencies, are not called upon to participate in contributing and weighing definite information and the specific facts of the matter.

The manner and the attitude with which facts are sought and used as a basis for finding solutions are equally important as the need for the facts themselves. We should review which procedures for compiling and analyzing facts have worked and which have failed.

Here are a few proven prescriptions to encourage failure:

1. Determine the answer first, then dig out the facts to prove it. If a regulatory agency today sets out to prove a conclusion—that pollution does exist in a given area, for example—it will prove it. If an industry sets out to prove that no pollution exists, it will prove that, too.

Technology has advanced to where any competent agency is clearly capable of clouding a complex water issue with an assortment of statistics, some relevant, some perhaps not, in order to develop a publicly convincing image of pollution. Industry, too, has demonstrated with at least equally competent men and equally convincing statistics an ability to checkmate the matter as often as not.

2. If you represent industry, consider all government men "the enemy." Nothing triggers your adrenalin better or makes you feel more like you are in a crusade than to declare government the enemy and fight all its representatives as though they were the advance guard of a growing army out to destroy free enterprise, with their feet firmly planted in the public trough and their hands clasping your wallet.

If you represent government, consider all industry and land owners "the enemy." Nothing stirs your adrenalin better or makes you feel more like you are in a crusade than to tell yourself and your friends that those industry guys manage resources only where and when they can make a buck, do not give a damn about water, fish, game, or people, and have too much land and too much money anyway.

3. Regardless of the issue, take the position that there will be no compromise. For example, a municipal water supply manager simply says to sportsmen, "There will be no compromise with any activity that tends to jeopardize the purity of the city's water... and that's that..."

I won't become maudlin about the concept of compromise. Some could remind me of the view that compromise is only the sacrifice of one right or good in the hope of retaining another, and too often ending in the loss of both. I think another view of compromise, however, is more realistic. I certainly prefer it; the observation of the 18th century Englishman, Edmund Burke, "All government—indeed, every human benefit and enjoyment, every virtue and prudent act—is founded on compromise and barter."

4. Work alone in gathering or analyzing your facts.

Surprise all other interested parties and agencies with your accomplishment. You are serving on an advisory committee charged with developing a plan that proposes the consolidation of a state's water handling functions and departments into a single agency. Don't ask the career people in these agencies for their views on what will work. Send them a copy of your recommendations after they are mimeographed.

You work for a regulatory agency concerned about a discharger on a vital waterway. You want him to improve his methods. Seek his cooperation by, (a) publishing a "surprise" departmental report on his operation, (b) blasting him in the newspapers, (c) making a speech or two about his unhealthy attitude to the local sportsmen's club, and (d) then asking his help in conducting a "cooperative" survey to determine what the stream conditions really are.

5. Speak loudly and carry a big stick. Approach all water quality problems with the following attitude:

- (a) Public opinion is what you are bidding for.
- (b) The public is sort of apathetic and possibly a little stupid, too, so overdramatize your story, use color book cartoons, leave out inconvenient truths.
- (c) Characterize waste dischargers, loggers, road builders, mill operators, and users of chemical sprays as potential, if not actual, murderers of little fish, little rabbits, or even little children.
- (d) Advocate law enforcement as the most important single factor in solving water problems.

This posture results in creating an educational-informational image of watershed management and water quality problems where the ingredients each smack a little of Mickey Mouse, Arthur Sylvester's Cuba and Murder, Incorporated, where the tools of the trade include the use of public hearings to gather opinion, not facts, where the enforcement tools are the mob, the rope, and the hanging tree.

At this point I want to be certain that I am clearly understood. These "prescriptions for failure" are not in my mind categorical. There will always be honest differences of opinion on what does, in fact, constitute pollution, or for that matter, what constitutes fact.

There will always be individual viewpoints which various parties are obliged to defend.

There will always be certain principles which morally compel exposition.

There will always be a need for governmental action, and private action, to be based on public opinion.

Something is to be said, however, on what kind of public opinion. Someone once observed that "accurate knowledge is the basis of correct opinions; the want of it makes opinions of most people of little value." This is not necessarily so in a democracy where the majority of people are right, whether they are right or wrong. A political fact most certainly may not be a scientific fact, yet in all likelihood it will be controlling in a democracy.

Consider the wisdom of James Russell Lowell when you are considering how you would shape public opinion on watershed issues.

All free governments, whatever their name, are in reality governments by public opinion, and it is on the quality of this opinion that their prosperity depends.

There are hopeful signs. In recent years private land owners, state and federal agencies, and university research centers have found it mutually beneficial to cooperate on management problems relating to deer, elk, porcupine, and bear damage and other watershed management problems. The Washington Pollution Control Commission, University of Washington's Fisheries Research Institute, and Weyerhaeuser are entering now upon an extensive, cooperative study of Boise Creek and its watershed. Other public agencies, both state and federal, have expressed interest in cooperating on certain phases of the study.

When the study is completed many months from now, it would be nice to think that conclusions will have been reached that are compatible with the interests of all water users on Boise Creek. With the principal parties working together, the conditions for mutual understanding of each water user's problems are certainly improved. Furthermore, the procedures evolving in the Boise Creek project, both as to technical fact finding and as to the cooperative administration of the program could well set precedents for effective work on other streams and watersheds.

In southwest Washington, a cooperative hemlock looper control program has been in the planning stages for many months. The infestation covers some 70,000 acres of lands owned by several private forest products companies, the state of Washington, the federal government, and others. Coordinated by the State Department of Natural Resources, some fifteen different agencies and organizations have participated in various phases of the planning to date. Among the cooperators are: U.S. Forest Service, U.S. Bureau of Commercial Fisheries, U.S. Bureau of Sports Fisheries and Wildlife, U.S. Public Health Service, Oregon State Sanitary Authority, Washington Pollution Control Commission, departments of Natural Resources, Health, Fisheries, Game, Conservation, and Agriculture, representatives of Pacific and Wahkiakum counties, and the principal land owners.

Commercial and sports fishing exists in or near the spray area. Oysters, crabs, clams, fish hatcheries, and dairy farms must be protected. All these parties have been or will be contacted before the project is launched, probably in June of this year. Every safeguard and control technique known to the men in governmental agencies and companies has been considered and will be employed.

The project could be a total success or a partial failure insofar as destroying the infestation and saving the timber or protecting the other resources in the area. What can be said with reasonable assurance at this time is that the chances of all around success are increased manifold by the cooperative attitude taken by all parties to date. Further, a similar project carried out in northwest Oregon last year was very successful.

In my limited direct experience in the watershed management field and my travels among its literature, three other propositions seem worthy of mention:

1. Utilize the resources and talents of university facilities to a greater extent than in the past. Here is a source of information and experience upon which both industry and government at times can draw and rely for competent work. Here, too, is offered the possibility of third party, detached objectivity, often necessary in watershed determinations.

2. Invite more industry representatives to participate in the conferences and symposiums on water quality research, particularly those which are sponsored by government. The day is long since past when government can afford to rely solely on

the judgment and experience of its own employees in watershed management deliberations. Similarly, the day is gone when industrial land owners can afford the luxury of leaving things solely to tax-supported research and decision making. Both as water managers and as water users, private industry and land owners must share in the knowledge and responsibilities of the conference table input and output. This has been a successful technique employed in forest and land management problems for years. It certainly should be employed in problems of water quality and watershed management.

3. Change the name of this venerable and worthy conference from "Industrial Waste" to something that looks more positively into the future. Five years ago I spoke to the Pacific Northwest Sewage and Industrial Wastes Association in Spokane. I think it is fair to say that some of the things said then about the name of that organization led to consideration of its name change.

The name of any group or conference creates an image in the public mind and affects its participants' attitude toward their deliberations. Too, there is a certain futility and ridiculousness in naming a group after something you are trying to reduce or eliminate rather than something you are trying to attain or emulate. Many people, including the public generally, will have more confidence in all of us if this biennial affair were called something like "Pacific Northwest Water Quality Conference" rather than "Pacific Northwest Industrial Waste Conference."

Industry, too, would feel better, I am sure. Too often industry comes to too many conferences of this type with a chip on its shoulder and a monkey on its back. By getting industry off the defensive we may contribute much toward solving such problems as we may have.

Watershed management has been for too long a time a field plagued with the concept that "any change in nature is a change toward evil," where too many conclusions have been reached before investigation, where the best way to solve problems has often been considered the use of the mob, the rope, and the tree, where the principal private and public parties have viewed each other as the "enemy," and where the competition for "facts" has often exceeded constructive, cooperative effort to gain them.

It is time to discard the methods of Mickey Mouse and Murder, Incorporated.

It is time to junk the paralyzing game of cops and robbers with its polarizing effects that divide the community into good guys and bad.

It is time to think of the past only long enough to remember the lessons it taught, of the future only long enough to plan for it and to remember that useless worries generally disappear in the face of constructive, cooperative activity.

It is time to tackle the tough problems with selected tools of precision, scientific techniques of the universities, industry, and government, and the social talents of mature men.

There is no question in my mind but that public watershed policy is shaping toward making room for all compatible interests on the same watershed. Right now, water and watershed users are about like 25 impetuous college freshmen making a dive for the same telephone booth. Given time, cooperation, and common sense, they all will make it. So will we.

One day soon I can visualize a meeting of the hunters and fishermen and game and fish biologists, of municipal water supply managers and health officers, of loggers and foresters and farmers—yes, and of regulatory men and lawyers, too—for they always will have important roles to fulfill.

It will be a happy meeting. It will be held on a local watershed, more than likely whose ownership is commingled public and private. The guests of honor will be the technical people in industry, education, and government who showed the way toward watershed compatibility and harmony.

The politicians, in whose hands our social decision making rests, will be relieved.

The public relations men will be pleased.

And the public will be served.

WATER SUPPLY AND WASTE DISPOSAL PROBLEMS OF THE FOOD INDUSTRIES

Walter A. Mercer

INTRODUCTION

As representatives of the food industries and suppliers to these industries, we cannot avoid or postpone recognition and study of our water problems—shortages of supply, deterioration of quality, and prevention of pollution.

From every side we hear that our water supply is running out. We are told that our water pollution problem is a national disgrace, that filth in our streams is a creeping menace and a galloping disease.

Whether the situation demands such dramatic language is questionable, but we must be realistic. Men of foresight in the food industry have said that our advancing technology in food production may enable us to win the battle to feed an ever increasing population—only to lose in the long run because we destroyed our water supply.

In the real sense we are not running out of water. Over the span of years our national rainfall remains constant within a few percent of the annual average of 30 inches.

Inherent in the causes of our problem is maldistribution of people and water. In the West our population and industries are growing at an explosive rate. Yet, broadly speaking, the western half of the nation receives only one-third of the annual national rainfall. In California, for example, 70 percent of the water supply from annual rainfall originates in the northern one-third of the state, while 77 percent of the need for water lies in the southern two-thirds of the state.

Added to the maldistribution problem is the increasing individual demand for water. Our 180 million people now use 300 billion gallons of water per day. For each of us, 1600 gallons of water per day must be used to supply the commodities and services we are so dependent upon. For a family of four, 550 gallons per day are required for bathing, dish washing, clothes washing, watering the lawn, washing the car, and filling the swimming pool. On the basis of water usage we are surely the cleanest and certainly the most extravagant people in the world.

Each year this personal need for water is increased. Because of this and our population explosion, within 20 years we will be withdrawing as much water from both surface and underground sources as we can possibly develop.

The only logical way that we as a nation can meet water requirements in the years ahead is to collect more of the water now wasted to the oceans and to use our available water over and over again—and water reuse means pollution abatement.

Regarding water pollution, our Public Health Service says that over the past 50 years the volume of municipal wastes in our nation's waterways has increased 200 percent, and industrial pollution has risen 2900 percent. It is said that \$7 billion must be spent over the next few years to adequately treat waste waters and correct pollution problems.

Recently, at a National Conference on Water Pollution sponsored by the Public Health Service, a national credo was pronounced. It goes like this:

1. Users of water do not have an inherent right to pollute that water
2. Users of public waters have a responsibility for returning them as clean as technically possible
3. Prevention is as important as control of water pollution

These statements, in broad aspect, reflect national thinking on water pollution. There are now many individuals and groups who believe that the streams of our nation should be restored to the pristine purity of that time when the white man first gazed on them. This, they believe, must be done at all costs.

The approach of the clean water fanatic is that water pollution control requires treatment for every waste discharge, whether needed or not. The consequences of such a requirement are that public and private monies are spent unnecessarily, public funds are diverted from other needed projects, and technical and scientific facts are ignored.

The definition of water pollution differs with who you are, how you make your living, but most of all depends on your choice of recreation. More than 32 million Americans purchased hunting

and fishing licenses last year. By 1980, it is predicted 60 million persons will buy licenses and spend \$6.3 billion in outdoor recreation. Today, 8 million pleasure boats are in use on the nation's rivers, lakes, and coastal waters. Skin diving has soared into a \$100 million business. Leisure-time activities in the nation, often grouped together as recreation, are now responsible for an annual outlay of \$40 billion, or more than 8 percent of the gross national production.

There are as many definitions of pollution as there are groups of people concerned with pollution. To the Fish and Game Commission pollution is any condition which prevents abundant fish life. In our opinion, a good, fair definition is that of Dr. Richard Hoak of Mellon Institute, who has said, "Pollution is the discharge of any material that unreasonably impairs the quality of water for maximum beneficial use in the overall public interest." We are fortunate in that a number of our state water pollution control agencies follow quite closely the philosophy of this definition.

Although some regulatory agencies may be sympathetic to our food industry problems, we would be unrealistic not to expect and plan for more rigid requirements with regard to water pollution control and protection of the quality of our ground water resources. We must realize that water used by industry is community property and must be returned after use in a condition which does not damage or otherwise cause undue inconvenience to the community.

WHERE DOES THE FOOD INDUSTRY STAND?

Where do the food processing industries stand with regard to this concern about water supply and water pollution problems? To produce our annual, nation-wide pack of 700 million cases of canned foods requires about 36 billion gallons of water. A river of 5 billion gallons of water is needed to process California's tomato crop. To can the bean crop of the Northwest requires more than 400 million gallons of water.

Together, the nation's canning and freezing industries use approximately 0.10 percent of the total usage of water by all industries.

We are most vulnerable with regard to the heavy load of organic wastes in the water leaving our plants. The 36 billion gallons of clean water we take in is discharged with a required

treatment potential equal to 300 billion gallons of domestic sewage. Processing 10 tons of tomatoes produces a liquid waste equivalent in strength to the daily sewage from 700 people. Liquid waste from canning one ton of peaches has a population equivalent of 500.

It has been said that on peak days of operation the food industries of the nation produce organic waste materials which, if untreated, would be equivalent in strength to the sewage produced by every man, woman, and child in the nation.

The disposal of liquid and solid waste materials from food processing is rapidly becoming one of our most perplexing problems. For most processors the net expense for waste disposal is already a substantial item in the cost of producing canned or frozen foods. For the future we can only expect waste disposal to be progressively more troublesome and expensive.

Twenty years ago it was commonly considered that to produce the average case of canned product 25 gallons of water were required. Today, because of quality improvements and a more rigid definition of clean foods, the average use per case is nearer to 50 gallons.

Fifteen years ago waste disposal or treatment costs amounted to about one-tenth of a cent per case. Today this expense is in the vicinity of seven-tenths of a cent per case. Costs as high as four and one-half cents per case are forecast within the next few years.

A major factor in the gloomy waste disposal situation in the West is the explosive increase in population and industrial growth. For the period 1955 to 1970, the average population growth rate for the nation is calculated to be a 27 percent increase; for California, 57 percent; for Washington, 33 percent; and for Oregon, 38 percent.

This means that existing treatment facilities are or soon will be inadequate. The trend toward suburban building means that food plants which may once have enjoyed relative isolation can now be surrounded by homes or other industries more fortunate with respect to the nature of their waste materials.

Even the economics of food processing have a troublesome influence on waste disposal problems. As the margin of profit per unit of finished product becomes smaller, the processor

must increase production to survive. Larger tonnages of raw product mean larger volumes of stronger waste materials to be handled and disposed of at higher costs. As an industry, we have been slow in awakening to the seriousness of the problems we are now facing.

WATER CONSERVATION RESEARCH

What is the canning industry doing about water supply and waste disposal problems?

An important part of the answer to that question is our realization of a hard but simple truth—the industry must learn to use less water. This must be done in the face of the fact that raw foods must be washed cleaner than ever before—but with less water. There must be more thorough removal of pesticide residues and, perhaps, even radioactive fallout.

Only through research can we determine how much water usage can be reduced and still allow an efficient sanitary operation. Reduced water usage can be rewarding not only in conservation of a commodity so vital to the industry and the nation, but also in reduction of the volume of fluid waste whose disposal becomes more troublesome each year. These reductions in water usage must be accomplished by procedures which cause no undesirable effects on the physical appearance, nutritional qualities, or sanitary condition of the product. This is an important area in our research on product protection.

The theme of this cooperative research is, simply, "Cleaner foods with less water." For example, we have worked together to determine the conditions which influence the effectiveness of raw product washing. Regardless of the water use situation, raw foods must be cleaned.

Our study of the conditions required to remove soil, insects, microorganisms, and chemical residues from raw foods shows that final cleanliness of the food is not dependent on the volume of water used but on the method of applying the water to the food.

As a result of this work we are able to supply information regarding the type of spray nozzles which give most effective cleaning. We know, for example, that nozzles which deliver a spray of medium-size droplets have more mechanical scrubbing

action than nozzles which atomize the spray. We are able to recommend the most effective arrangement of the spray washing system with regard to the construction of the belt conveying the product beneath the sprays, location of the sprays with regard to height and spacing above the product, the pressure of the sprays, and the temperature and volume of water to be used.

The need for more economical methods in food production has brought about development and, now, widespread use of bulk-handling methods in preparing foods for canning. Within the factory, bulk handling includes the use of hydraulic dumps for receiving raw foods and hydraulic systems for moving raw foods to and from operations which prepare them for final processing.

Fruits of all kinds, spinach and peas, and even fish are extensively flumed and pumped. Indiscriminate operation of such hydraulic systems for food handling creates situations of concern with respect to the sanitary condition of the food. Our research has shown that microbial counts for foods in the can are influenced by the sanitary condition of the water in which they were pumped or flumed.

Of equal concern is the excessive water demand of hydraulic systems when used in areas faced with current or potential shortages in water supply. In any area the disposal of resultant large volumes of waste water may create water pollution and public nuisance problems. Excessive use of water in these hydraulic systems may insure the good sanitary condition of the foods being conveyed, but we must stress the need to conserve water and prevent waste problems through more efficient use of the water. This can only be accomplished by extensive reuse of the water.

Based on our research, we are prepared to suggest the flume systems which use clean waters reclaimed from other operations in the cannery and which recirculate the water to the extent possible without causing unsatisfactory sanitary conditions.

The water-saving potential of these water reuse procedures is highly significant. In pea canneries, for example, where all clean waters are collected for reuse and the flume water is recirculated to the maximum extent, water consumption may be reduced by as much as 45 percent.

Hydraulic conveying systems are usually operated as though they are inflexible with regard to the volume of water used. The setting on the water valves is always wide open. In such systems the sanitary condition of the water varies with the load of product being conveyed, the gallons water used per unit weight of product, and the use or not of chlorination. Where the volume of water is constant and the rate of production, measured in cases per hour, increases, the gallons of water used per case decreases. Since the ratio of water volume to product load is decreased, the concentration of organic solids in the water and numbers of bacteria are increased. With the addition of chlorine held constant, an increase in organic solids causes a resulting decrease in chlorine residual.

Our previous and current studies have convinced us that means must be found for controlling the sanitary quality of the water in these hydraulic systems. This must be done as a safeguard for product quality.

We are impressed with our experimental results which indicate that measurement of selected physical characteristics in these recirculated waters is a reliable means of estimating their sanitary condition. Such a relationship is that between total solids and total numbers of bacteria.

Values for turbidity and color can also be related to sanitary conditions. We are convinced that these measurements can be made the basis for operation of continuous, automatic monitoring devices which can control the addition of fresh water to hydraulic systems. By this means satisfactory sanitary conditions can be maintained without excessive use of water. This work is being supported in part by a grant from the Division of Environmental Engineering and Food Protection of the Public Health Service.

Under the conditions of food plant operation, there is now no practical test by which the bacteriological condition of food washing or fluming waters can be determined. Such methods or tests must necessarily be limited to those which give an immediate answer since the condition of concern is that at the moment of sampling. For this reason counting the number of bacteria by plate culture methods cannot supply the information needed at the time of sampling.

Presently, we are working with model flume and pumping systems. Measurement and control of the physical condition of

the water recirculated through these systems has been designed around a sensitive turbidimeter. Previous study of waters recirculated in commercial hydraulic systems serves as a basis for formulating simulated waters which are pumped through the model flume.

We believe that use of such control systems suitably automated to give continuous monitoring of the water's condition would have important advantages, among which are the following:

1. "One-pass" uses of water could be eliminated.
2. Discharge of clean water during work slow-down or stoppage would be prevented.
3. Continuous monitoring methods for measuring the organic concentration in waste waters would allow issuance to industry of permits to discharge to storm sewers or streams, waters which comply with prescribed conditions. In many situations such controlled discharge of relatively unpolluted waters would relieve the overload on sewage treatment plants.

With reference to water usage and fluid waste disposal problems, we urge the canners to keep these goals constantly in mind:

1. Development of in-plant practices which will limit the volume of process waters to that necessary to carry out a sanitary canning operation.

The thought here is that containment of the waste load in as small a volume of water as possible is essential in reducing capacity requirements, in treatment facilities, and in promoting more efficient treatment.

2. Segregation at the point of origin of strong waste waters from weaker, cleaner waters.

A case in point here are the blancher waste waters in pea canneries which, volume-wise, represent only about 2 percent of the total waste flow, yet contain 60-70 percent of the total organic load. In some cases clean waters, thus segregated, can be re-used or discharged to streams without causing a pollution problem.

TREATMENT AND DISPOSAL OF LIQUID WASTE

With water usage reduced to a level which still allows a bacteriologically safe and sanitary operation, and the liquid waste adequately screened to remove solid wastes, the final volume of liquid waste must be disposed of with or without treatment.

Much of the difficulty involved in the satisfactory disposal of liquid cannery wastes is a result of the nature of the wastes. As compared to domestic sewage, their polluttional strength is ten to fifteen times higher. They are unusually high in soluble sugars, starches, and other complex organic materials. Unfortunately, the concentration is usually less than one percent, which does not justify attempts to recover useful constituents.

A further difficulty is the large volume of liquid waste resulting from the usual cannery operation. The average waste flow for western canneries is more than a million gallons daily. Multiply this volume by 60, 100, or 200 days of plant operation and the enormity of the problem is more clearly seen.

In spite of the difficult nature of cannery wastes, many improvements have been made within the scope of the following general methods of disposal:

1. Discharge to a municipal sewage treatment plant. This is the preferred method. Its success depends on adequate capacity of the receiving plant and sufficient dilution of the cannery wastes to prevent disruption of the necessary biological processes.

2. Discharge to a land disposal system. The use of lagoons is decreasing since this method of disposal is often complicated by odor, fly, and mosquito problems. However, improvements have been made in the design and operation of cannery waste lagoons.

Spray irrigation is increasing as a method of liquid waste disposal. Under suitable conditions this method will prevent stream pollution and odor problems. It is usually less expensive than other methods of treatment. With average conditions it can be roughly estimated that 40 to 50 acres of land will be needed for each one million gallons of waste produced each day. In some areas this acreage is not available or is too expensive to be used for waste disposal. In one of our studies we are deliberately saturating experimental plots to determine how much water

the soil and cover crop can take. The volumes of waste sprayed on the plots are accurately measured. The plots are graded so that the run-off is collected and measured. Samples are tested to determine how much improvement has occurred in the quality of the water.

Our preliminary studies with tomato waste show that:

- a) The polluttional strength of the run-off from the plots was reduced by 52 percent.
- b) The dissolved oxygen content was increased from zero to an average of 4.2 ppm.
- c) Allowing 8 hours rest between spray periods the area of land required to handle one million gallons of waste per day could be reduced from 60 to 24 acres.

These results are encouraging and will be supplemented by the results of further experiments.

3. Discharge to cannery-operated treatment systems.

Chemical treatment is now seldom used for fruit and vegetable canning waste. However, all food plant wastes are amenable to biological treatment methods. Partial or complete treatment of the total waste flow involves extremely high costs for equipment having sufficient capacity to contain the flow for the time period required for adequate treatment.

Our research is now concentrating on high-rate treatment methods suitable for handling relatively small volumes of strong wastes. It is expected that, in some cases, the disposal of liquid waste will become so troublesome that canners and other food processors will be required to treat strong waste to some degree before it is discharged to the sewer.

DISPOSAL OF SOLID WASTES

With reference to solid wastes from canning operations, the problems of disposal are rapidly reaching a critical stage. Much of this waste material is presently dumped or spread on land. The infiltration of urban industry and population into once rural areas no longer allows the isolation necessary to prevent nuisance and public health problems arising from this method of disposal. The breeding of flies and agricultural pests in fruit and vegetable refuse can be demonstrated.

Heightened activity in protection of stream and ground water quality has given rise to justifiable doubt about land-fill disposal of these high moisture waste solids. Because of the wet nature of the solids and air pollution problems, incineration cannot be considered as a solution. Utilization in by-products recovery is seriously limited by pesticide residue problems.

OCEAN DISPOSAL OF SOLID WASTE

Solid wastes are being barged out to sea from one area in California. Approximately 70,000 cubic yards of fruit, tomato, and vegetable solids are collected by a scavenger company and accumulated in a concrete sump located near the Oakland side of San Francisco Bay. From the sump the solids are bulldozed into a hammer mill for breaking up the larger pieces of fruit and the peach pits. Following this the solids are pumped into a converted oil barge which, when loaded, is towed to a disposal area about 26 miles beyond San Francisco's Golden Gate.

The mechanics of disposal at sea consist of pumping the waste material from the barge at a rate of discharge prescribed by the pollution control agency. The speed and direction of the barge is also prescribed.

A monitoring program was required by the pollution control agency. This was carried out by sampling the ocean at various depths and distances behind the barge. All regulatory agencies concerned with the operation are pleased with this method of disposal. The results of all tests indicate that the discharge creates only momentary changes in the water.

COMPOSTING OF SOLID WASTES

Ocean disposal of solid wastes is, of course, limited just to coastal areas. Even there, because of the threat of maritime labor strikes and the excessive cost of the operation, it cannot be considered as a permanent solution to the disposal problem. It is an alarming fact that if open dumping or land-fill disposal were suddenly prohibited there is no alternative method known to be reliable and economically feasible.

For the past two seasons our laboratory has conducted a series of pilot experiments to study the feasibility of composting fruit waste solids. The Sanitary Engineering Research Laboratory of the University provided a composting site at their Richmond field station. We are just now initiating a four-year study

program, supported in part by the Division of Environmental Engineering and Food Protection of the Public Health Service.

It was realized from the beginning that to be successful and practical the compost process would have to be rapid, non-odorous, and free from fly problems. In composting language this means a high-rate, aerobic process.

The process offers considerable promise as a means of disposal. The current season's experiments are attempting to determine the conditions necessary to accelerate the compost process. Previous experiments indicated that an initial lag in the process was due to the low pH of the starting mixture of fruit waste and dry waste materials, such as sawdust and rice hulls. Lime is now being added to control pH level within a range more optimum for rapid microbial growth. Because of the low available nitrogen content of these compost mixtures, nitrogen in the form of urea is being added. Preliminary results of current experiments indicate that these additives are having the desired effect in accelerating the breakdown and stabilization of the fruit wastes.

It is expected that population growth and industrialization of many areas will limit the land space available for compost operations. In many situations it will be desirable for the food processor, on his own premises, to convert waste solids into compost or other stabilized by-products no longer capable of causing nuisance problems. In view of this prospect, a second phase of the current experimentation is investigating the mechanics of continuous composting. The overall aim is to develop machinery and handling techniques which automate composting of the waste solids and maintain conditions which allow continuous feeding of wet solids into a system producing a dry, stable end-product.

CONCLUSIONS

The National Cannery Association feels that food processors should make determined efforts to reduce the wastage of raw products which it processes and the volume of water used in the process, for these are the causes of pollution and disposal problems. The Association feels that the industry should attempt to correctly evaluate its responsibilities in the prevention of waste disposal and water pollution problems. At the same time the Association feels that much of the complexity and magnitude of the waste disposal problem facing the industries today are not of

their making, and the search for solutions to these problems not entirely the responsibility of these industries. Explosive increases in population and industrialization of once rural areas have created problems which can be solved only by community efforts. To this end research programs designed to aid in these efforts should have support from public funds administered by the Public Health Service. In turn, the Public Health Service should have the good will and cooperation of industry.

PROBLEMS ON WHICH HELP IS NEEDED

The use of water in food plants and disposal of waste waters from these plants create problems which are varied in character and always complex. Solution of current and future problems will require the attention of engineers, chemists, and other workers in many fields.

I wish to direct my concluding remarks to food machinery manufacturers, agricultural scientists, representatives of the University, and to all who may be in a position to help with the industry's water and waste problems.

Briefly outlined, some of the problems which deserve your attention are:

1. New designs in equipment for harvesting canning crops should give consideration to the sanitary condition of the harvested crop. Excessive amounts of soil, leaves, and stems necessitate the use of excessive volumes of water to clean the product.

2. New designs in food plant equipment using water should consider factors which increase the efficiency of water use. In addition, the design of the equipment should be such that it is easily cleaned without excessive use of water. I include here raw product washers using less water to give cleaner products, can coolers using less water to accomplish cooling, and evaporative condensers which require less water.

3. Methods for cooling water, prerequisite to its reuse, should be more efficient and less expensive. Many canners now without cooling systems feel that the conventional redwood towers are too expensive and inefficient.

4. Greatly needed is equipment which would make possible the screening or filtering of process waters to remove soil

and organic debris, thus rendering the water reusable. Perhaps a liquid cyclone separator would do this.

5. Evaluation of food plant waste waters for irrigation of field crops could have far-reaching consequences. Basic questions must be answered before irrigation of crops with waste water would be widely accepted.

- a) How do various types of organic waste waters affect soil structure, ground water levels, and ground water quality?
- b) What are the soil building potentialities of organic waste waters?
- c) What crops would be best suited to irrigation with waste waters?
- d) What are the economics of transporting waste waters to suitable sites for irrigation disposal?

6. Of great value would be an investigation of the feasibility of disposal of food waste waters by direct injection into confined aquifers. Injection by pumping into a water-bearing stratum would not be a health hazard since waste waters from fruit and vegetable canning contain no microorganisms of public health significance. Admittedly, many problems would have to be solved by experimentation, but artificial recharge of ground water resources with waste waters of this type would have considerable potential for the ultimate solution of some of the state's water problems.

Assistance in these and other related problems would enable food processing and other industries to rest easier and at the same time be a step in the direction of improvement in our water resources situation.

COMPOSTING FRUIT WASTE SOLIDS

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INTRODUCTION

Composting may be defined as a biological process in which many types of microorganisms decompose organic matter into stable material, usually called humus. To this definition we add that it must be a high-rate oxidative process which is maintained under aerobic conditions by either turning or forced aeration. Anaerobic composting results in low temperatures, slow rate of decomposition, and the production of malodorous gases.

Composting involves many types of microorganisms which appear in sequence, and each group contributes towards completing the cycle. The first group to appear are the mesophilic acid-producing bacteria. These bacteria break down simple organic compounds and raise the temperature of the composting material so that the thermophilic bacteria begin to predominate. Because of the intense biological activity of these organisms, the temperature has been known to reach 160°-170°F. During the thermophilic cycle most of the readily available organic compounds are utilized, after which the temperature begins to decline. The actinomycetes now become the predominant group as indicated by the alkaline pH of the compost mixture. This is due to the production of ammonia gas. The fungi are present throughout the cycle but never become the predominant group. They do utilize acids and perhaps raise the pH for the thermophilic bacteria. The fungi also attack and decompose complex materials such as lignin, cellulose, and pectin. Each group has a specific job, and their sequence is independent of most environmental factors.

Because composting is a biological process, environmental factors influence the activity of the organisms and determine the speed and course of the cycle. Some of the more important factors to be considered are particle size of the material to be decomposed, moisture content, aeration, hydrogen ion concentration, and the initial carbon-nitrogen content. It is our job to manipulate these factors so that optimum conditions exist throughout the compost cycle.

In regard to the disposal of cannery waste solids, the particle size can be controlled by grinding. The moisture con-

tent can be adjusted by the use of moisture absorbent material. Oxygen requirements can be met either by turning or forced aeration. The low pH of fruit wastes can be neutralized by alkaline substances and the carbon or nitrogen content can be adjusted by adding the appropriate compound.

For the past two seasons our laboratory has conducted pilot experiments to study the feasibility of composting fruit waste solids. Our objective was to develop techniques and operational procedures for composting fruit and vegetable solids which result from peeling, coring, trimming, sorting, and otherwise preparation of foods for final processing. This coming season we shall begin field scale experiments to establish a cost basis, space requirements, and other factors involved in the practical operations of windrow composting fruit and vegetable wastes.

METHODS OF PROCEDURE

The experiments to be described were carried out in open-top redwood bins. The bins were 4 feet square and 5-1/2 feet high. Previous work by others indicated that a compost mass of one cubic yard would give reliable information applicable to large-scale field operations. Three bins were arranged as shown in Figure 1, at opposite ends of a concrete slab. The slab was used in mixing and turning the compost from the bins.

For each experiment the solid fruit waste material and the moisture absorbent material were weighed separately before mixing. The bins were filled by alternate layers of fruit waste and dry material. After filling each bin, the height and volume were recorded as well as the weight of each admixture. At the end of a cycle these values were recorded again except that a combined weight was taken to compare with the initial weights.

On the following day the material was removed from the bin onto the concrete slab. Here it was mixed and turned with a shovel and returned to the bin. This procedure was repeated for five consecutive days, after which it was turned on alternate days until the end of the cycle.

Separate samples of the fruit waste and the dry material were taken for chemical analysis before each experiment. After each turning, approximately 2 pounds of sample were taken for pH and moisture determination. At the beginning and end of each cycle a complete analysis was made on samples.

Temperature measurements were made daily at nine points in each bin. Temperatures were taken at 2-inch depths and 8-10 inches below the surface, as shown in Figure 2. The values used in this presentation were taken at point number 5 and at a depth of 8-10 inches.

Since space requirements would be a major consideration in evaluating the feasibility of large-scale composting of fruit and vegetable waste solids, particular attention was given to the changes in the weight and volume of the mixture at the end of a cycle. Also, we were quite concerned as to whether or not the finished air-dried compost could be recycled as the absorbent material for additional batches of fresh waste. Figure 3 shows the compost being dried at the end of a cycle.

EXPERIMENTAL RESULTS

Experiment 1

To compare the time periods required for composting ground and unground peach solids, Experiment 1 was performed using the weight ratios given below for unground fruit and dry, recycled compost.

Bin No.	Weight Ratio of Peach Solids to Recycled Compost (Pounds)	Total Weight in Each Bin (Pounds)
1	150 to 100	2500
2	200 to 100	3000
3	250 to 100	3150

In this and the following experiments the dry recycled compost and the fruit solids were placed in the bins in alternate layers. After a 24-hour period the mass was removed from each bin to the concrete slab, there mixed, and returned to the designated bin. After an additional 24-hour period the first temperature readings were made and grab samples taken for chemical analysis of the initial mixture.

Figure 4 has been prepared to show temperature changes in the mixtures. The first readings were made 48 hours after the fruit waste and dry material were layered into the bins, and 24 hours after the first turning for aeration. At this time the temperature was approximately 115°F for bins 1 and 2 and about 102°F for bin 3. Temperature readings taken before turning the

piles on three successive days were lower in each case. These unexpected variations in temperature levels are believed to be due to changes in the free moisture concentration, and consequently changes in pH value throughout the mass in each bin. Although the laboratory determination of initial moisture content was 74, 76, and 79, respectively, for bins 1, 2, and 3, these results did not represent the moisture concentration in all parts of the pile. Much of the moisture and fruit acids, during the first days of the compost period, was concentrated in the tissues of the fruit pieces. Moisture and pH determinations on slurried samples did not indicate true conditions in the bins. Release of juices from the fruit tissues and turning of the mixtures resulted in moisture and pH conditions less optimum for microbial growth than beginning conditions.

Between the fourth and fifth day after the initial turning of the compost mixtures, elevations in temperatures occurred. About the eighth day, after reaching a medium range (120°-125°F) the temperature for the three lots decreased, as shown by the curves in Figure 4. By the twelfth day the temperatures again increased for each bin to reach a high level within the range of 140°-150°F. Thereafter the temperatures remained high for a period of 20 days, then rapidly subsided.

The cause for the second decline in temperature is not definitely known. It is conjectured that at the initial pH, between 4.0 and 5.0, only acid-tolerant microorganisms were able to develop. Acid production by these organisms retarded growth of other types. After utilization of the readily available fruit sugars, growth of fermentative organisms declined, with a consequent fall in temperature. Increased growth of molds destroyed organic acids and resulted in an elevation of pH and conditions more optimum for growth and development of thermophilic aerobes. It is known that failure to turn the compost frequently after reaching thermophilic temperatures can cause a decline through either partial sterilization or depletion of oxygen. The curves in Figure 4 show the rapid temperature increases which occurred about the tenth day of the compost period. Figure 5 shows the changes in pH for the three compost mixtures.

In Figure 6 are curves for changes in percent moisture, and values for temperature and pH for the compost mixture of 250 pounds fruit waste and 100 pounds of recycled, air-dried compost. After 25 days the moisture concentration was reduced from 79 to 30 percent. Although the pH continued a slow increase up to the final day of the experiment, the process could have been terminated

after 25 days. After this period the temperature showed the decline characteristic of the final stages of the compost process. Table 1 gives the results of the laboratory determinations made before and after the third use of the recycled compost.

Experiment 2

The previous experiment worked with fruit waste as it came from the cannery. Whole fruit and pieces of fruit were not ground before being composted. It was apparent that slow release of moisture from the larger pieces and the proportionately small surface area open to microbial attack were conditions which extended the time required for decomposition of the compost mass. Shortening of the time required for satisfactory composting was considered to be an important factor in determination of the feasibility of industrial application of composting as means of disposal for high-moisture organic wastes.

Peach waste solids were passed through a Reitz disintegrator having a screen opening of 0.75 inch. The ground waste was mixed with the municipal compost recycled from Experiment 1. The following weight ratios were used:

Bin No.	Weight Ratio of Peach Solids to Recycled Compost (Pounds)	Total Weight in Each Bin (Pounds)
1	100 to 100	1600
2	150 to 100	1500
3	200 to 100	1800

As shown by the graphs in Figure 7, the temperature of the mass in bins 1 and 2 began increasing after the third day and continued to increase until reaching, on the seventh day, levels between 150° and 170°F. A gradual decline in temperature followed. Figure 8 shows that increases in pH value followed the pattern of temperature changes. Between the seventh and ninth days the pH for bins 1 and 2 ranged between 7.5 and 8.5, and remained stable within this range.

Bin 3 received the highest weight ratio of peach waste to dry material. The initial moisture concentration was 71 percent. For bins 1 and 2 the initial moisture concentration was 59.6 and 63.4 percent, respectively. The high moisture content of the mixture in bin 3 caused the mass to be too compact for adequate

aeration. The soggy consistency of the mixture prevented it from falling apart during turning of the pile. When shoveled back into the bin the weight and fluidity of the mixture eliminated air spaces in the mass. As shown in Figures 7 and 8, the temperature and pH for this mixture remained relatively unchanged for a period of 9 days. During this time the mixture was spread in a 6-inch layer on the concrete slab and air-dried for 24 hours. The first drying failed to start the compost process. Following a second air drying period a rapid increase in temperature occurred. After a 7-day period the temperature decline and the pH remained stable at a level above 8.0.

The mixtures in bins 1 and 2 composted in a satisfactory manner and reached stability within 8 days. Bin 2 contained 150 pounds of fruit solids to 100 pounds of the recycled, dry compost from Experiment 1. Figure 9 gives the curves for changes in moisture, temperature, and pH in this mixture. The curves for temperature and pH show that an initial lag period of approximately three days elapsed before the composting process became evident. The question arises as to whether or not the initial acid reaction (pH 5.4) retarded microbial growth and multiplication, and whether or not adjustment of the pH with lime or other alkaline material would have shortened the lag period and, thus, shortened the time required for composting.

Table 2 gives the results of chemical analysis of the ingredient materials and of the initial and final compost mixture contained in bin 2. Comparison of the analysis for the finished compost from Experiment 2 to that for the compost recycled from Experiment 1 indicates that slight increases occurred in percentages for carbon, nitrogen, phosphorus, and potassium.

Comparison of the analytical results for the finished compost to the results for the initial mixture shows that slight reductions occurred in percentages for carbon, nitrogen, and potassium. The phosphorus concentration was unchanged. The increase in percentage of ash indicated changeover, through microbial activity, of organic compounds to an inorganic state.

Finished compost from Experiment 2 was air-dried and set aside to be used for the third time as the dry material in later experiments. Comparison of the analysis for this finished compost to that obtained after the first use (Table 1) indicates slight increases in nitrogen, phosphorus, and potassium.

Experiment 3

Previous results indicated a slow beginning of the compost cycle. Sometimes there would be a lag of up to 5 days before a noticeable pH or temperature rise began. Since one of our specific objectives was to accelerate the compost cycle, we set up some experiments to determine the benefits from the use of alkaline and nitrogen containing compounds. By examining the results it was noticed that the pH was low and probably prevented maximum growth of the microorganisms.

Ground apricot waste solids were mixed with recycled municipal compost (used in the experiments in 1961). The apricot waste solids were ground with a Reitz disintegrator with 0.75-inch screen opening. The two bins received the following mixtures of recycled municipal compost and ground apricot waste:

<u>Bin No.</u>	<u>Weight of Fruit Waste to Municipal Compost</u> (Pounds)	<u>Total Weight in Each Bin</u> (Pounds)	<u>Lime Added Per 200 lb of Compost</u> (Pounds)
1	200 to 100	3150	0
2	200 to 100	3150	1

Because the lime was not added until the seventh day, no attempt was made to determine the length of the compost cycle with and without added lime. However, the bin which had the lime added reached a temperature of 147°F six days after the lime had been added. The bin without added lime had a temperature of 83°F at this time. Figure 10 shows a comparison of the average temperatures of bins 1 and 2. The addition of lime to the compost mixture reduced the time required to reach maximum temperatures by four days.

Figure 11 shows a comparison of the pH values for bins 1 and 2. Bin 2 (lime added) reached a pH of 8.1 eight days before the pH of bin 1 reached the same value. The changes in pH, temperature, and percent moisture for both bins are given in Figures 12 and 13. Table 3 presents the results of chemical analysis of the materials and of the initial and final composted mixtures.

The initial wet weight of the mixtures were reduced 56.4 percent (bin 1) and 53.9 percent (bin 2). The volumes were reduced 39.4 percent (bin 1) and 36.9 percent (bin 2) during the

compost cycle.

Following the compost period, the lots of finished compost were weighed, and air-dried. The increases in dry weight and amount of waste utilized is listed below.

	Bin 1 <u>Control</u>	Bin 2 <u>Lime Added</u>
Wet weight of raw fruit waste utilized	2100 lb	2100 lb
Increase in dry weight at end of cycle	150 lb	236 lb

Ground apricot waste solids were mixed with sawdust. One-half of the sawdust had been used in the experiments during the 1961 season. The new and used sawdust was mixed before it was put into the bins. The apricot waste solids were ground with a Reitz disintegrator with 0.75-inch screen opening. The two bins received the following mixtures of sawdust and ground apricot waste:

Bin No.	Weight of Fruit Waste to Sawdust	Total Weight in Each Bin	Lime Added Per 200 lb Fruit Waste
	(Pounds)	(Pounds)	(Pounds)
1	200 to 45	1715	0
2	200 to 45	1715	1

As shown in Figure 14, the bin which had the lime added reached a temperature of 152°F in 15 days from the start of the cycle, while the bin without added lime did not reach 150°F until 19 days after start of the cycle. The addition of lime reduced the time required to reach maximum temperatures by four days. Figure 15 shows a comparison of the pH values for bins 1 and 2. The pH value for the bin with lime added reached 8.0 eight days before bin 1 reached the same value. There is an initial lag of 3 days before the pH of the bin with added lime begins to rise, whereas there is a lag of 9 days before the pH begins to rise in the bin without added lime.

Table 4 gives the results of chemical analysis of the materials and of the initial and final composted mixtures.

The initial wet weights of bin 1 and bin 2 (lime added)

were reduced 54.1 and 57.6 percent. The volumes of bin 1 and bin 2 (lime added) were reduced 25 and 24.3 percent.

There was an increase in dry weight of 225 pounds in bin 1 and 290 pounds in bin 2. The reason for the high increase in dry weight was that the apricots used in this experiment had numerous free pits which amounted to 40 percent of the initial weight.

The finished compost from this experiment was air-dried, screened, and set aside to be used in later experiments.

Experiment 5

The purpose of this experiment was to determine the effect of the additions of nitrogen, nitrogen plus lime, and lime on the time required to complete the compost cycle. The concentration of nitrogen and lime used in this experiment was 1 percent. The ratio used in these experiments was 150 pounds of ground peach waste to 45 pounds of sawdust. The peach waste was ground with a Mr. Gilead apple grater. The four bins received the following mixtures of sawdust and ground peach waste:

Bin No.	Weight of Fruit Waste to Sawdust (Pounds)	Total Weight in Each Bin (Pounds)
1	150 to 45	1560
2	150 to 45	1365 + 1% N(urea)
3	150 to 45	1365 + 1% N(urea) & 1% lime
4	150 to 45	1365 + 1% lime

Figure 16 has been prepared to show temperature changes for the different mixtures in this experiment. The bin with 1% N (urea) and 1% lime was the first to reach a maximum temperature (142°F) in six days. The bin with 1% N (urea) reached 147°F in seven days. It should be noted that there was rapid drop in temperature after reaching a maximum temperature in the bin containing 1% N (urea) and 1% lime.

However, the bin containing 1% N (urea) did not have as rapid a drop in temperature. The difference in the temperature curves may be due to the more rapid utilization of the readily available fruit sugars in the bin with 1% N (urea) and 1% lime added. When the readily available fruit sugars have been utilized the growths of fermentative organisms decline, with a consequent

fall in temperature. When the temperature curves for the control bin and the bin with 1 percent lime are compared, the benefits from the addition of lime to the compost mass is again shown by the more rapid rise in temperature and an overall higher temperature. The addition of N (urea) plus lime, or N (urea) reduced the time required to reach maximum temperatures by five to six days when compared to the bin with lime added.

Tables 5 and 6 give the chemical analysis of the materials and of the initial and final composted mixtures.

The initial wet weight and volumes of the bins in this experiment were reduced as follows:

Percent <u>Reduction</u>	Bin 1 <u>Control</u>	Bin 2 <u>1% N</u>	Bin 3 <u>1% N + 1% Lime</u>	Bin 4 <u>1% Lime</u>
Volume	33.3%	32.1%	28.4%	17%
Wet weight	54.7%	53.3%	52.8%	51.9%

After the compost cycle was completed the finished compost was weighed and air-dried. The increases in dry weight and amount of waste utilized is listed below:

	Bin 1 <u>Control</u>	Bin 2 <u>1% N</u>	Bin 3 <u>1% N + 1% Lime</u>	Bin 4 <u>1% Lime</u>
Wet weight of raw fruit waste utilized	1200 lb	1050 lb	1050 lb	1050 lb
Increase in dry wt at end of cycle	53 lb	43 lb	50 lb	52 lb

SUMMARY OF RESULTS

The results of preliminary investigations indicate that composting offers a feasible and esthetically acceptable method for disposal of high-moisture wastes, such as fruit and vegetable solids. The following summarizes the results obtained and conclusions based on the results:

1. Dry materials, such as municipal compost, sawdust, or rice hulls, can be used to absorb the moisture from fruit waste solids and to adjust the moisture concentration of the mixture within the range optimum for high-rate composting.

2. For fruit waste-dry material mixtures, the optimum initial moisture concentration was in the range of 60 to 65 percent.

3. The maximum weight ratio of fruit to dry material successfully composted was 250 pounds of peach solids to 100 pounds of municipal compost. More optimum composting conditions were obtained when the weight of fruit was reduced to 200 pounds.

4. When peach solids were ground previous to composting, the weight ratio of fruit to dry material had to be reduced, since grinding released juices from the tissues and gave a higher initial moisture concentration for the mixture. However, under optimum conditions grinding the fruit shortened by approximately 50 percent the time required for stabilization of composted unground fruit.

5. Aerobic conditions in the compost were maintained by a turning schedule in which an initial turning was done 24 hours after layering the fruit and dry material into the compost bins, followed by daily turning for 5 to 6 days and, thereafter, turning on alternate days until the process was judged to be complete.

6. The initial low pH (4.5 to 5.0) of the fruit compost mixtures appeared to be the cause of an initial lag in development of desirable microbial flora and elevation of temperature in the compost pile. Because the shortest possible composting time is an important requirement for industrial use of composting, adjustment of pH by addition of alkaline materials should be investigated.

7. Of the dry admixtures used, municipal refuse composted by the Dano process and rice hulls performed satisfactorily. Shredded redwood bark failed to adequately absorb moisture and appeared to inhibit microbial growth, probably because of the high tannin concentration. Wheat straw did not provide the necessary structural strength to prevent compaction. White pine sawdust performed adequately in absorption of moisture and maintenance of porosity in the compost pile. However, the strong buffering system in the wet sawdust depressed changes in pH and prolonged acidic conditions in the compost mixture. Addition of alkaline materials makes the material more suitable for composting use.

8. With municipal compost as the dry admixture, the C/N ratio appeared to be within the range for optimum microbial development and rapid composting. With rice hulls and sawdust the fruit waste-dry material mixtures were low in nitrogen. The addition of nitrogen-rich materials, such as sewage sludge and animal manures, is indicated and should be investigated.

9. Because fruit waste solids are approximately 85 percent moisture, evaporation during composting and microbial action on carbohydrates to give carbon dioxide and water resulted in marked losses in weight and volume of the compost mixtures. Reductions ranging up to 70 and 59 percent, respectively, occurred in the initial weight and volume of the mixtures. Consequently, the weight of the air-dried compost increased only slightly when it was recycled for absorption of moisture in successive lots of compost.

10. Offensive odors did not develop in the fruit waste solids. During the initial stage of the compost process slight fruit fermentation odors were noticeable. The odor of ammonia could be detected in the final state of the process. Fly breeding in compost was not a problem. Fruit pieces exposed in the compost pile attracted flies but egg deposition was not observed.

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TABLE 1

CHEMICAL ANALYSIS OF COMPOST INGREDIENTS
AND INITIAL AND FINAL COMPOSTED MIXTURE

Ratio: 250 lbs. of Peach Waste to 100 lbs. of Recycled Compost

<u>Determinations</u>	<u>Analysis of Individual Ingredients</u>		<u>Analysis of Compost Mixture</u>	
	<u>Recycled Compost</u>	<u>Raw Peach Waste</u>	<u>Initial</u>	<u>Final</u>
Ash %	49.3	7.6	42.2	52.9
Moisture %	40.3	85.0	79.0	30.0
Carbon %	28.2	51.3	32.1	26.2
Nitrogen %	1.77	1.08	1.7	1.67
Phosphorus as PO_4 %	1.23	0.40	1.2	1.86
Potassium %	0.91	1.14	0.91	0.54
C/N Ratio	15.9	47.5	18.9	15.7
pH	8.05	3.95	4.5	8.6

TABLE 2

CHEMICAL ANALYSIS OF COMPOST INGREDIENTS
AND INITIAL AND FINAL COMPOSTED MIXTURE

Ratio: 150 lbs. of Ground Peach Waste to 100 lbs. of Recycled Compost

<u>Determinations</u>	<u>Analysis of Individual Ingredients</u>		<u>Analysis of Compost Mixture</u>	
	<u>Recycled Compost</u>	<u>Raw Ground Peach Waste</u>	<u>Initial</u>	<u>Final*</u>
Ash %	52.3	7.6	46.7	49.3
Moisture %	36.0	85.0	63.4	40.3
Carbon %	26.5	51.3	29.6	28.2
Nitrogen %	1.71	1.08	1.78	1.77
Phosphorus as PO_4 %	1.16	0.4	1.23	1.23
Potassium %	0.88	1.14	1.16	0.91
C/N Ratio	15.5	47.5	16.6	15.9
pH	8.7	3.95	5.4	8.05

*End of second cycle.

TABLE 3

CHEMICAL ANALYSIS OF COMPOST INGREDIENTS
AND INITIAL AND FINAL COMPOSTED MIXTURE

<u>Determinations</u>	<u>Analysis of Individual Ingredients</u>	
	<u>Recycled Municipal Compost</u>	<u>Raw Apricot Waste</u>
Ash %	54.9	7.6
Moisture %	23.0	61.8
Carbon %	25.06	51.33
Nitrogen %	1.65	2.56
Phosphorous PO_4 %	0.36	0.71
Potassium %	0.77	0.35
C/N Ratio	15.2	20.1
pH	8.0	4.5

<u>Determinations</u>	<u>Analysis of Compost Mixtures</u>			
	<u>Bin 1</u>		<u>Bin 2</u>	
	<u>200 lbs. of Fruit Waste to 100 lbs. of Recycled Municipal Compost</u>		<u>200 lbs. of Fruit Waste to 100 lbs. of Recycled Municipal Compost*</u>	
	<u>Initial</u>	<u>Final</u>	<u>Initial</u>	<u>Final</u>
Ash %	48.6	51.9	46.9	55.1
Moisture %	51.0	30.2	51.0	28.0
Carbon %	28.56	26.72	29.5	24.94
Nitrogen %	1.79	1.69	1.71	1.63
Phosphorous PO_4 %	0.68	0.76	0.80	0.79
Potassium %	0.96	1.10	1.07	1.05
C/N Ratio	15.96	15.81	17.3	15.3
pH	5.3	7.42	6.1	7.15

*One pound of lime per 200 lbs. of compost was added to compost mixture 7 days after start of cycle.

TABLE 4

CHEMICAL ANALYSIS OF COMPOST INGREDIENTS
AND INITIAL AND FINAL COMPOSTED MIXTURE

<u>Analysis of Individual Ingredients</u>				
<u>Determinations</u>	<u>Sawdust</u>		<u>Raw Apricot Waste</u>	
Ash %	4.6		7.6	
Moisture %	32.8		61.8	
Carbon %	53.0		51.33	
Nitrogen %	0.56		2.56	
Phosphorous PO_4 %	0.13		0.71	
Potassium %	0.39		1.79	
C/N Ratio	94.6		20.1	
pH	6.7		4.5	

<u>Analysis of Compost Mixtures</u>				
<u>Determinations</u>	<u>Bin 1</u>		<u>Bin 2</u>	
	200 lbs. of Fruit Waste To		200 lbs. of Fruit Waste to	
	45 lbs. of Sawdust		45 lbs. of Sawdust, plus 1 lb. of Lime/200 lbs. Waste	
	<u>Initial</u>	<u>Final</u>	<u>Initial</u>	<u>Final</u>
Ash %	5.7	11.2	9.1	13.8
Moisture %	64.0	34.0	70	31.0
Carbon %	52.39	49.33	50.50	47.89
Nitrogen %	0.99	1.38	1.67	1.20
Phosphorous PO_4 %	0.34	0.63	0.60	0.69
Potassium %	0.86	1.17	1.27	1.21
C/N Ratio	52.9	35.7	30.2	39.9
pH	4.9	7.9	4.8	8.1

TABLE 5

CHEMICAL ANALYSIS OF COMPOST INGREDIENTS
AND INITIAL AND FINAL COMPOSTED MIXTURE

<u>Analysis of Individual Ingredients</u>				
<u>Determinations</u>	<u>Sawdust</u>	<u>Raw Peach Waste</u>		
Ash %	9.7	7.1		
Moisture %	16.6	87.2		
Carbon %	50.17	51.61		
Nitrogen %	1.03	1.09		
Phosphorous PO ₄ %	0.54	0.48		
Potassium %	0.69	2.02		
C/N Ratio	48.7	47.2		
pH	7.1	3.8		

<u>Analysis of Compost Mixtures</u>				
<u>Determinations</u>	<u>Bin 1</u>		<u>Bin 2</u>	
	<u>150 lbs. of Fruit Waste 45 lbs. of Sawdust</u>		<u>150 lbs. of Fruit Waste 45 lbs. of Sawdust-1%N(urea)</u>	
	<u>Initial</u>	<u>Final</u>	<u>Initial</u>	<u>Final</u>
Ash %	8.3	12.8	9.4	10.7
Moisture %	70.0	50.0	70.2	52.0
Carbon %	50.94	48.44	50.33	49.61
Nitrogen %	0.94	1.74	3.49	2.23
Phosphorous PO ₄ %	0.51	0.30	0.27	0.34
Potassium %	1.03	1.06	0.86	1.01
C/N Ratio	54.2	27.8	14.4	22.2
pH	4.25	8.3	5.0	8.8

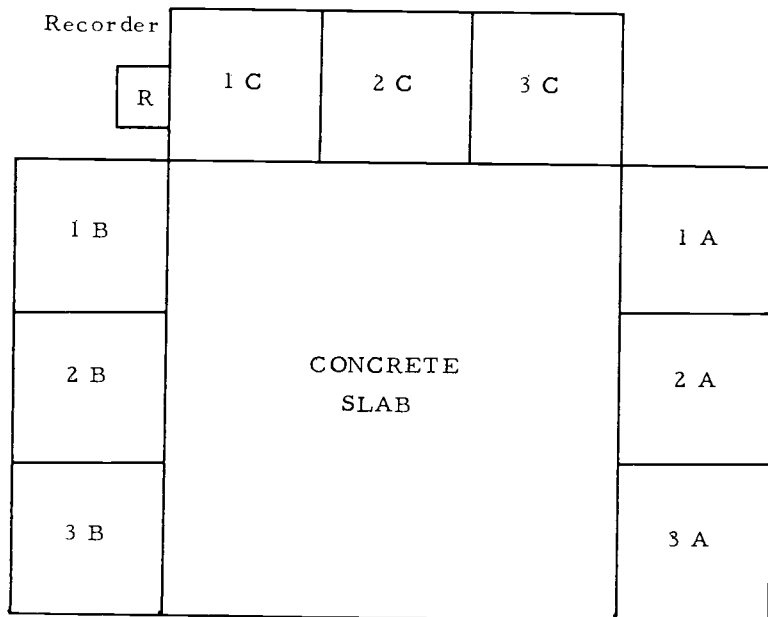
TABLE 6

CHEMICAL ANALYSIS OF COMPOST INGREDIENTS
AND INITIAL AND FINAL COMPOSTED MIXTURES

<u>Analysis of Individual Ingredients</u>				
<u>Determinations</u>	<u>Sawdust</u>	<u>Raw Peach Waste</u>		
Ash %	9.7	7.1		
Moisture %	16.6	87.2		
Carbon %	50.17	51.61		
Nitrogen %	1.03	1.09		
Phosphorous as PO_4 %	0.54	0.48		
Potassium %	0.69	2.02		
C/N Ratio	48.7	47.2		
pH	7.1	3.8		

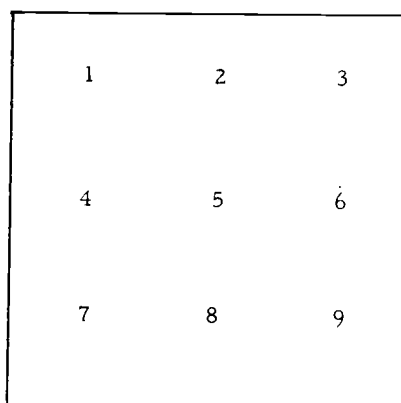
<u>Analysis of Compost Mixtures</u>				
<u>Determinations</u>	<u>Bin 3</u>		<u>Bin 4</u>	
	150 lbs. of Fruit Waste 45 lbs. of Sawdust + 1% N(urea) and 1% lime		150 lbs. of Fruit Waste 45 lbs. of Sawdust + 1% lime	
	<u>Initial</u>	<u>Final</u>	<u>Initial</u>	<u>Final</u>
Ash %	25.5	17.8	16.5	15.4
Moisture %	72.2	51.4	68.6	52.0
Carbon %	41.39	45.67	46.39	47.0
Nitrogen %	3.45	2.12	0.98	1.56
Phosphorous as PO_4 %	0.55	0.32	0.51	0.33
Potassium %	1.01	0.95	0.95	1.01
C/N Ratio	12.0	21.5	47.3	30.1
pH	8.0	8.4	5.9	8.6

FIGURE 1



ARRANGEMENT OF COMPOST AREA

FIGURE 2



TEMPERATURE POINTS OF AN INDIVIDUAL BIN



FIGURE 3. DRYING OF COMPOST AT END OF CYCLE

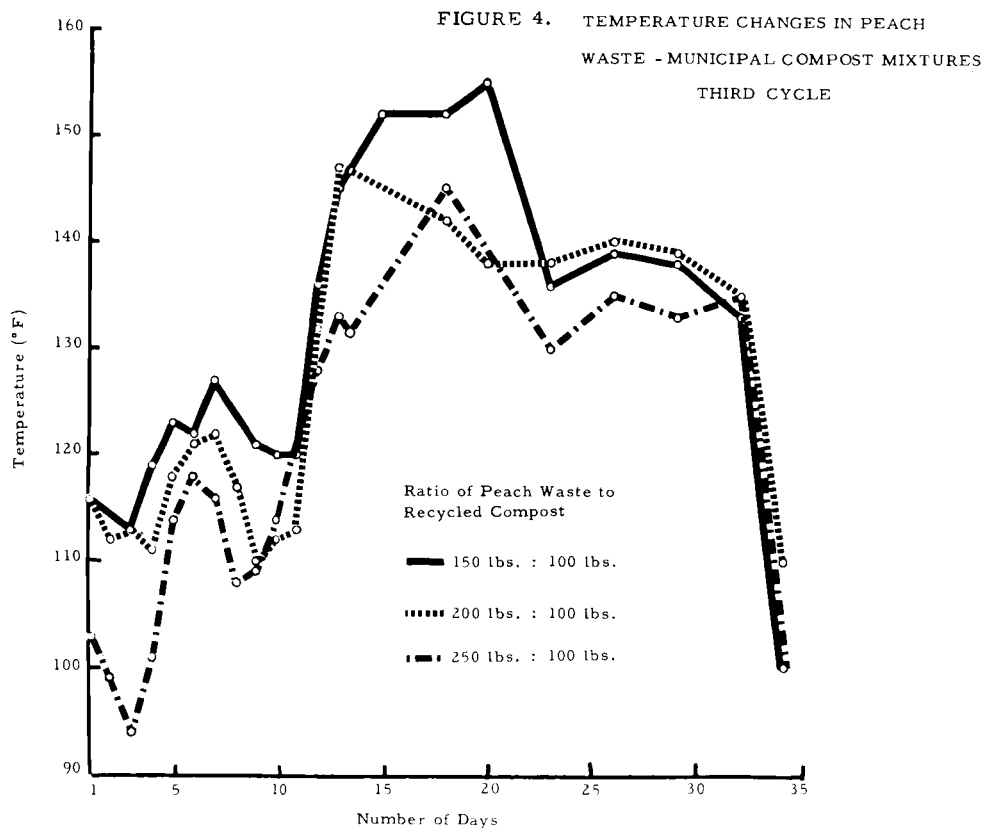


FIGURE 5. pH CHANGES IN PEACH WASTE -
MUNICIPAL COMPOST MIXTURES
THIRD CYCLE

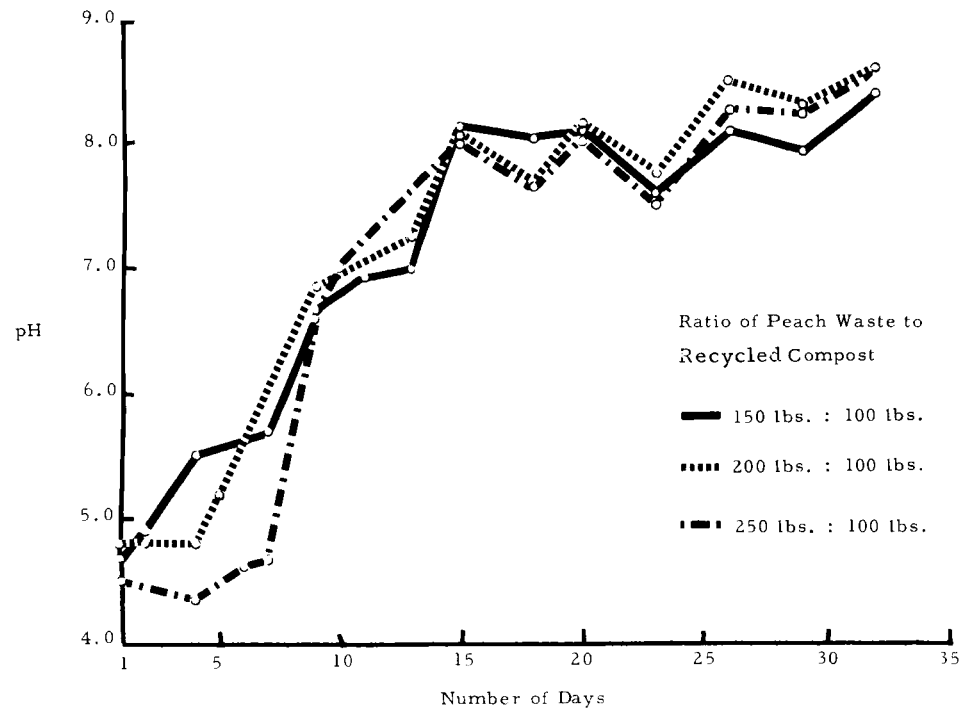


FIGURE 6. MOISTURE, TEMPERATURE AND pH CHANGES FOR
PEACH WASTE - MUNICIPAL COMPOST MIXTURE
THIRD CYCLE

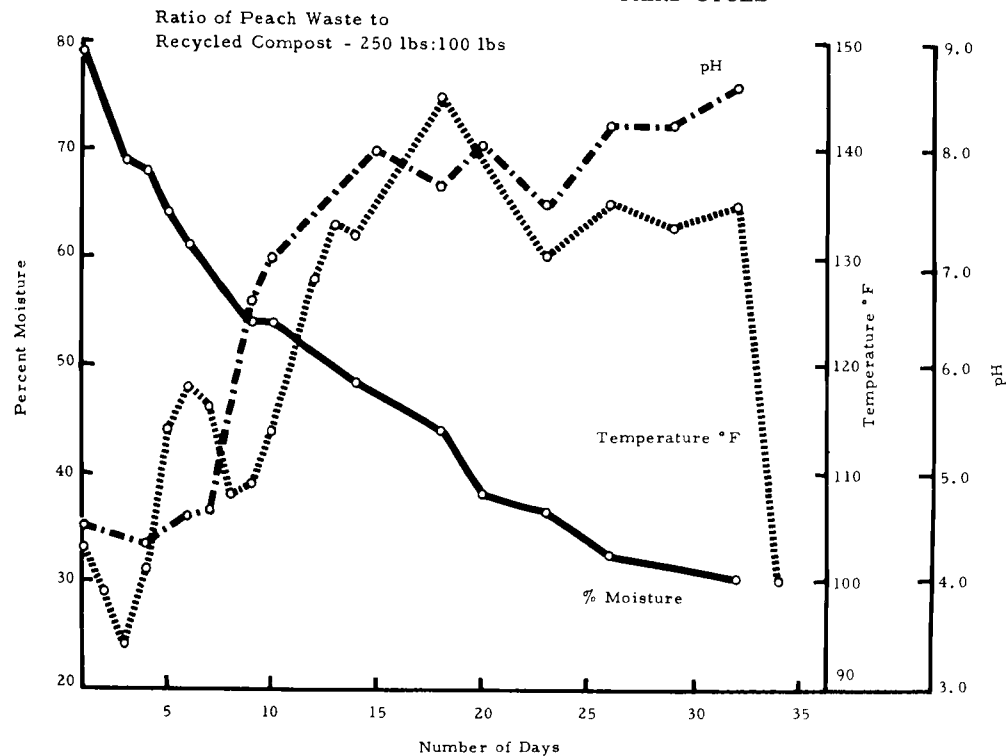


FIGURE 7. TEMPERATURE CHANGES IN GROUND PEACH
WASTE - MUNICIPAL COMPOST MIXTURES
SECOND CYCLE

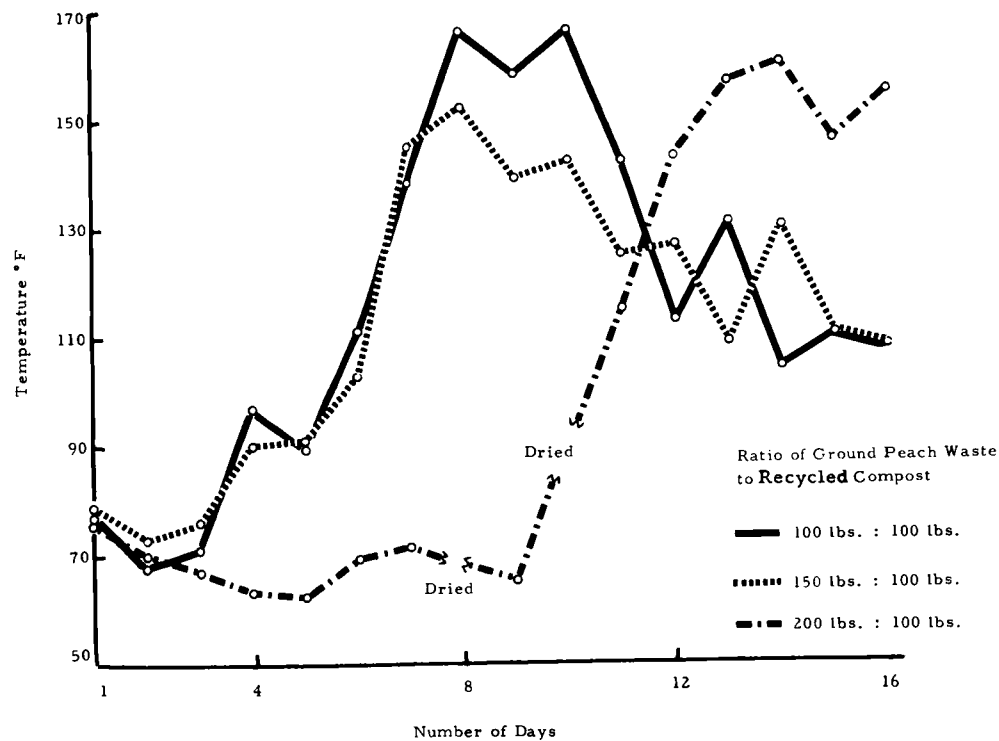


FIGURE 8. pH CHANGES IN GROUND PEACH WASTE -
MUNICIPAL COMPOST MIXTURES

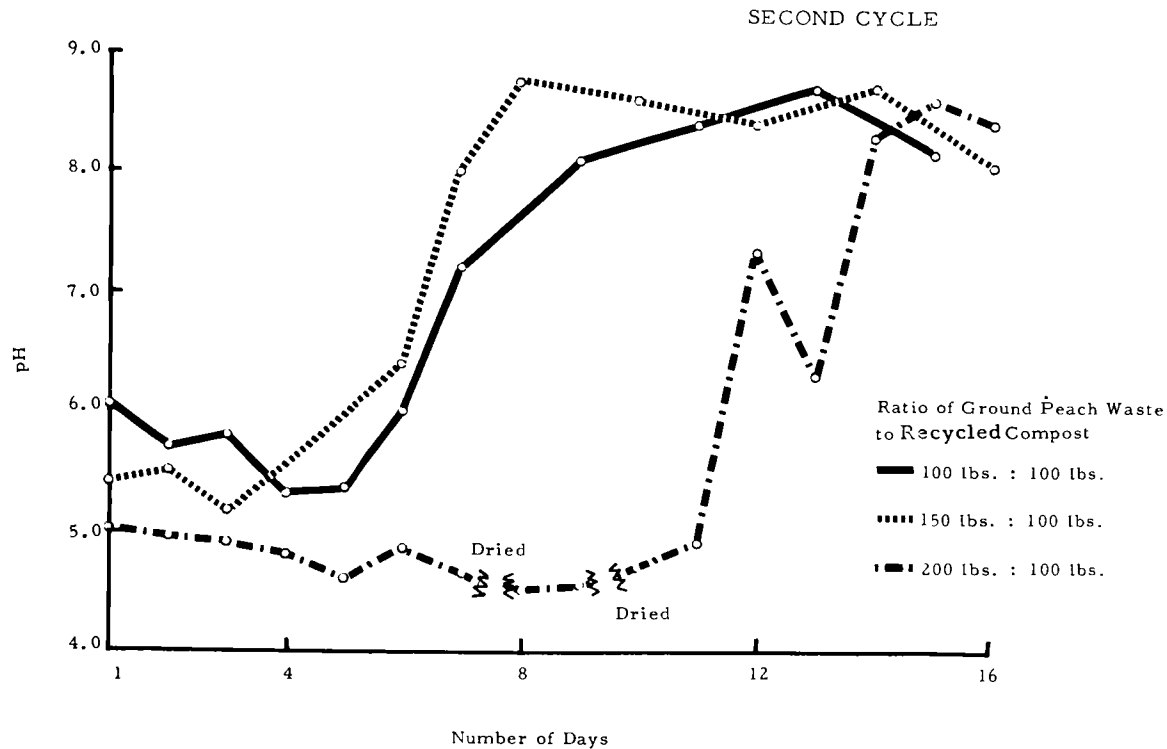


FIGURE 9. MOISTURE, TEMPERATURE AND pH CHANGES FOR GROUND

PEACH WASTE -- MUNICIPAL COMPOST MIXTURE

SECOND CYCLE

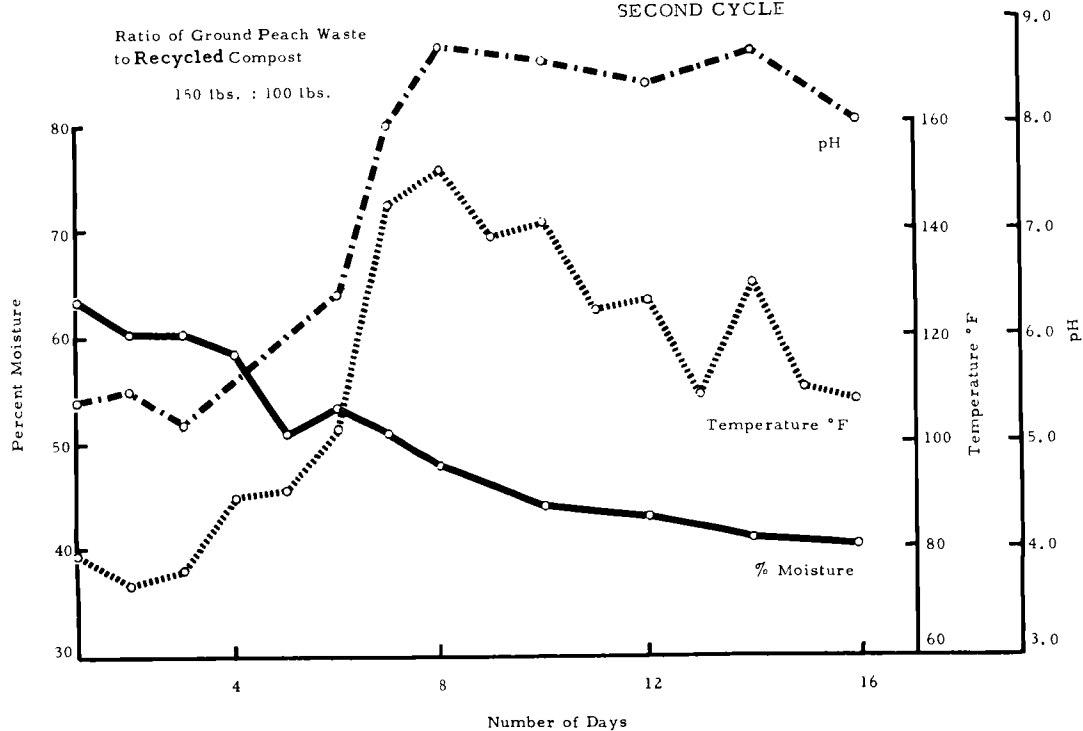


FIGURE 10.
COMPARISON OF TEMPERATURE CHANGES FOR GROUND
APRICOT WASTE - RECYCLED MUNICIPAL COMPOST MIXTURES

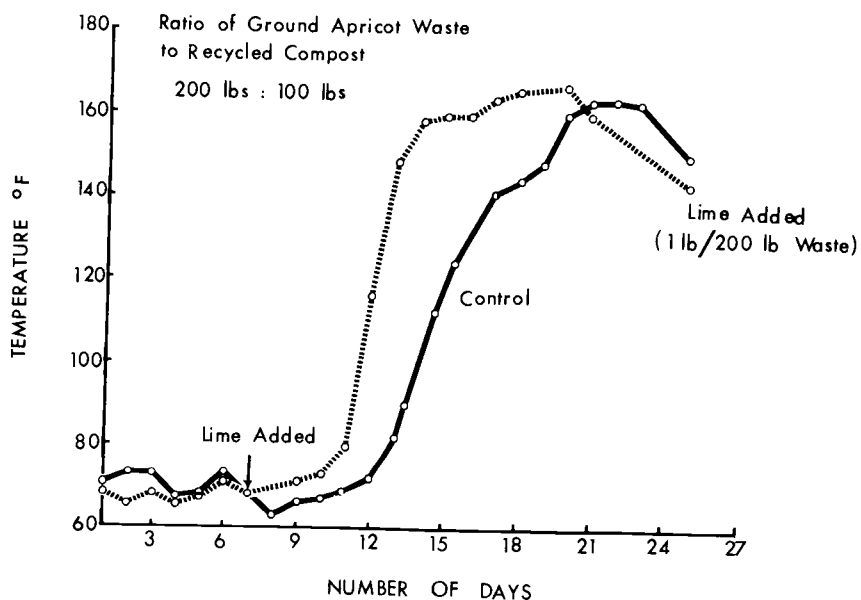


FIGURE 11.
COMPARISON OF pH CHANGES FOR GROUND APRICOT
WASTE - RECYCLED MUNICIPAL COMPOST MIXTURES

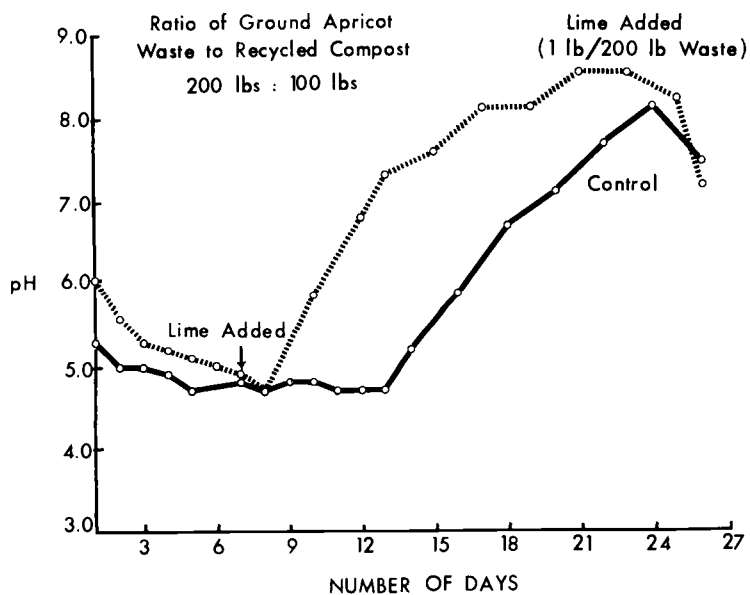


FIGURE 12.

MOISTURE, TEMPERATURE AND pH CHANGES FOR GROUND
APRICOT WASTE - RECYCLED MUNICIPAL COMPOST MIXTURE

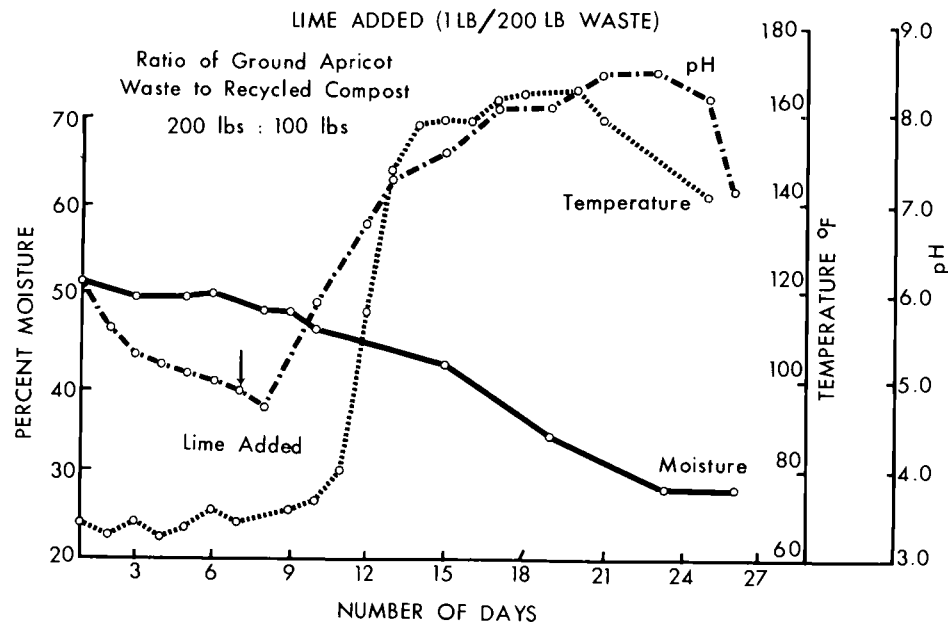


FIGURE 13.

MOISTURE, TEMPERATURE AND pH CHANGES FOR GROUND
APRICOT WASTE - RECYCLED MUNICIPAL COMPOST MIXTURE

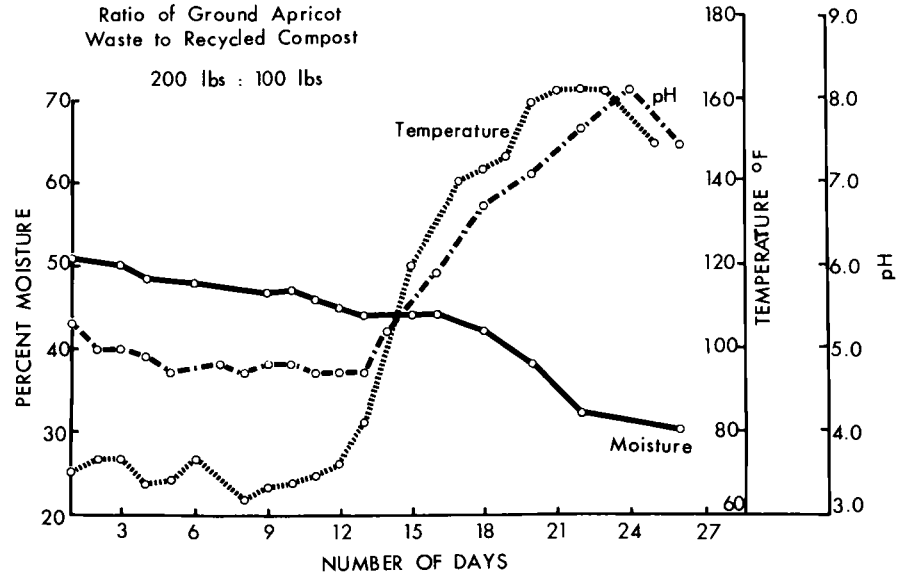


FIGURE 14.
COMPARISON OF TEMPERATURE CHANGES FOR
GROUND APRICOT WASTE - SAWDUST MIXTURES

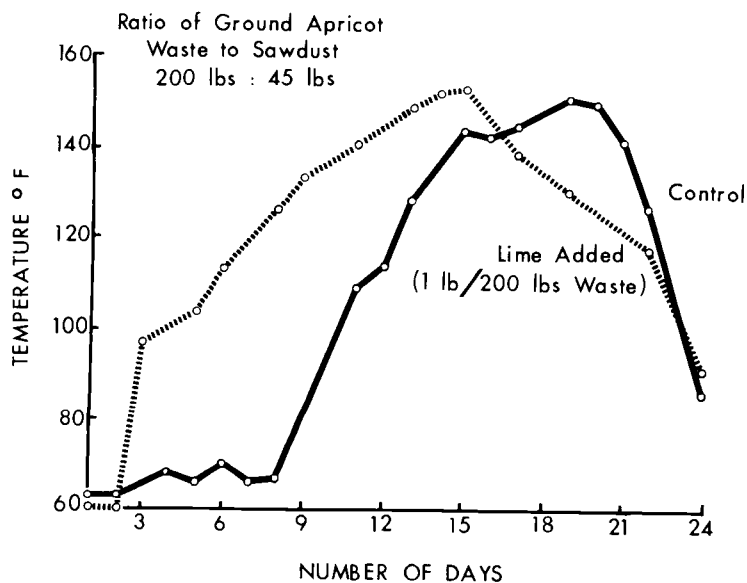


FIGURE 15.

COMPARISON OF pH CHANGES FOR GROUND
APRICOT WASTE - SAWDUST MIXTURES

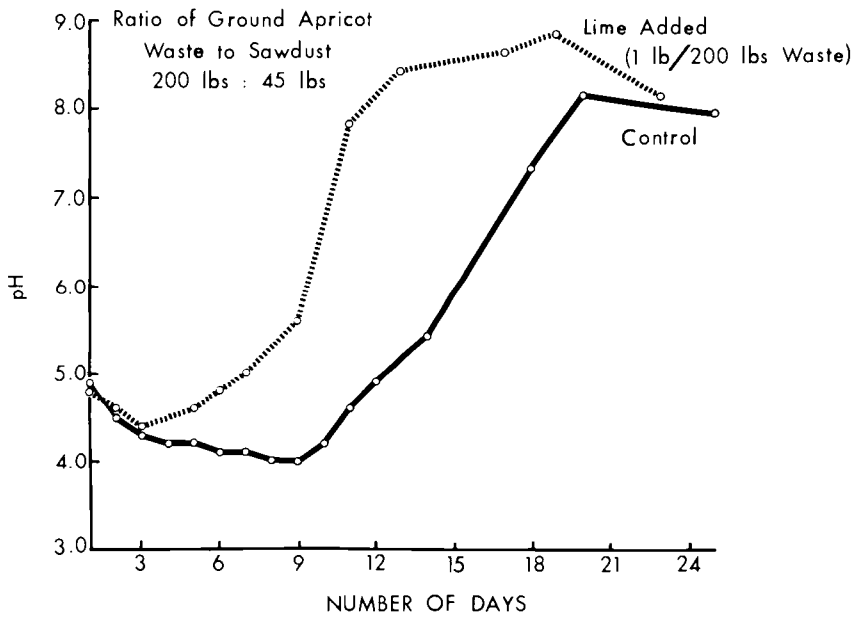
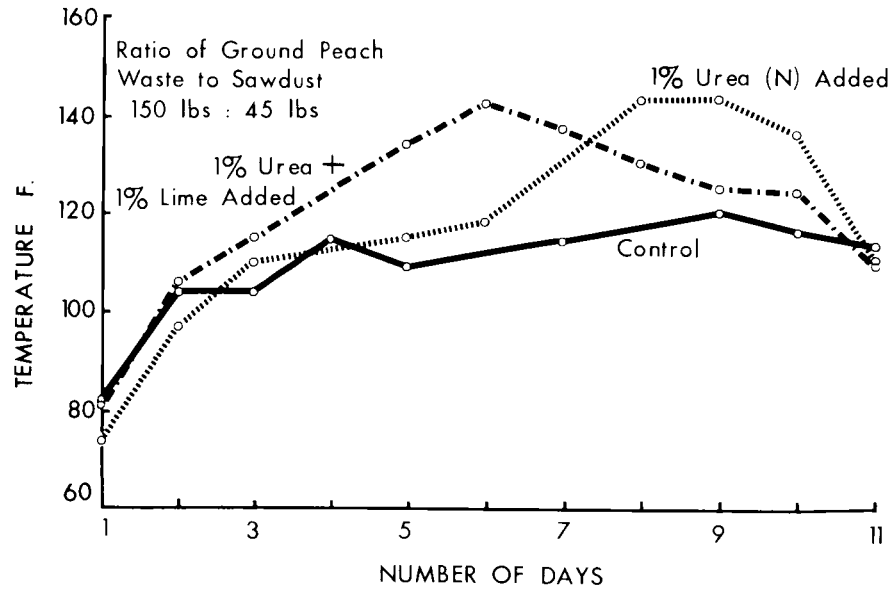


FIGURE 16.

COMPARISON OF TEMPERATURE CHANGES FOR
GROUND PEACH WASTE - SAWDUST MIXTURES



WATER RESOURCES PLANNING IN THE PACIFIC NORTHWEST

W. W. Towne

We in the Public Health Service welcome this opportunity to discuss with you the various phases of water resources planning and development which, at the Federal level, are the particular responsibilities of the U.S. Department of Health, Education, and Welfare, and of the Public Health Service, an agency of that department. These responsibilities are concerned with determining the municipal and industrial water supply needs and the development of comprehensive plans for pollution control and water quality management.

The responsibilities and duties of the department and service are contained in the Public Health Service Act (Public Law 410, 78th Congress) and the Federal Water Pollution Control Act (Public Law 660, as amended by the 87th Congress in 1961). The Federal Water Pollution Control Act defines several areas of responsibility for the department which are necessary to carry out an integrated water pollution and water quality control program. These include responsibilities for carrying out and encouraging intramural and extramural research, the provision for grants to state and interstate water pollution control agencies to assist them in maintaining adequate control measures, the provision of grants to municipalities and other political subdivisions to finance the construction of necessary treatment works, the development of basic data relating to water quality and water pollution control, the provision of technical assistance to state and interstate agencies and to municipalities in connection with the prevention and control of water pollution, the provision for Federal action to abate pollution of interstate or navigable waters within the specified limits as set forth in the Act, and the development of comprehensive plans for pollutional control. This last named responsibility is the subject of our discussion today.

Section 2 of the Act directs the Secretary to develop comprehensive programs for eliminating or reducing pollution and improving the sanitary quality of surface and ground waters. It further stipulates that such programs shall be developed in cooperation with other Federal agencies, with state and interstate control agencies, and with municipalities and industries.

Section 2(b) of the Act, which was an amendment to the original Act by the 87th Congress and which was approved by

the President in August of 1961, requires that consideration be given to the inclusion of storage for the regulation of stream flow for the purpose of water quality control in reservoirs being constructed by the Corps of Engineers, the Bureau of Reclamation, or other Federal agencies. Congress has placed a constraint on the use of this flow regulation, however, by stipulating that storage in Federal reservoirs will not be provided as a substitute for adequate treatment or other controls at the source. This policy is also in keeping with the public policy recorded at the National Conference on Water Pollution called by President Eisenhower in 1960, which stated "that the goal of pollution abatement is to protect and enhance the capacity of the water resource to serve the widest possible range of human needs, and that this goal can be approached only by accepting the positive policy of keeping waters as clean as possible, as opposed to the negative policy of attempting to use the full capacity of water for waste assimilation," and that "users of public waters have a responsibility for returning them as nearly clean as is technically possible."

Water, as found in nature, the universal solvent that it is, always contains impurities. Unfortunately, both the concentration and types of these impurities increase as man puts water to his beneficial uses. Any such impurity is a pollutant when it becomes objectionable or interferes with other essential uses of water. These pollutants may be physical, biological, or chemical, and they may stem from man-made or natural sources. In this context, therefore, water pollution control and water quality management are synonymous terms.

Today, we recognize three methods of controlling pollution. The most effective of these is in-plant control, which will keep concentrated wastes from entering the industrial outfalls. Such control not only is more effective but, many times, is more economical than treatment. Industry is well aware of the benefits of this control measure and has spent large sums of money in research on reclaiming useful by-products from waste streams in order to reduce the total amount of pollution per unit of production. Good housekeeping practices and the segregation of wastes to reduce the size of treatment works have also been demonstrated as effective in-plant control measures. Had we been more concerned with some of the waste problems associated with manufacturing processes and the effects of manufactured products on water quality, we might now be experiencing less difficulty with detergents. The development of soft detergents

(those that are degraded by biological action) might have been developed and put into production several years ago. Also, we might well have concerned ourselves with developing pesticides and herbicides that lose their toxic effects shortly after application.

The second method of control is the treatment of waste water to destroy or alter undesirable pollutional characteristics. The science of waste treatment, both domestic and industrial, is not yet developed to the point that all pollutants can be removed. In fact, some are little affected by the conventional waste treatment methods we know today. There is a definite need to improve our knowledge in this field, and considerable sums of money are being spent by both industry and other research institutions in this respect. For instance, one of the major research efforts of the Public Health Service is directed at developing advance waste treatment methods which will more completely remove the impurities which find their way into our waterways as a result of man's activities.

Stream flow regulation for quality control is the third line of action. As previously stated, however, this method cannot be used as a substitute for either in-plant control or adequate treatment at the source but, in combination with these control measures it can play an important part in long-range water quality control plans. Treatment as we know it today does not completely cleanse used waters, and many streams are polluted by natural sources or by man-made sources which are not amenable to waste collection and treatment. Water quality is often degraded by biological nutrients and chemicals which find their way into the water courses as a result of land-use practices. Under such circumstances flow augmentation can prevent adverse quality conditions which would otherwise occur during critical stream flow periods. Furthermore, from the standpoint of optimum development of water resources, storage now provided for quality control may be available for other beneficial uses as the science of waste treatment is perfected. It has been the history of water resources development that the availability of water attracts uses which are not predictable. Sooner or later there will be a need for water that can now be economically stored in reservoir developments and, when that addition need arises, the value may be greater than it is today.

The Federal Water Pollution Control Program is directed to the elimination of pollution and the maintenance of surface and ground waters in a satisfactory sanitary condition

through the application of all approaches to water quality control. This can best be done through the development of a comprehensive river basin plan and the implementation of such a plan in an orderly and systematic way. At the present time comprehensive programs for water supply and water quality management are being carried out in seven of the major drainage basins of the country. These include the Arkansas-Red, the Chesapeake-Susquehanna, the Colorado, the Delaware, the Great Lakes-Illinois, the Upper Ohio, and the Columbia River basins. The latter project also includes the coastal waters of Oregon and Washington. Within the next decade it is proposed that comprehensive programs will be developed in all of the 21 major basins in the country. This is in keeping with the Senate Select Committee Report, which was completed in January 1961, and which recommended that the Federal Government, in cooperation with the states should prepare and keep up to date plans for comprehensive water resource development and management for all major river basins of the United States, and that such studies should be undertaken and completed by 1970. Both the Eisenhower and the Kennedy administrations have strongly supported the need for better planning in the development of the nation's land and water resources.

The Columbia River Basin Project varies slightly from the other ongoing projects in that practically all of the others were started largely because of the immediate need to correct a serious existing pollution problem. For instance, in the Arkansas-Red River Basin salt from natural salt springs, and to a lesser extent from oil field brines is destroying the usefulness of some 40 million acre-feet of water each year. In the Ohio Basin, acid mine water from improperly operated or abandoned coal mines is seriously limiting the use of the waters of that basin. In the Colorado Basin, the radioactive pollution from industries of our nuclear age is imposing a threat to man's beneficial use of the waters, while in the Great Lakes Basin the diversion of Lake Michigan waters to the Illinois waterway by the Chicago Sanitary District and the State of Illinois is being challenged in the Supreme Court by the other Great Lakes states, and there is a need to evaluate the water quality effects of present and proposed practices. Here in the Columbia Basin, however, the primary objective of our program is to prevent the need for similar extensive corrective action at some future date by better planning for the orderly development of our land and water resources. Fortunately, in contrast with many parts of the Nation, man's activities here in the Pacific Northwest have not yet

seriously deteriorated the quality of our water resources except in a relatively few instances. Because of this fact, the people of this area still have it within their power to chart a course in resource development that will maximize benefits and minimize conflicts in water uses. While water, adequate in quantity, is a primary prerequisite for economic development, history has demonstrated that the adverse effects of man's activities on his water supply are first reflected in a downgrading of water quality. In many instances this has proceeded to the point that most beneficial uses are seriously impaired. Once this state has been reached, it is difficult, and frequently economically impossible, to restore water to a quality level that could have been maintained by the application of appropriate and feasible preventive measures. Clean water constitutes a major appeal to tourism, one of our most important industries.

While the Pacific Northwest is endowed with a bountiful supply of extremely high-quality water, it is also true that the continued economic development of the area is closely related to, and dependent upon, this very feature. The comprehensive plan for water quality management being undertaken by the Public Health Service is designed to preserve this quality so that the maximum development of land and water resources may be realized. In carrying out this undertaking it will be our objective to spell out how preventive measures can be applied to reduce future conflicts in water uses and to develop essential data and information on water supply and water quality which can serve as a guide to the public in arriving at the political and legislative decisions necessary for the development of the region along those lines that are in the best interests of the public. These evaluations will also serve as guides to state, local, and Federal agencies and municipalities and industries in carrying out their responsibilities for pollution control.

Studies upon which such planning is based must include the collection and evaluation of data on all factors that will have an effect on water quality. Economic base studies and projections to determine the economic and population potentials and to project water supply needs and waste discharges on the basis of future area development are one of the basic elements of the plan. The type, magnitude, location, and potential development of natural resources will influence the growth and location of populations and industries, as well as the water uses and the pollutional characteristics of the used waters. These, in turn, will govern future water quantity and quality requirements and when and where such requirements will occur. It is in this area

of resource planning that industry can be of major assistance to the planner. As we move further into our economic studies, we will want to counsel with you concerning the long-range industrial growth potentials as you envision them. We are also working closely with other Federal and state planning agencies which are engaged in similar economic and population projections.

Another important factor requiring consideration is related to the total water resources and water needs of the region. Water supply inventories provide data on the history and present use of surface and ground waters for domestic, municipal, industrial, agricultural, power, recreation, and other uses. The quantitative dependability of our water resources, the variability in seasonal stream flows, the locations of water withdrawals and uses, and the quality characteristics of both surface and ground waters are essential planning tools. Likewise, it is important to know how much water is lost to the area in flood flows, and where and in what quantities it may be economically retained for beneficial uses. We have already contacted several industries in the Willamette River Basin to determine their present water supply requirements. These will serve as the basis for projecting future demands. Your assistance in providing such information is indeed appreciated.

From the standpoint of industrial water supply, we recognize that quantity considerations are undoubtedly more controlling than are the quality factors. Where necessary, it is usually possible for industry, through water treatment practices, to supply process water to meet its quality requirements. However, we should not lose sight of the fact that meeting the water supply demand is only a part of the total water supply picture. The maximum industrial development may be limited more by the ability of the receiving stream to receive residual wastes without damage than by the quantity of water that can be developed to supply the industrial demands. Water withdrawn for domestic and industrial purposes usually results in essentially the same quantity of used water being returned to the stream.

A third important element of a water resources plan is related to the location, source, quantity, and characteristics of waste discharges and their effects on water quality. It is also essential to have an understanding as to the treatability of wastes and how the residual waste, following treatment, will react when discharged to the receiving waters. Some wastes (chlorides, for example) are not changed in character or quantity as they pass on

down the stream; they are only reduced in concentration by dilution from increased stream flows. Other wastes are affected by physical, chemical, and biological phenomena and change in both quality and quantity characteristics with the passage of time. Here it is important to determine those stream characteristics that affect the ability of a particular stream to assimilate residual wastes without destroying its usefulness for other purposes. This information will also serve as a basis for predicting where flow augmentation may be beneficial and how much will be required to maintain desirable water quality. It is equally essential to evaluate the potential damages to water quality that may result from water resource developments and their operation. The facilities which are being developed to enhance water quality for one use may damage it for another. For example, the impoundment of mountain streams can produce an environment more favorable to algae growths within the reservoir, which may be carried downstream to cause tastes and odors in public water supplies.

Here in the Willamette Basin we have spent considerable time in developing a computer program which will permit us to predict the cause-and-effect relationships among waste loadings, stream flow, quality parameters, and low-flow augmentation requirements. For example, by using dissolved oxygen as a quality parameter and by establishing a minimum concentration that can be tolerated in any stretch of the stream, for any given waste loading at different points throughout the stream, we can predict stream flow requirements necessary to satisfy the dissolved oxygen requirements. If additional flows are required, it is possible to predict the low-flow augmentation storage requirements and the tributary or tributaries which can best supply the demands.

Still another factor requiring consideration is that of water quality criteria. A knowledge of the water quality requirements for all legitimate water uses likely to be practiced in a drainage basin is basic to the development of a water quality control plan and program. Information on the types and magnitude of those quality characteristics that interfere with existing and anticipated water uses will permit the establishment of quality requirements to serve both as planning guides and as pollution control objectives. This information, together with an assessment of the effects of waste discharges on water quality, will also serve to indicate where conflicts in water use are most likely to develop. At the present time our knowledge in the field

of quality criteria leaves much to be desired. In my opinion, the state water pollution control agencies in this area have acted wisely in establishing as their objective the maintenance of the waters of the Pacific Northwest at the highest practicable level. This policy is expressed in the "Water Quality Objectives" of the Pacific Northwest Pollution Control Council, an organization of state water pollution control agencies in the five Northwest states:

The Pacific Northwest is at present in an enviable position as regards its natural resources and potential development when compared with many other areas of this country. This is especially true of natural waters which are admittedly one of the area's greatest assets. Water is so definitely tied in with the health, welfare, and pleasure of citizens, and with the whole economic structure of the area as to make high water quality objectives not only desirable, but imperative.

This statement serves as one of our important guides in evaluating the water quality needs of the area, and we think that it would be "penny-wise and pound-foolish" to establish water quality objectives, developed on the basis of very limited knowledge, which would barely satisfy the needs of the various water uses. In this area of high water quality, such requirements would not be standards of quality but would become standards of degradation inviting all users to load the stream to the point that only minimum quality would be maintained.

From the previous discussions I am sure it is apparent that we do not have all the answers that are needed to develop the best technical approaches to the solution of our water quality problems. If we wait until such knowledge is fully developed, however, we will have waited too long. Nevertheless, we should not stop seeking the best possible answers. With the recognition of this fact, therefore, another important element is to define the research needs required to solve some of the perplexing problems confronting us. The project has made some accomplishments in this direction and has prepared a report which delineates the status and critical needs of water pollution research in the project area and the capacity of the area to meet these needs.

It should also be noted that the Water Pollution Control Act authorizes the construction of nine new regional and special

purpose water quality laboratories throughout the United States. One of the first to be constructed will be located here on the Oregon State University campus. Plans and specifications for the laboratory are now being prepared by a firm of engineer-architect consultants, and it is anticipated that construction will start within the next few months. The facility will cost somewhat in excess of \$200,000,000 when completed and fully equipped, and will house a staff of approximately 150 scientists and supporting personnel.

The role of these laboratories as outlined by Congress, will be to conduct research, investigations, experiments, field demonstrations and studies, and training, all related to the prevention and control of water pollution. This facility will serve six western and northwestern states, and will work closely with research institutions and universities throughout the area. A significant function of the laboratory will be to stimulate extramural research in these non-Federal research facilities.

The primary purpose in developing a comprehensive plan for water pollution control and water quality management is not fulfilled when the report is completed. The plan is of no value unless it is implemented. This will be done largely by the people who will be called up to determine how their funds shall be spent and how their resources shall be developed. It is in this area that the state agencies responsible for water quality control will assume their appropriate role, a role which was recognized by Congress in Section 1 of the Federal Water Pollution Control Act when it was declared "to be the policy of Congress to authorize, preserve, and protect the primary responsibilities and rights of states in preventing and controlling water pollution."

In closing, I would like to mention some of the benefits that should accrue to industry as a result of our comprehensive study.

The study will indicate the adequacy of the water resources to meet the needs of the major water-using groups, making available information on the physical, chemical, and biological quality of the region's waters. The findings will be used by Federal construction agencies as guides in determining storage requirements in multiple purpose reservoirs necessary to meet the municipal and industrial water supply needs. The study will evaluate the impact of natural resource development on the demands for water and the water quality problems

resulting from such developments. It will provide information on waste treatment requirements and the ability of the surface waters to receive residual waste loads without seriously damaging other water uses.

The study will indicate those areas where stream flows may be critical and where high water quality uses are likely to develop. This information will indicate potential areas of conflict in uses, and the advantages and possibilities of alternate site locations for future industrial developments. The study will also provide information as to the need for, and value of, water storage for stream flow regulation for quality control purposes, and where such storage can be most economically developed.

Intelligent planning now can do much to insure that the future development of the water resources will be in the best interests of the public. The assistance and cooperation of all private and public agencies and groups are essential to develop such a plan.

CHANGES IN WATER QUALITY DUE TO IRRIGATION

Gilbert H. Dunstan, Donald E. Proctor, Ervin Hindin

The Columbia Basin Irrigation Project includes 3, 900 square miles of semi-arid plateau in Central Washington, and consists of portions of Grant, Franklin, and Adams counties. The area lies east of the Columbia River and north of the City of Pasco. The most easterly point is approximately 60 miles from the river, and the northern boundary is slightly north of Ephrata, about 120 miles north of Pasco.

The project has created thousands of farm units from wasteland, and more are being added each year. The project area is divided into blocks ranging from 2, 000 to 40, 000 acres in size, with several blocks being placed under irrigation each year since 1952. Approximately 450, 000 acres are to be irrigated under the current program. With towns and industries springing up, the ultimate population, sometime in the future, is estimated at about a quarter of a million persons.

Figure 1 shows the area involved. In a previous paper (1), Skrinde has described the physiography and geology of the area. He also pointed out that there has been a considerable increase in water levels. In several areas water levels are now within 30 feet of the surface.

In the area south of Quincy, from Winchester to Burke, which was brought under irrigation between 1952 and 1955, the average rise in water level between 1952 and 1958 was 17 feet per year for 60 wells. In the Moses Lake area, brought under irrigation in 1952 and 1953, the average yearly rise in 28 wells was 12 feet. Since 1955, however, no noticeable rise has taken place, due presumably to increased westward migration of water toward Potholes Reservoir. Similar results can be shown for other areas.

Published data on wells in this area are given in Water Supply Bulletin No. 8, "Geology and Ground Water Resources of the Columbia Basin Project Area, Washington," Vol. 1 (2).

The change from a semi-arid area, with limited crop production, to an irrigated area results in many changes, one of which has already been indicated by the rising water table. But what of the quality of the water in the wells and in streams as a result of run-off from irrigated lands? Do these changes

constitute a potential health hazard? This investigation was undertaken primarily to determine the changes in ground and surface water brought about by irrigation in the region under consideration. The use of fertilizers, insecticides, and weedicides was considered likely to alter the quality of the water. Whether a health hazard exists will depend upon the allowable limits of these substances in water, and must be determined by toxicologists and medical scientists.

GROUND WATER CHANGES

Chemical analyses of a number of wells were made during 1960-62, and whenever possible data from previous tests were assembled. Results will be given here for selected wells, leaving a complete tabulation for the project report which is under preparation (3).

Wells vary in depth from 16 to more than 1,000 feet, although the majority range from 200 to 500 feet. There is no significant difference in mineralization between shallow and deep wells. Most of the waters can be considered hard, an average of 50 wells being 240 mg/l. The principal cations are calcium, magnesium, and sodium. Sodium may be present in excess of the total for calcium and magnesium combined. The principal anions are bicarbonate, sulfate, and chloride. When sodium is high, chlorides are usually high also. However, due to the length of time samples were held in bottles before sodium was determined, sodium values shown are open to question.

Concentrations of salts have accumulated in the soil and waters in various areas of the basin over the past years. This is due in part to the natural topography of the basin, which does not permit easy drainage, and to evaporation losses. In highly mineralized areas, such as Soap Lake, ground waters prior to irrigation were extremely high in dissolved salts. This has made Soap Lake a tourist attraction. With the advent of irrigation, a freshening effect has occurred both in the lake and in the ground water.

Table I shows changes in the chemical content of the water from a well 66 feet deep near Soap Lake. Total hardness is expressed in mg/l as calcium carbonate. Although the 1953 analysis is incomplete, over the nine-year period the hardness and chlorides were reduced to less than 20 percent of the original concentrations. This illustrates a water which was so highly

mineralized as to be unfit for human consumption before irrigation, and which was rendered usable after irrigation.

Other wells have shown reductions. In the Moses Lake area, a well 352 feet deep shows a decrease to a hardness of about one-third the original over a nine-year period, with a much greater decrease in chlorides. These data are given in Table II.

In general, where the water table has risen and where the land was not highly mineralized prior to irrigation, the chemical concentrations have increased. In some cases this increase has been slight, but in others it has been several hundred percent.

Table III gives data for a well between Moses Lake and Warden, in which both hardness and chloride content have more than doubled. This well is 342 feet deep. This well shows an increase in nitrate of approximately seven times since irrigation developed. Even the well in Table I shows a slight increase in nitrate content. Since nitrogen has increased consistently in well waters since irrigation was initiated, it is probable that the increase in nitrate content of the water is due to the fertilizer application for crop production. Other factors may include natural deposits of nitrogen compounds and the growth of nitrogen fixing crops. Water with nitrate-N above about 10 mg/l should not be used as it may cause methemoglobinemia, or blue babies. It is therefore noted that this well is over the safe limit established by the 1962 drinking water standards, as are some other wells in the basin.

A well in the Warden area, which is 185 feet deep, shows a very great increase in nitrate content, although the final values are slightly less than for the well just noted, and are just about at the danger point. Hardness and chlorides have more than doubled since irrigation. Data is given in Table IV.

Data are given for a well in the Quincy area in Table V and for one in the Mesa area in Table VI. These show increases in dissolved mineral content, as well as in nitrate content, but the latter is still well within safe limits. It does not seem likely that nitrates will ever be a health hazard in these areas, except possibly in isolated wells. Since nitrogen is very soluble, it will tend to leach out through drainage systems.

Some benefit is to be derived from the increase in nitrates. A nitrate-N content of 5 mg/l provides about 40 pounds

of nitrogen per million gallons of water, which is equivalent to about 3 acre feet.

During the initial summer a total of 42 sampling stations were established for the periodic collection of surface waters. These were located on creeks, canals, drains, and springs. They were selected to provide information on all major surface outlets to the Columbia River, on irrigation water entering the basin, at several points where long-term retention or prior irrigation use could have an effect on water quality, and at inlets and drains for nine "self-contained" irrigated areas.

In general, each station was sampled and analyzed weekly throughout the irrigation season. Temperature and pH were determined at the time of sampling and a dissolved oxygen test sample was "fixed" for later analysis. At a field laboratory established in Ephrata, Washington, analytical tests were performed to determine electrical conductivity, phenolphthalein and total alkalinity, calcium, magnesium, hardness, chlorides, sulfate, nitrites, nitrates, ammonia, orthophosphates and polyphosphates. Small samples were stored for sodium and potassium analysis by flame spectroscopy at a later date.

The nine "self-contained" areas were regions in which drainage limits could be closely defined. Farm surveys were made to determine the crops grown and acreage of each, amounts of fertilizer and pesticides used, and crop yields. From the chemical analysis data a study of outlet-inlet concentration ratios were made for such variables as hardness, chlorides, bicarbonate alkalinity, nitrates, and orthophosphates. On the basis of the ratios of chlorides and nitrates and also the farm survey data, it was decided that only two of the self-contained areas would be studied further after the first summer.

To illustrate the changes that occur in some water quality characteristics, Figures 2 through 7 show respectively the electrical conductivity in micro-ohms/cm $\times 10^6$, the total hardness in mg/l as CaCO_3 , the total alkalinity in mg/l as CaCO_3 , chloride ion in mg/l, sodium ion in mg/l, and nitrates in mg/l as N. The open circles on each graph represent the characteristics of water from the West Canal, which has not been used previously. The solid circles represent water that has been used one time on a self-contained farm unit south of Quincy, Washington. The squares are for water in Potholes Canal south of Othello, and is water that has been used one or

more times for irrigation. Water quality at this point is also influenced by evaporation and long-term storage in Potholes Reservoir. To some extent it contains surface water from a small, natural stream, Upper Crab Creek, and does receive some unused irrigation water from wasteways connected to the main canals. Triangular data points on the figures are for samples taken at Ringold Springs. This spring has appeared in the bluffs along the Columbia River at a point southwest of Mesa since the advent of widespread irrigation in the Columbia River Basin Project. The large flow from these springs is probably water that has traveled underground for variable distances ranging up to perhaps 20 miles through strata that was well above the water table prior to irrigation in the southern half of the basin.

By inspection of Figures 2 through 7 and other plots not included in this paper, it appears that all characteristics of the water entering the basin (open circles) are fairly constant. Sodium concentrations show some marked changes, but this may well be caused by sample storage in glass vials rather than by variations in water quality. Ammonia nitrogen (not shown) was also quite variable though never higher than 0.25 mg/l in the inlet water to the basin.

Water quality in the drain from the self-contained area south of Quincy (solid circle) shows a marked but variable increase in conductivity and in all dissolved constituents as a result of the single pass over or through the soil. For conductivity, hardness, total alkalinity, nitrates, chlorides, and sulfates a noticeable rapid increase in concentration occurs in late June or early July each year. Numerically, the greatest increases were in hardness (from about 70 in the inlet to about 300 in the outlet on occasion) and in alkalinity (from about 80 to about 225 at times in the outlet drain water). The percentage changes were quite large for nitrates, but still the nitrate-N content never exceeded 5.5 mg/l in any surface water sample throughout the basin in the three-year study period.

Much of the return water from irrigation in the northern one-third of the basin finds its way by underground seepage or drains into Potholes Reservoir and on out into the lower portions of the basin via Potholes Canal. Some dilution of used water by flow from wasteways occurs in the reservoir and also by runoff from Upper Crab Creek. This dilution probably explains the fact that Potholes Canal water (shown by squares) has less of nearly every dissolved constituent than the once used water from the self-contained area. The water is definitely more mineralized

than the water in the main canals entering the project, however.

The water quality data for Ringold Springs (solid triangles) is somewhat surprising because of its variability. As previously mentioned, these springs issue from the steep hill or bluff along the Columbia River southwest of Mesa. The springs discharge immediately above a nearly impervious consolidated strata in the Ringold Formation. The springs extend almost continuously for approximately 1/4 to 1/2 mile along the hillside. Considering the large volume of flow and the distances of underground flow involved, it is difficult to explain the rapid changes that occur in conductivity, hardness, nitrates, and chlorides. It should be noted that existing knowledge of the geology of the area does not support the idea that solution channels, such as might be found in limestone regions, could allow the rapid transmission of surface water to the springs. The fluctuations in chlorides, hardness, conductivity, and nitrates appear to be in seasonal cycles that are out of chronological phase with similar changes at other surface water sampling stations. This suggests that the time of flow from irrigation areas to the springs is perhaps as much as 4 to 8 months.

Unfortunately, data were not obtained on fluctuations in rate of flow at the springs. This prevents estimation of the effect that the springs may have on water quality outside of the irrigation project area.

The use of certain chlorinated organic compounds for the control of pests on irrigated croplands in the Columbia Basin has given rise to a new consideration in regard to water quality. Because of the low solubility of this class of pesticides in water, concentrating techniques were required to obtain samples of sufficient concentration for analysis. The carbon filter technique using activated carbon as an adsorbent, similar to that used by the U.S. Public Health Service, was used in the study. Though perhaps not giving quantitative recovery of pesticides, activated carbon is thus far the best, available, nonspecific medium for the removal of organic compounds from water.

A number of analytical techniques were investigated to determine the identify and to quantitatively estimate the individual pesticides in residues extracted from the activated carbon. It was found that gas chromatography was the best approach for the separation of the residue into its individual constituents. Gas chromatographic columns, containing either 5 percent Dow 200 silicone or 5 percent Epon 1001 on 60/80 mesh Chromosorb P,

gave satisfactory separations of mixtures into the individual pesticides. Four types of detecting systems used in gas chromatography: thermoconductivity, hydrogen flame ionization, electron capture, and microcoulmetric titrator in conjunction with a microcombustion furnace, were investigated. The latter was the most specific for analyzing, both qualitatively and quantitatively, the chlorinated hydrocarbon pesticides in extracts from field samples. D.S. May, et al (4) at the 18th Purdue Industrial Waste Conference described the analytical procedure and detector comparison.

As a result of sampling in the Columbia Basin during the 1961 and 1962 growing season, pesticides were found on occasion in all wasteways, impoundments, and lakes in the Columbia Basin. On three different occasions aldrin, DDT, and the esters of 2,4D were found, each in concentrations ranging from 0.1 to 3.0 parts per trillion (ppt), in the flow of the West Canal near Quincy, Washington. Aldrin, DDT, DDD, and the esters of 2,4D were present on two occasions in concentrations ranging from 0.1 to 0.7 ppt in the flow of the Potholes Canal below the Scooteny Reservoir. Sampling stations on Crab Creek, the Potholes Canal above Scooteny Reservoir, and the low canal above Warden gave concentrations ranging from 0.1 to 0.5 ppt. DDT, aldrin, and the esters of 2,4D were the predominate chlorinated pesticides present.

Mud samples from Evergreen, Coffin, and Moses Lake revealed that the sediments contained DDT, aldrin, and the esters of 2,4D, each in concentrations in the parts per billion range.

CONCLUSIONS

It may be concluded from this study that rather marked changes have occurred both in ground and surface water. In the highly mineralized water of the Soap Lake area dilution has resulted in reducing mineral content. In the waters of the lake this has caused concern, since the tourist business is a major economic factor here and tourists are attracted by the high mineral content of the lake waters. In other areas drainage flow which enters lakes and streams shows increases in mineral content from that in the applied waters.

From the health viewpoint no particular hazard is evident except in the case of several wells where the nitrate-N content exceeds 10 mg/l. Such waters should be used with care.

However, pesticides have been detected in the water in drains, lakes, and reservoirs, and in bottom muds. At present these are in low concentrations. Until toxicities are determined and allowable limits are prescribed by public health authorities, it cannot be stated whether or not there is a health hazard from these substances.

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REDUCED MINERAL CONTENT

Table I
Well No. 22/27 - 30 P2
Depth 67 Feet
(Soap Lake Area)

	8/4/53 (mg/l)	8/15/60 (mg/l)	9/12/60 (mg/l)	6/21/61 (mg/l)	8/1/62 (mg/l)
Total Hardness	2370	370	756	357	----
Sodium	----	113	98	97	----
Potassium	----	9	13	8	----
Total Alk (CaCO ₃)	550	262	249	258	----
Sulfate	----	286	565	270	----
Chloride	430	33.5	59.8	31	22.5
Nitrate-N	----	1.9	0.75	2.18	2.06
Phosphate	----	0.27	----	----	----

Table II
Well No. 19/29 - 22 C1
Depth 352 Feet
(Moses Lake Area)

	1/8/52 (mg/l)	8/15/60 (mg/l)	9/12/60 (mg/l)	6/21/61 (mg/l)
Total Hardness	176	38	41	52
Sodium	37	23	46	23
Potassium	8	2.3	2.6	2.3
Total Alk (CaCO ₃)	244	86	88	87
Sulfate	82	14	14	13
Chloride	46	1	1.3	0.25
Nitrate - N	----	0.11	0.4	0.8
Phosphate	----	0.15	----	----

INCREASED MINERAL CONTENT

Table III
Well No. 18/29 - 17 P1
Depth 342 Feet
(Between Moses Lake and Warden)

	2/ /52 (mg/l)	8/30/60 (mg/l)	8/9/61 (mg/l)	8/1/62 (mg/l)
Total Hardness	102	258	277	----
Sodium	36	56	29	----
Potassium	11.0	3.9	3.2	----
Total Alk (CaCO ₃)	140	150	140	----
Sulfate	29	60	68	----
Chloride	18	42.5	51.5	52.2
Nitrate-N	2.08	13.40	16.30	14.21

Table IV
Well No. 18/30 - 16 R1
Depth 185 Feet
(Warden Area)

	11/1/53 (mg/l)	8/30/60 (mg/l)	8/9/61 (mg/l)	8/1/62 (mg/l)
Total Hardness	121	258	252	----
Sodium	33	78	48	----
Potassium	2.7	5.7	4.3	----
Total Alk (CaCO ₃)	292	129	140	----
Sulfate	30	131	125	----
Chloride	17	44	42	49.5
Nitrate-N	0.05	10.8	10.06	12.3
Phosphate	----	0.11	----	----

Table V
Well No. 20/23 - 10 N1
Depth 351 Feet
(Quincy Area)

	9/11/53 (mg/l)	8/22/60 (mg/l)	7/17/61 (mg/l)	8/1/62 (mg/l)
Total Hardness	158	232	246	----
Sodium	27	67	40	----
Potassium	3.9	7.7	7.5	----
Total Alk (CaCO ₃)	296	144	144	----
Sulfate	53	77	81	----
Chloride	15	63	70.8	76
Nitrate-N	0.16	3.55	3.23	3.61
Phosphate	----	0.04	----	----

Table VI
Well No. 13/29 - 26 B1
Depth 175 Feet
(Mesa Area)

	12/10/54 (mg/l)	8/15/60 (mg/l)	8/16/61 (mg/l)	8/1/62 (mg/l)
Total Hardness	175	312	312	----
Sodium	24	71	35	----
Potassium	5.5	8.4	7.4	----
Total Alk (CaCO ₃)	221	280	274	----
Sulfate	71	63	68	----
Chloride	----	27	30	30
Nitrate-N	----	4.8	4.4	4.2
Phosphate	----	0.05	----	----

Note: Mesa Area only area where total Alk (CaCO₃) has increased

General Nitrate-N Concentration Trends

<u>Down</u>	<u>Up</u>
Soap Lake - Ephrata Area	Moses Lake Area
Ringold Springs Area	Quincy Area
	Warden Area

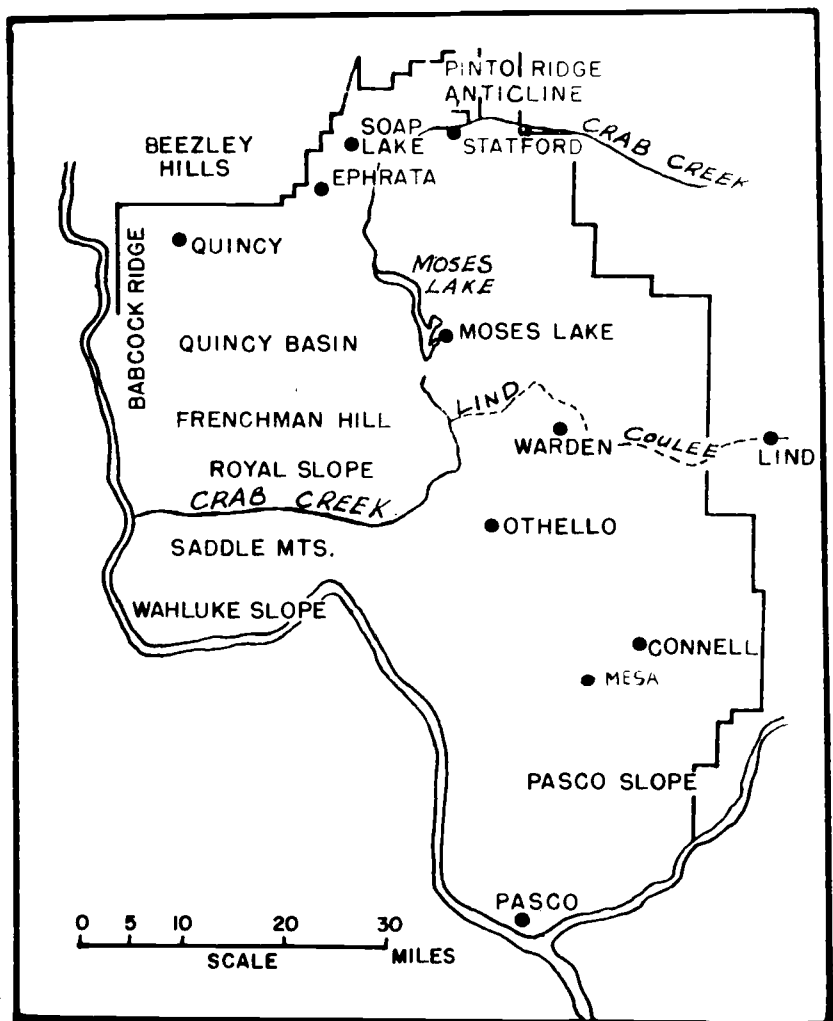


FIG. 1 COLUMBIA BASIN PROJECT AREA

LEGEND
FOR SURFACE WATER QUALITY GRAPHS

Figures 2-7

- = New water sampled at inlet to self-contained area south of Quincy.
- = Once used water in drain from self-contained area south of Quincy.
- = Multi-used water from Potholes Canal south of Othello. Contains some unused water from wasteways and is influenced by long-term storage.
- ▲ = Water from Ringold Springs west of Mesa at Columbia River bluffs. Probably used irrigation water flowing underground up to 20 miles.

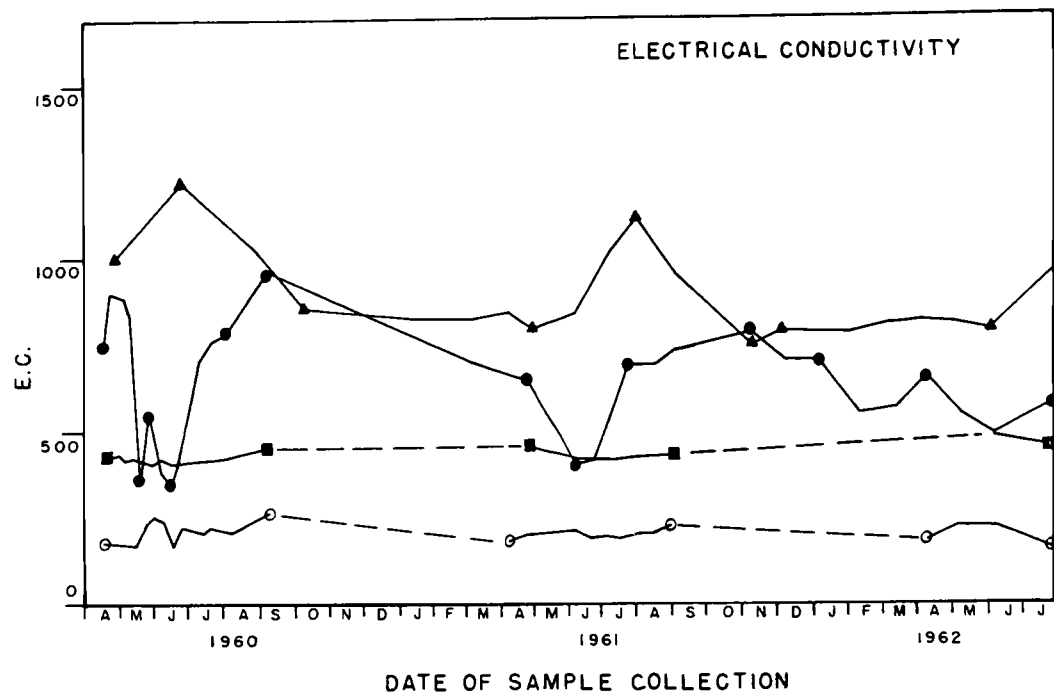


FIGURE 2.

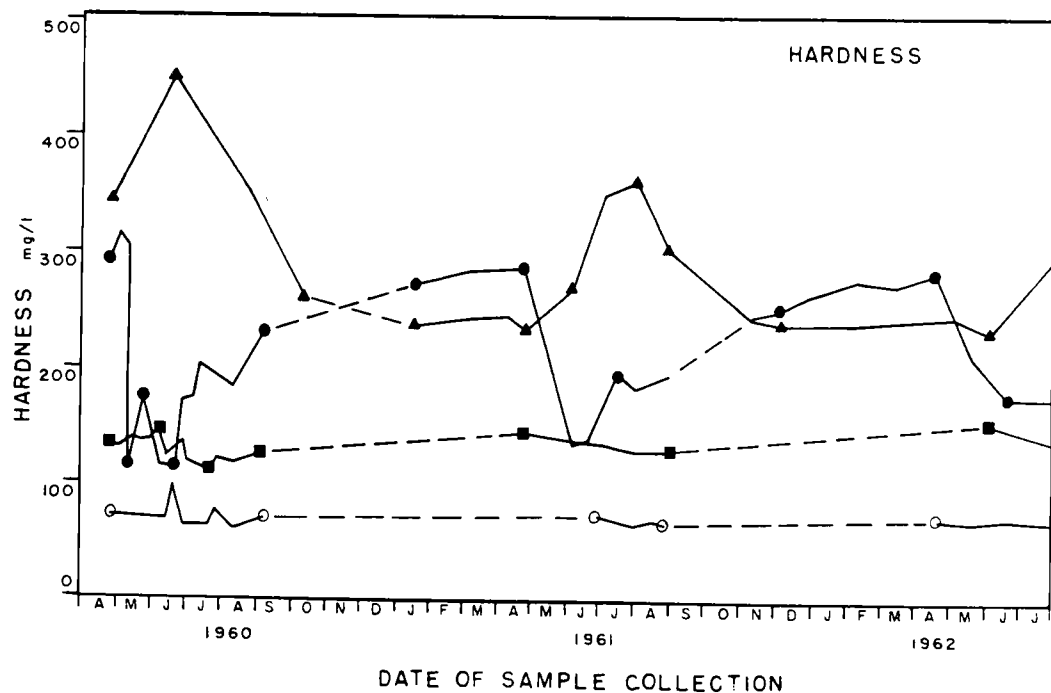


FIGURE 3.

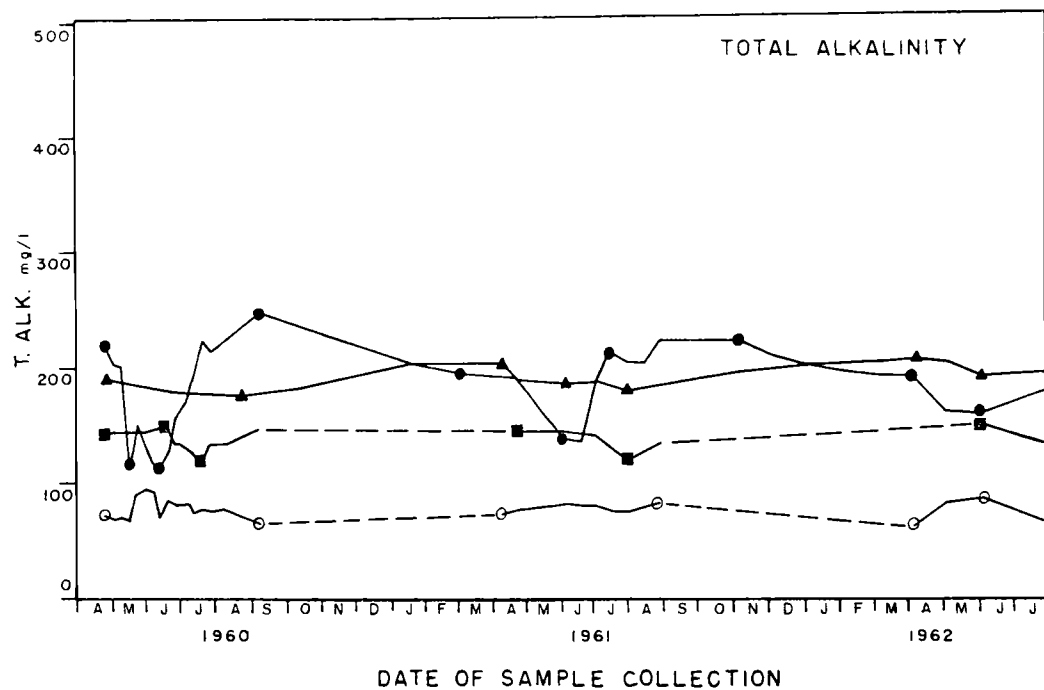


FIGURE 4.

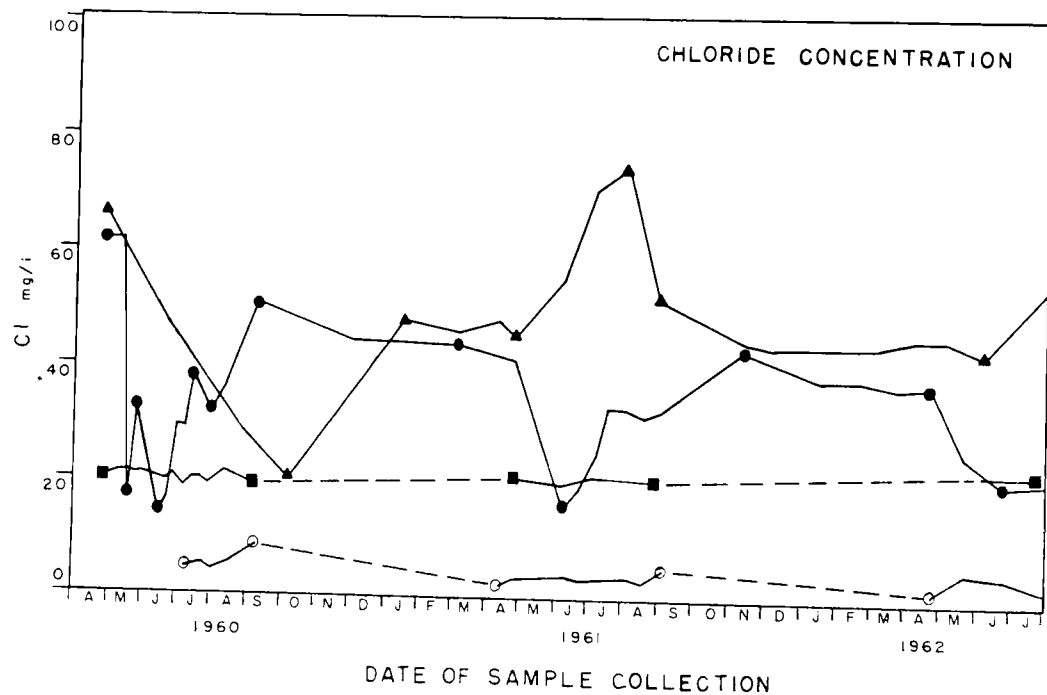


FIGURE 5.

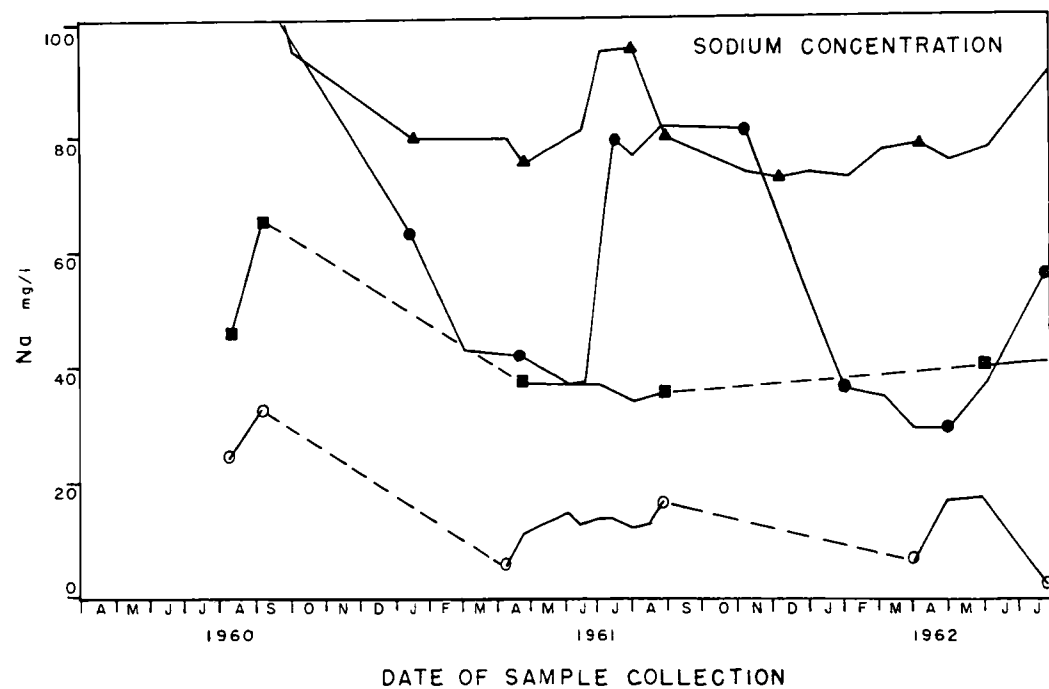


FIGURE 6.

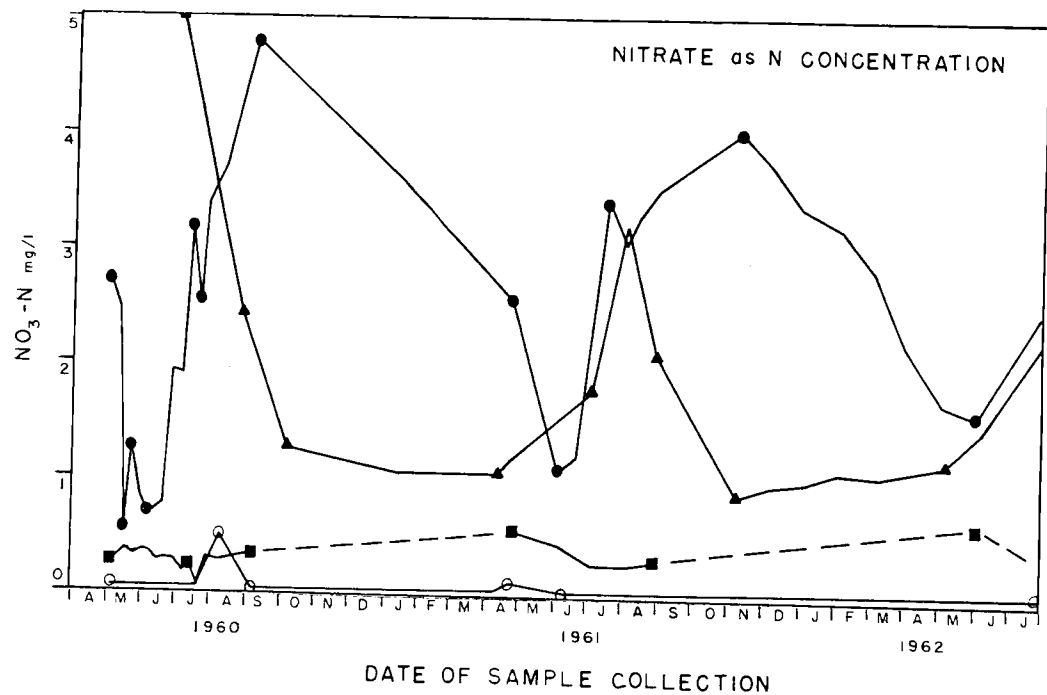


FIGURE 7.

WASTES MANAGEMENT IN THE FOOD PRODUCING AND PROCESSING INDUSTRIES

S. A. Hart and P. H. McGauhey

"Wastes!" To produce and refine but a single pound of food for the American household requires that five to ten pounds of solid wastes be left in the field or processing factory and that many gallons of process water acquire the unholy status of waste water.

Any substance, liquid or solid, becomes a "waste" when its owner or producer considers its value insufficient to justify its retention. Any suggestion that further money be invested in its disposal or other financially unrewarding objective is likely to be considered absurd. The true problem of wastes management lies in this attitude, and in no case has the consequence become more critical than in the food producing and food processing industries.

Time was when the U.S. population was almost exclusively agricultural; food production, processing, and consumption, along with the handling of wastes so produced, lay with each individual, and because population density was low, wastes management posed little problem beyond using up some otherwise productive labor. In today's urban society there is great separation of the activities of food producing, food processing, and food consuming. Waste disposal too has followed this same evolution, to the end that municipal wastes, industrial wastes, and agricultural wastes are generally looked upon as separate, discrete, and unrelated problems. Nothing could be further from the truth, either in actual practice or in developing satisfactory solutions. Nevertheless, economical and comprehensive solutions to the overall community wastes handling must await future awareness of the interrelation between rural and urban waste disposal problems. In the meantime, the food industry must look to separate solution of its own problem. A closer look at the character of these problems may, however, enable us to see better what must be done to save modern man from being engulfed by mountains of his own wastes.

FIELD AND FARM WASTES

Agriculture is by far the biggest producer of wastes. The most significant of these are crop residues and animal manures (1). For example, three pounds of manure are defecated

for each quart of milk produced. Livestock produce six to twenty-five pounds of manure per pound of weight gain; or a total of 1.12 billion cubic yards of manure per year—enough to supply each family with more than twenty-five cubic yards. Some of this manure is left in pastures and on rangeland, and hence does not create disposal problems, but at least half of it is deposited in feedlots and barns, from whence it must be removed for disposal.

One, of course, immediately thinks, "Ah, but manures can be used as fertilizers. They are not in fact wastes." Strictly speaking, this is true; if some profitable use can be found for a waste, it can be called a by-product. But livestock are not kept for the sake of their manure; farmers (and processors) would be much happier if there were no portion of their produce that had to be handled as a waste. The farmer can buy and distribute bagged chemical fertilizers cheaper than he can scrape up manure and spread it on the field (2). He handles manure only because he has to control fly breeding, odors, dust, and disease hazard to his animals.

The management of manure is the number one technical problem facing the livestock industry today. This is particularly true in the high-investment rural belt impinged on by the post-war expansion of cities. Here, both the urban and rural dwellers are confronted with difficulties, the farmer finding it extremely expensive to pick up animal manure and transport it to an acceptable disposal site, the latter finding fly and odor nuisance of gargantuan proportions. Some idea of the magnitude of this problem may be gained from statistics of California communities. Here, in the vicinity of burgeoning cities, there are egg and poultry installations, each housing 10,000 to 100,000 hens (3), and feeding pens in which a single owner fattens as many as 6,000 steers per year. It is estimated that such concentrations produce a total of 20 million cubic yards of manure annually, with a fly-producing potential beyond calculation.

Needless to say, the animal manure problem in the newly urbanized rural area is imperfectly resolved. Wastes cannot be left where they fall; land on which they may be spread is seldom to be found nearby; high investment in fixed installations, plus the speculative pricing of land further out, tends to pin down the owner disinclined to give up and sell his land for subdivisions; and local jurisdictions are neither organized nor educated for waste disposal on an area basis. Current solutions to this dilemma involve a combination of expedients. The individual farmer seeks to pursue the historic land disposal method, or goes out of

business under the impact of urban enforcement of nuisance abatement laws or ruinous taxes as the city overruns his property. Meanwhile, research seeks new solutions through lagooning, digestion, or composting of animal manures, either alone or in combination with other organic debris.

Like the animal grower, the crop farmer is faced with prodigious quantities of residues. The tonnage of stalks, stems, leaves, and cull fruit left in the field far exceeds the tonnage of crop harvested and hauled to market. The ear of corn is but one-third of the total plant weight, and tomatoes actually harvested are but one-fourth of the weight of residue left in the field (4). The story is the same for all crops, from asparagus to zucchini. Since some 112 million tons of plant crops are harvested each year in the United States (5), the field wastes are overwhelming enough to give each American family 8 tons of cull fruit, dead plants, and field trash to go with his mountain of animal manure.

As with manures, something must be done with these wastes to prevent fly breeding and other sanitation problems, and to allow the farmer to prepare the land and grow the next crop. There are three ways of disposal: plowing under, burning, or surface spreading. Probably the most universal is the plowing of wastes into the soil. Sanitation-wise it is effective, but it is expensive. In addition, the nutrient imbalance of the residues often creates soil fertility problems when they are turned over, thus requiring additional chemical fertilizers.

Burning of residues, such as cereal stubble and tree prunings, is a simple procedure but adds to the air pollution problem already vexing more than 10,000 U.S. communities. Trash cutters and wood chippers are sometimes used to reduce the volume of tree prunings, corn stalks, and cotton plants. The residue is then left on the field, but this procedure may foster diseases and insects that will attack succeeding crops. Control may then call for stronger insecticides, which can lead to greater problems of water pollution for processors of the produce. In any event, such waste disposal can be done only after the complete crop is removed. But many fruits and vegetables are harvested over several weeks to several months. Cull fruit from the beginning of harvest must just lay in the field and rot and create problems until the harvest is finished and disposal of the total crop residues can be undertaken.

FOOD PROCESSING WASTES

The U.S. could not support and sustain its population without our modern-day food processing industry. Pasteurization, canning, freezing, dehydrating, and all other purifying and preserving techniques remove the time limitation of food harvesting and eliminate the health hazard of eating. The increased refinement and tastiness of foods, convenience of use, and generally lower cost to the consumer are other benefits of modern food technology.

But even here, all these benefits are not without their price in the production and management of wastes. Creameries use and discharge more water than the amount of fluid milk they process (6). The prime example, however, is cannery waste. Here, both liquid and solid wastes are produced in tremendous quantities. The problem is further compounded by the fact that most of these wastes occur in a short period, during the harvest season.

In volume of wastes from a cannery, the liquid is by far the greatest, varying from 1/4 gallon to over 4 gallons per pound of fruit or vegetables processed (7)(8). The concentration of pollutants in the process waters may be small; nevertheless, for a number of reasons they are difficult to deal with. For example, water used in washing raw products may be high in inert solids (dirt) and contain insecticides and other chemicals. Pea blancher wastes have a high BOD, fruit processing wastes contain readily available sugars, etc. Biological methods developed for sewage treatment are often ill-suited to the task of stabilizing cannery wastes because of the poor balance of carbohydrates and nitrogenous compounds in the wastes and the seasonal load imposed precipitously on treatment plants designed for domestic sewage. Mechanical and chemical purification methods, such as screening, flotation, heavy chlorination, and chemical oxidants, have all been tried but with only moderate success. The current approach is to get rid of process water quickly by spray irrigation onto land (9), provided, of course, that the cannery has moved from its city location and has not yet been overrun by urban development.

Solid wastes—the skins, reject fruit, pits, etc., present truly unique problems in waste disposal. Here, not only cost, but inadequate process technology combine to present almost insurmountable difficulties. In specific cases some solid wastes

such as tomato skins and seeds may be dehydrated for animal feed. Fruit pits are often converted to charcoal for industrial use or for backyard barbecues—some 25,000 tons of peach pits were handled this way in a single plant in California in 1961 (10). These specific by-products represent but a fraction of the solid wastes. Each year, for example, 60 to 75,000 tons are produced in the East Bay area of California, and at least 300,000 tons in the great Central Valley. The high sugar content of some of these solid wastes suggests its use in the manufacture of industrial alcohol. Here, no unusual process problems are involved, but it is impossible to build a satisfactory economically competitive fermentation industry around a short-term, high-volume waste, either as a separate enterprise or as an activity of the canning industry itself. In addition, the wastes from such an alcohol plant would still represent a secondary disposal problem.

During the past several years a number of canneries in the Oakland, California, area have disposed of their solid wastes by barging them out to sea. This is expensive as well as physically hazardous, and of course is not practical for inland areas. In any event, it is looked upon with an increasingly jaundiced eye by a growing band of "true believers" who would guard the sanctity of the sea as fearlessly as the Isaac Walton League does our fresh-water streams. No one considers dumping wastes in the ocean an adequate answer.

One hopeful process—disposal of cannery solid wastes by composting—was begun in 1962 by the National Canners' Association and the University of California, and was described earlier this afternoon by Mr. Rose (11). It may represent to urban waste disposal a solution that may later be applicable to all solid wastes produced by the domestic and industrial community.

THE NEED TO MANAGE WASTES

Wastes are, of course, an inevitable result of man's production and use of food and fiber. Just as inevitably as wastes are produced, so must they be managed. The ultimate goal of the food-producing and processing industries with which this paper is concerned is to furnish food for the consumer. That food nourishes and sustains him, and in due course itself becomes a waste. However, only the water-borne segment of such waste has been subjected to well-engineered disposal systems capable of accepting similar liquid wastes from the industrial sector of the community. The cans, bottles, packaging, food scraps, and fancy wrappings that entice the housewife are usually managed in

the haphazard manner that characterizes the disposal of food producing and food processing wastes. Only, this is done by a different jurisdiction not concerned with coordinating the disposal of its solid wastes with that of other segments of the food waste chain.

The need for an integrated approach to wastes management is nowhere more evident than at the so-called "urban-rural zone of contact." As previously noted, urban centers have, since World War II, been spilling out into the surrounding countryside in a suburban sprawl. Here is where high-cost homes, food processing plants, and agriculture meet. In the historic pattern the rural area adjacent to a metropolis is devoted to intensive agriculture. Here are the truck crop farms, dairies, egg ranches, and perhaps feedlots, all designed to supply the metropolitan area with foodstuffs adequately and efficiently. Since investment in land and equipment is high, this rural shell loses its adaptive flexibility. It also exists in considerable depth and has a profound effect on the waste management problems of the entire community. Thus, when the city expands, it comes into direct clash with intensive agriculture and creates problems for both.

Integrating the disposal and utilization of area wastes has received some small attention, but the motivation has generally been economy to the segment of the food chain that is in trouble at the time. This passing of the wastebucket, of course, began with the consumer when he became a city dweller and delegated the chores and the wastes back to the processor or producer. The processor in turn frequently tries to shift the waste burden forward or backward.

A specific example is seen in the movement of dairy processing plants to cities so that their process water may be handled by the municipal sewage treatment plant. Or the shift may put the burden of waste disposal back upon agriculture, as when the pea and bean processor makes the farmer take back the shelled-out vines and dispose of them on the field where they were grown, or the cannery develops a spray irrigation system to dispose of its waste water on agricultural land. The farmer, too, often tries to shift the burden, as when he goes to mechanical harvesting of a crop without field sorting and cleaning, and passes this chore on to the processor. While this approach is undoubtedly proper, it is regrettable that the motivation is narrow and that each segment of the community attacks its own waste problem with myopic concern only for itself, without regard for the impact of the whole waste problem upon society.

POSSIBLE SOLUTIONS TO THE PROBLEM

There appear to be no simple and separate solutions to the problem of management of wastes from the food producing and food processing industries. In fact, the problem exists because of the failure of attempts to dispose of individual wastes by methods suited only to a far less complicated rural society. Regrettably, too, the emphasis in disposal has been on cheapness rather than adequacy of method. Two principal approaches now seem imperative: (1) a program of education of the citizen, his elected representatives, and the food producer and processor; and (2) a program of research into economical and technologically feasible methods of community waste disposal.

The objectives of the educational program must include the concept that in a modern urban-industrial-agricultural complex there is no longer any way by which a single jurisdiction, or individual sector of the economy, can dispose of its wastes by simple export to some area beyond its own limits, to be burned, buried, or dumped without concern; but that instead a comprehensive program of integrated community wastes management is necessary.

The educational program must also lead the public to understand that waste disposal is worth whatever it costs within the framework of sound engineering and administration, and that the cost is a part of the price we must pay for the urban-industrialism from which our high standard of living derives. Citizens are well aware that it costs more to police, provide fire protection, and operate an urban society than it does for the people to live as hermits. The advantages and benefits of community life are generally recognized as worth the cost, however grudgingly the citizens pay the taxes that provide municipal services. It remains to apply this same rationale to the development of a more efficient and satisfactory solution to the problems of waste disposal in the food industry. Obviously, the farmer or processor cannot be expected to demonstrate greater altruism than the urban citizen by voluntarily burdening himself with costs of waste management beyond what will benefit him directly. Nor will many housewives buy "Product X" simply because its manufacturer spends an extra cent per can going the second mile in waste disposal. The solution will come only when coordinated systems are developed that will give society its desired level of sanitation, and when the citizenry is convinced of the necessity of paying for it.

The search for economical and technically feasible methods should begin with a recognition of certain fundamental assumptions. Concerning solid wastes, it should be recognized that animal manures, crop residues, cannery solid wastes, and municipal refuse may all have to be combined and treated as a composite waste. Certainly it must be realized that the ultimate disposal of most of such stabilized material will have to be upon agricultural land. Further, such material, even more than manure, will probably not be able to compete with commercial fertilizers. Thus, encouraging the farmer to use it will probably require that it be given or sold to him at a cost below the actual cost of stabilizing it. Research funds to establish the technology and economy of area-wide waste disposal must come from public sources since the food industry, unable to resolve its waste problems separately, can in no way be expected to resolve the overall community-wide problem. Necessary studies of the feasibility of waste disposal districts or other jurisdictional arrangement to carry out a comprehensive program must be a part of the research program.

A hopeful approach to solid wastes research has been reported today by Mr. Mercer (12). Although its immediate objective is the disposal of cannery wastes, its sponsors look to its application to combined community wastes. Again, the integrated approach will be necessary but the motivation will be to benefit all segments of the food chain; indeed, to benefit the whole of society.

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POTATO WASTE TREATMENT

Robert E. Pailthorp

In 1961, the potato processing industry of Idaho was confronted with the problem of waste treatment to protect the waters of the state. In only two years the processors have banded together into a working unit and, with the assistance of equipment manufacturers, state agencies, and engineering consultants have conducted pilot plant studies, made equipment evaluations, developed design criteria, and designed and constructed treatment plants.

Idaho's potato processors produce potato flour, starch, chips, french fries, granules, alcohol, flakes, slices, and other items. The growth of the industry has been phenomenal. In 1950, the industry in Idaho used 202,500,000 pounds of potatoes, and in 1960, this had increased to 2,009,300,000 pounds. In only 10 years the industry expanded nearly 10 times and, consequently, so had the waste disposal problem. In 1961, 2,561,700,000 pounds of potatoes were used by processing plants in Idaho.

During the processing of potatoes between 20 and 25 percent of the raw product is lost as waste. This means that between 500,000,000 and 625,000,000 pounds of potatoes must be disposed of each year by the potato processors.

A majority of the processing plants are located along the Snake River or its tributaries and have, in the past, discharged waste directly to the stream after it had been screened to remove large solids. The Snake River is also used for municipal water supplies, sewage disposal, irrigation, and recreation. Over the past years the flow in the river has decreased as a result of increased irrigation needs and as a result of the fact that Idaho has recently experienced some very dry years. All of these factors have caused deterioration of the water quality in the Snake River, which resulted in the State Board of Health requiring, in a report dated February 1961, that all potato processing plants above American Falls Reservoir remove 50 percent of the pollution from their waste flow and plants operating below American Falls Reservoir remove 90 percent. Proposals for providing treatment were to be submitted to the State Board of Health by July 1, 1961, and the plans for treatment were to be submitted by January 1, 1962. The treatment facilities were to be completed by September 1962.

In view of the treatment requirements, a survey of all available information was made. It was found that no information existed which could be directly applied to the waste treatment problem, and that processors in other parts of the nation and Canada were asking the same questions and pondering the same problems.

PROCESS

Most of the potatoes are processed to produce prepared foods. Therefore, the waste from this source was of major concern. Although all potato plants are individual and have their own peculiarities, the general sequence of operations is similar throughout the industry. The flow diagram in Figure 1 illustrates a typical plant and the sources of waste.

The first operation is to wash the potatoes to remove the soil. This waste contains rocks, soil, and some potato solids.

The next step is to peel the potatoes. Two processes are used—steam peel or caustic peel. In either system the outer layers of the potato are softened so that they can be removed by high-pressure water sprays. A majority of the waste is produced at this point. This waste contains the outer layers of the potato and, in the case of caustic peel, an amount of sodium hydroxide which results in a waste with very high pH.

The potatoes are passed from the peelers to the trim tables, where bad spots, eyes, and other blemishes are removed by hand. A majority of the waste trimmed from the potatoes can be removed from the waste flow by screening. A relatively small amount of water is used in this operation.

Next, the potatoes are cut to a desired shape and then blanched in hot water. The waste from the blanchers is of high strength and the solids are largely dissolved.

After the blanchers the potatoes are processed into the final product. Wastes result from many sources during the final processing but, in general, they are of minor significance and vary widely from one plant to another.

Cleanup of the plants results in sewage flows of high strength. The character of the waste flow from cleanup operations varies widely from one plant to another.

Potatoes can be conveyed within the plants with water or mechanically conveyed from one operation to another. When water is used to convey potatoes, it is discharged to waste after being recycled several times. This water contains both dissolved and suspended solids. Water use varies in processing plants from 1-1/2 to 2-1/2 gallons per pound of potatoes processed, with 2 gallons per pound as an estimated average use.

APPROACH BY PROCESSORS

The potato processors realized that they all faced the same problems and, therefore, to eliminate duplication of effort organized a waste disposal committee which consisted of representatives of most of the major potato processors of Idaho. The committee was formed in the spring of 1961. The objective was to develop the best method for treating potato waste so that the requirements of the State Board of Health could be met. The group set out to conduct laboratory and pilot plant work for removing solids from the waste and disposing of the solids. The methods of treatment first considered were sedimentation, screening, centrifuging, flotation, lagooning, and spray irrigation.

The studies were financially supported by a majority of the processors of the state. Most of the pilot plant equipment was made available by various equipment manufacturers. A full-sized sedimentation unit was constructed in an existing concrete tank at the R. T. French plant in Shelley, Idaho.

IN-PLANT CHANGES

Most of the processing plants measured and ran tests of individual waste flows within their plants to determine the extent of their particular problems and to indicate the methods of reducing waste flow. The flume water, which in most plants is used to convey the potatoes to the processing plant from holding cellars and to remove soil from the potatoes, was not treated. In most plants the flume water was already separated from the other waste flows and was being recycled. Plants which were not doing this have since changed to the flow pattern so that the flume and wash water is separated from other plant waste flows. It is probable that at some future date this waste will have to be treated. Make-up water must be added to the flume water system to displace soil from the system.

The greatest saving of water within the plants was made by recycling water in the peelers or by reusing water from other

points in the plant in the peelers. In some plants this saved up to 250 gallons per minute of water usage. In some cases water from the waste treatment plant can be reused within the processing plant.

The reuse of water is controlled by biological buildup and foaming. Potato waste foams very easily and produces a very stable foam, which can cause annoying problems. A high biological count in the food product as a result of excessive water reuse would, of course, be disastrous.

Numerous methods of water reuse were investigated by most plants, and in some cases nearly a 25 percent saving in water could be made.

PILOT PLANT RESULTS

Laboratory and pilot plant tests were run to develop a maximum amount of useful information in as short a time as possible. It was suspected by the processors that 50 percent of the COD could be removed from the waste flow by settling. It was also recognized that when 50 percent of the COD was removed by settling, the result would be a large quantity of solids for disposal. It was hoped that the solids could be used as cattle feed.

Preliminary tests indicated that the solids content of the underflow from a clarifier would be about 5 percent. Therefore, a plant processing 1 million pounds of potatoes per day would have approximately 5,000 cubic feet of solids to dispose of each day. An underflow which contained only 5 percent solids was found to be very fluid and difficult to handle. For cattle feeding purposes, the palatability of such a liquid material was very poor. It was necessary to find a way to further dewater the solids and then to determine if they would make an acceptable cattle feed.

Many tests of various types were conducted. The following is a discussion of those tests which appear to be significant. It was found that sedimentation in a clarifier with an overflow rate of approximately 800 gallons per square foot per day would result in at least a 50 percent removal of COD for waste from both caustic peel and steam peel plants. Tests with screens and centrifuges failed to produce 50 percent removal.

Carbon dioxide from the plant boiler stack gases was diffused through caustic peel waste to lower the pH. It was found to be effective, and if not applied at too great a rate did not cause excessive foam. This technique may prove useful in the future to condition caustic waste for secondary treatment.

It was thought that perhaps chemical coagulation could produce the 90 percent removal required of some processors; therefore, tests were run using activated silica, alum, ferric, chloride, ferric sulphate, Hagan No. 2, lime, magnesium chloride, magnesium sulphate, sodium silicate, separan, soda ash, and a chemical sold by Panta Industries.

Activated silica, lime, and the Panta chemical proved to be the most effective. Presettling of the waste prior to the coagulation did not decrease the chemical requirements. With chemical treatment it was possible to effect over an 80 percent COD removal from the potato waste by sedimentation. In all tests it was noted that as the strength of the waste increased, so did the percentage removal by sedimentation. Sludges which resulted from chemical treatment were noted to be less dense than sludge from plain sedimentation tests. A combination of lime and activated silica worked best on caustic potato waste. The cost of chemicals for this treatment was estimated as approximately 5.7 cents per 1,000 gallons of waste.

Fermentation was studied as a means of reducing the pH of the caustic potato solids, dewatering the solids, or preparing the solids for dewatering by mechanical equipment. It was found that the pH of caustic waste solids would reduce from over 11 to 5.5 in about 12 hours at room temperature. The sludge would filter more easily if fermentation had not progressed too far. However, if the fermentation was allowed to proceed, the pH would continue to fall and the filterability of the solids decreased.

It was found that the solids settled from steam peeling waste could be dewatered without chemical treatment to about 15 percent solids on a vacuum filter. It was found that the solids settled from the caustic peel waste could not be successfully vacuum filtered unless they were preconditioned by the use of chemicals. Many chemicals were tried and many combinations were used. It was found that a combination of about 2 percent ferric sulphate and 10 percent lime was the most successful in the pilot plant operation and would allow the production of a filter cake with about a 15 percent solids content. Dewatering of

the conditioned solids was also attempted with a centrifuge, but was found not to be as successful as a vacuum filter.

A plant which is processing one million pounds of potatoes per day would produce approximately 150,000 pounds of filter cake for disposal each day. Many feed tests were conducted and others are being continued. The solids are palatable to cattle and there is every indication that they can be disposed of as a feed.

TREATMENT METHODS

The particular details of individual waste treatment plants have varied because of problems and conditions peculiar to each plant. In general, however, each plant is screening its waste and then settling it in mechanically-cleaned clarifiers which have a design overflow rate of about 800 gallons per square foot per day and a side water depth of about 12 feet. The deep clarifiers provide for concentration of the settled solids.

In plants using steam peeling the clarifier underflow is pumped directly to a belt-type vacuum filter for dewatering. The filter cake is trucked away and either used fresh, as cattle feed, or is placed in silos and then fed to cattle after it has fermented.

In plants using caustic peel the waste treatment is more difficult. The wastes are screened and then settled in clarifiers as with steam peel waste, but facilities are provided so that the clarifier underflow can be treated with lime or ferric sulphate. Lime is mixed with the solids and allowed to react for about 30 minutes in a thickener, then the solids are withdrawn and ferric sulphate is added and mixed with them in a flocculator. The conditioned solids are vacuum filtered and trucked away for use as cattle feed. Schematic diagrams of the treatment systems are shown in Figure 2.

A caustic peel plant which was constructed at the R.T. French Company of Shelley, Idaho, in the latter part of 1962, has been in operation long enough so that experimental work could be done on the full-scale plant. It has been found that during certain times of the year, as a result of a change in the character of the potatoes, the caustic peel solids can be vacuum filtered successfully without the use of chemical coagulants. The exact reasons why this is true have not been resolved, but studies are

continuing on this important development in the waste treatment process. Tests are also being conducted by a processor on a system which would employ fermentation followed by solids separation in a centrifuge.

FUTURE STUDIES

The problem of secondary treatment, disposal of solids, and other items which have developed will be studied in the future. Particular attention will be given to methods for dewatering the solids and producing a stable and acceptable cattle feed product. Some tests with presses have already been conducted, but so far have proven unsuccessful. Methods of secondary treatment will be studied. Emphasis will be placed on fermentation, aerated and nonaerated ponds, trickling filters, activated sludge, spray irrigation, chemical treatment, anaerobic digestion, and combinations of the above methods.

Work will be conducted to resolve the problem of possible contamination of the potato solids by insecticides. Cattle feeding experiments will be continued to determine the value and the best use of the solids. New uses for the potato solids will continue to be studied in hopes of developing other outlets for the disposal of the separated solids. When all plants effect a 50 percent removal of COD from the waste flow, an equivalent of approximately 300,000,000 pounds of potatoes must be used or disposed of in some manner. The problem of disposal of the solids which will result from secondary treatment processes has yet to be considered. Methods for reducing the cost of chemicals for treating caustic peeler solids before vacuum filtration will continue to be studied in the full-scale plants which are now in operation.

Dr. Jackson of the University of Idaho, is directing research on oxygen transfer with venturi aerators; the effect of surface agents and other variables in venturi aerators; treatment of potato waste with carbon dioxide, pectic enzymes, and natural fermentation; anaerobic digestion; and foam separation of potato waste solubles.

Although the time limits set by the State Board of Health have not been met in all cases by the processors, treatment methods have been developed for the treatment of a difficult waste in a very short time, and several treatment plants were in operation by the fall of 1962, which would reduce the COD of the waste at least 50 percent. Only by the joint effort of all processors and diligent work of very enthusiastic individuals could

so much information have been developed and applied in such a short time.

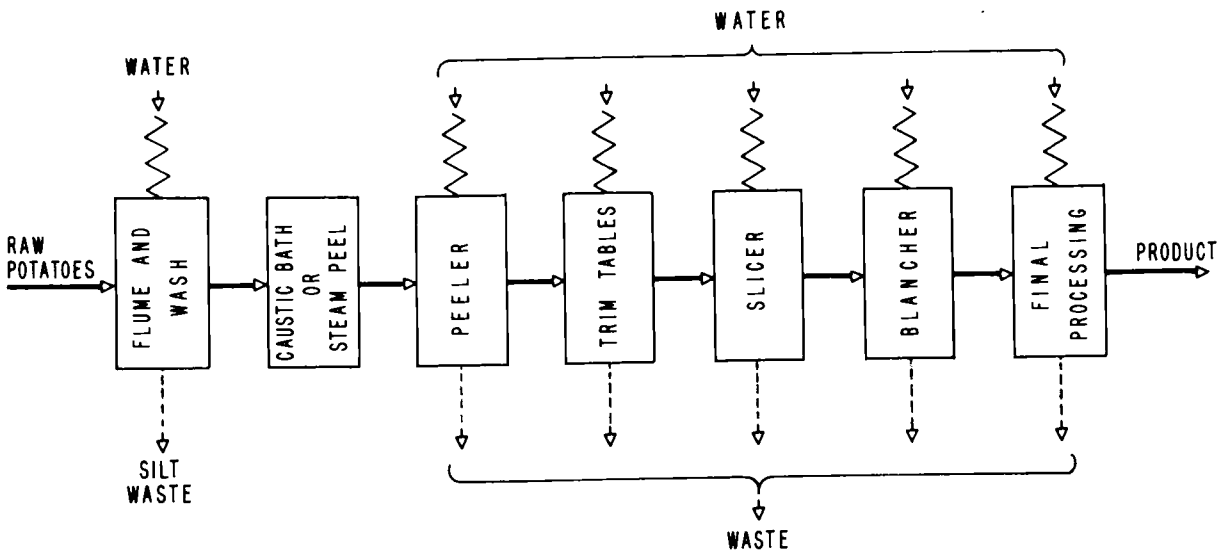
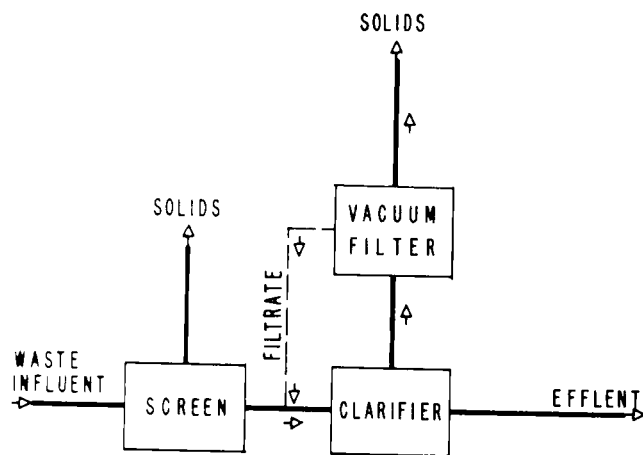
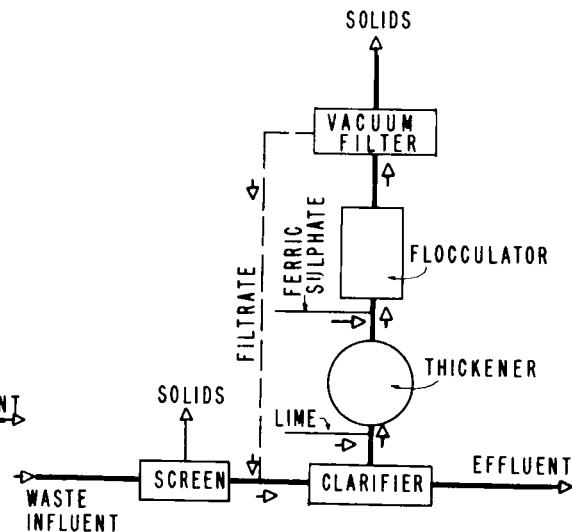


FIGURE 1 - POTATO PLANT - SCHEMATIC PROCESS DIAGRAM



WASTE TREATMENT FOR
PLANT USING
STEAM PEEL



WASTE TREATMENT FOR
PLANT USING
CAUSTIC PEEL

FIGURE 2

TREATMENT OF RADIOACTIVE CONDENSATE WASTE

J.M. Skarpelos

INTRODUCTION

With the growth of the atomic energy industry and associated increases in the rate of production of radioactive wastes, increased emphasis has been placed on developing methods for "ultimate" waste disposal. Considerable work is being done to develop techniques for immobilizing radioisotopes in high activity level liquid wastes by incorporation into solid forms. The high-level waste solidification schemes as well as conventional nuclear fuel reprocessing plants produce large volumes of low- and intermediate-level radioactive condensate wastes. In remote areas such as Hanford, these wastes are now safely and economically discharged to the ground; hazardous long-lived radioisotopes are effectively retained by the soil and short-lived radioisotopes reaching ground water are adequately decayed before the ground water reaches water supply sources. Such methods are feasible at Hanford because of the favorable location and environmental conditions there. These methods probably would not be feasible if the nuclear processing plants were located near heavily populated areas. Economic and effective decontamination of large volumes of these low- and intermediate-level waste streams may be a major consideration in locating future nuclear materials processing plants. Since much of the technology which can be used for treating radioactive condensate wastes has been developed using synthetic or simulated "cold" streams, a program was considered necessary in which an actual condensate stream would be used as feed for treatment process studies. Treatment processes using inexpensive ion exchange adsorbents with large capacities for removing radioactivity were of prime interest. The waste chosen for this work is produced when the vapors given off by the self boiling alkaline wastes in the Purex Tank Farm are condensed. This report describes the experimental evaluation of a radioactive condensate waste decontamination process on a small engineering scale.

DISCUSSION OF THE PROBLEM

Source of Waste

A simplified flow diagram of the Purex Tank Farm is shown in Figure 1. The neutralized high-level radioactive wastes

and organic wash wastes are jetted from the Purex Plant to a diversion box. The waste then flows by gravity to a second diversion box from which it can be routed to any of six underground storage tanks. Vapors produced by heat evolution due to radioactive decay in the stored waste are routed to an entrainment removal cyclone and then to one of three surface condensers. The entrained liquid collected in the entrainment removal cyclone drains to one of the storage tanks. The condensed vapors are routed to a 40,000-gallon underground retention tank. The condenser cooling water is sent to a swamp (surface disposal pond), the equipment is vented through a de-entrainment tower and then to a local stack, any de-entrained liquid being discharged to a crib (a sub-surface excavation filled with gravel and covered by earth).

Most of the aqueous condensate collected in the 40,000-gallon tank is returned to the high-level waste storage tanks for volume control. Equipment has been provided to allow future re-cycling of the condensate to the Purex Plant, if desired. The major amount of organic along with a considerable amount of aqueous condensate is periodically overflowed through the proportional sampler pit to a crib. The waste used in the study reported in this report is the aqueous phase obtained from the lower part of the retention tank (241-A-417) by tapping off the process pump discharge line.

Radioisotopes Present in Purex Tank Farm Condensate

The significant radioisotopes found in the Purex Tank Farm condensate waste are listed in Table I. Also listed are the Maximum Permissible Concentrations allowable in potable waters for each radioisotope, if it was the only one present, along with the decontamination factor required of a treatment process to produce water having the MPC_w values. As can be seen by these figures, the most hazardous isotopes of concern are Sr^{90} and Cs^{137} .

TABLE I
RADIOISOTOPES PRESENT IN AQUEOUS PHASE PUREX
TANK FARM CONDENSATE WASTE

Constituent	Half Life ^(a)	Typical Concentration ($\mu\text{c}/\text{ml}$)	MPC _w ^(b) ($\mu\text{c}/\text{ml}$)	Decontamination Factor ^(c) Required
Sr ⁹⁰	28 years	10 ⁻⁴	1 \times 10 ⁻⁶	> 100
Cs ¹³⁷	30 years	10 ⁻²	2 \times 10 ⁻⁴	> 50
Zr ⁹⁵	65 days	10 ⁻²	6 \times 10 ⁻⁴	> 17
Ru ¹⁰⁶	1 year	10 ⁻³	1 \times 10 ⁻⁴	> 10
Ce ¹⁴⁴	285 days	10 ⁻³	1 \times 10 ⁻⁴	> 10
Sr ⁸⁹	50 days	10 ⁻³	1 \times 10 ⁻⁴	> 10
Nb ^{95(a)}	35 days	10 ⁻²	1 \times 10 ⁻³	> 10
Y ⁹¹	59 days	10 ⁻³	3 \times 10 ⁻⁴	> 3
I ¹³¹	8 days	10 ⁻⁵	2 \times 10 ⁻⁵	--

(a) Half lives given are for parent substance only except for Nb⁹⁵ which is listed separately. Nb⁹⁵ was the only daughter radioisotope present in sufficient concentration and with long enough half life to be considered in this study.

(b) Maximum Permissible Concentration in Water for 168-hour week from National Bureau of Standards Handbook 69 (June 5, 1959).

(c) Decontamination Factor =
$$\frac{\text{Isotope concentration in untreated waste}}{\text{Isotope concentration in treated waste}}$$

Nonradioactive Substances Present in Purex Tank Farm Condensate

The significant nonradioactive impurities found in Purex Tank Farm condensate during normal operation are listed in Table II. The organic matter which is present both in solution and as a very stable emulsion did not noticeably change the decontamination ability of bed packing materials. However, it did cause considerable difficulty with respect to physical plugging of the packed beds. The ammonium ion present, because of its similarity to the cesium ion, alters the ion exchange performance of an ion exchange material with respect to removal of Cs¹³⁷. The nitrite and nitrate ions form complexes with ruthenium which cause difficulties in removing this element.

TABLE II
NONRADIOACTIVE SUBSTANCES PRESENT IN AQUEOUS
PHASE PUREX TANK FARM CONDENSATE WASTE

<u>Constituent</u>	<u>Typical Concentrations</u>
Butyl Phosphates	30 to 200 mg/l
Hydrocarbons	10 to 70 mg/l
Ammonia	35 to 200 mg/l
Sodium	1 to 2 mg/l
Nitrate Ion	1 to 5 mg/l
Nitrite Ion	5 to 10 mg/l
pH	9 to 10 mg/l

PRETREATMENT OF WASTE

The presence of organic matter in the waste, especially in emulsified form, tends to be mechanically removed by packed beds which act as filters. The emulsion globules fill the bed void spaces during downflow operation, causing an excessive increase in pressure drop across the bed after only a fraction of the adsorption capacity of the bed is used. The organic "fouling" is characterized by the formation of a distinct layer of an orange-colored, wax-like material in the top inch of the bed. Relatively large quantities of ammonia in the waste compete for exchange sites when cation exchange is attempted. Because of the similarity between the ammonium ion and cesium, the capacity for cesium can be seriously decreased, in particular.

A pretreatment step was thus desirable for the purpose of decreasing the amount of organic matter and ammonia so that ion exchange could be used to remove and concentrate the radioisotopes present from the bulk of the waste. Steam stripping was considered feasible for this purpose.

A steam stripper for removal of gross amounts of ammonia and organic impurities present in the condensate waste was designed and fabricated. The unit consisted of a stripping column fabricated from an 8-foot length of 2-inch schedule 40 pipe packed with 1/4-inch stainless steel Raschig rings. Steam which entered the bottom of the column was generated by heating the bottom stream in a reboiler containing a small steam coil. With a feed rate of 96 ml/min to the stripper and an overhead distillate rate of 6 ml/min, the ammonia concentration in the bottom ranged from 1 to 4 mg/l, the butyl phosphate concentration was less than 1 mg/l, and the hydrocarbon concentration

varied from 1 to 7 mg/l. Thus, the stripper was effective in removing greater than 97 percent of the ammonia and organic impurities. The condensed overhead stream consists of organic and aqueous phases. Some of the iodine and ruthenium radioisotopes are volatilized and travel with the overhead stream. These isotopes tend to concentrate in the organic phase, so that the aqueous phase can be released to the environs without any further special treatment. Actual concentrations of radioisotopes in these two phases are shown in Table III. Because radiocesium is not detected in the overheads, even though it is present in the feed in concentrations greater than any other isotope, entrainment of the aqueous feed is considered negligible.

TABLE III
RADIOISOTOPES PRESENT IN STEAM STRIPPER OVERHEADS

Radioisotope	Concentration in Aqueous Phase ($\mu\text{c/ml}$)	Concentration in Organic Phase ($\mu\text{c/ml}$)
Iodine-131	5.9×10^{-6}	2.7×10^{-3}
Ruthenium-106	5.6×10^{-6}	3.4×10^{-4}
Zirconium-Niobium-95	9.4×10^{-7}	Not detected
Cesium-137	Not detected	Not detected

Although the steam stripper bottom stream is very clear, the residual organic matter is present as filterable particulate matter. This was apparent when lengthy adsorption experiments were performed. In one run at a flow rate of 1 gpm/ft², the initial pressure drop across a 11-inch deep bed was about 0.1 psi. The run was terminated after 6000-column volumes of waste had been processed at which time the pressure drop across the bed had increased to about 4.9 psi. Most of the filterable organic matter was removed in a 1-inch layer at the top of the bed, although some organic matter was dispersed throughout the bed. Since the organic matter had adhesive properties which caused considerable resin particle agglomeration, it was necessary to use mechanical means to break up the agglomerate and solvent treatment to dissolve the organic matter adhering to the resin beads before regeneration could be accomplished. A filtration step is thus considered necessary to protect ion exchange beds.

ADSORPTION OF RADIOISOTOPES FROM WASTE

With the nonradioactive impurities reduced to relatively

low concentrations in the steam stripper bottoms, the decontamination of the waste by ion exchange adsorption becomes attractive. Choice of adsorbent then is dependent upon the forms in which the radioisotopes are present. The cesium in the waste is present almost entirely as the positively charged cation, as would be expected. The waste leaving the stripper in the bottom stream has a pH of 5 to 7. At this pH the strontium, cerium, and zirconium are present primarily as positively charged cations. However, 1 to 3 percent are present in nonionized forms. The pH must be reduced to less than 4 in order to more completely ionize these elements. Ruthenium which is present is primarily complexed with nitrites and nitrates in the waste. These complexes of ruthenium are chiefly in the form of anions, and most of the remainder is in the cation form.

Cesium Removal

Being present entirely as the positively charged cation, cesium can be removed efficiently from steam stripper bottoms using conventional cation exchange resins. The capacity of a strong acid cation resin for removing cesium from this waste stream is dependent upon the residual sodium and ammonium ion present. As can be seen in Figure 2, cesium can be removed from about 11,000 column volumes of steam stripper bottoms by Amberlite IR-120 before the MPC_w value of Cs^{137} is reached if 0.27 meq of cations/l of feed are present. With 0.50 meq of cations/l of feed the MPC_w value was reached after only 6000 column volumes of steam stripper bottoms were processed.

The naturally-occurring mineral clinoptilolite which has been studied for some time at Hanford was also used to remove cesium from the steam stripper bottom stream. Although 0.44 meq of cations/l were present in the feed to the clinoptilolite bed, about 15,000 column volumes of waste were processed before the MPC_w value of Cs^{137} was reached. This is also illustrated in Figure 2. The greater capacity available with clinoptilolite is because the crystal structure of this zeolite mineral is of near optimum dimensions for selectively removing cesium even when larger amounts of ammonium and sodium are present.

Strontium, Cerium and Zirconium Removal

The radioisotopes of strontium, cerium and zirconium can also be removed by cation exchange. The efficiency of removal, however, is significantly related to the pH of the feed. Strontium, for example, can be removed with a decontamination factor (DF) of 500 when the steam stripper bottom stream having a pH of 6 to 7 is passed through a bed of Amberlite IR-120. However, if the pH is reduced to 4 or less by the addition of nitric acid, the decontamination factor is increased to 5000. As can be seen in Figure 3, the strontium was removed with this efficiency for about 11,000 column volumes by Amberlite IR-120 with no signs of breakthrough. The MPC_w value of Sr^{90} was reached after about 6000 column volumes of acidified steam stripper bottoms were processed through a bed of clinoptilolite. The shape of the breakthrough curve indicates that the crystal structure which favors cesium adsorption probably limits the diffusion of strontium into the zeolite particle.

Although it is not illustrated, cerium and zirconium radioisotopes were adequately removed whenever strontium was being removed effectively.

Ruthenium Removal

Many difficulties have been encountered in attempting to remove ruthenium by an adsorption process. In view of the complex chemistry of ruthenium, this was not without expectation. While in the separations plant the ruthenium was present in solutions of high nitric acid concentration, and thus significant nitrate and nitrite complexes of the element were formed. When neutralized with caustic soda, water-soluble or colloidal complexed polymeric species may be formed. Determining the exact form in which the ruthenium is present is exceedingly difficult and time consuming. We found, however, that 10 to 20 percent of the ruthenium was removed when waste was passed through a bed of strong acid cation resin. When waste was passed through a bed of strong base anion exchange resin 80 to 90 percent removal was observed. One would thus expect to remove greater than 90 percent if the two types of resin were used in series or together in mixed beds. This we found to be the case, as is shown in Figure 4, where over 99 percent was actually removed during the early part of the experiment. While the initial removal efficiency for ruthenium was good, the capacity of the two-bed system for ruthenium was relatively low. The reduction in efficiency of removal of

ruthenium coincides with the saturation of the bed by nonradioactive ions. However, even after this bed saturation had occurred, 80 to 90 percent of the ruthenium continued to be removed.

SUMMARY AND CONCLUSIONS

The overall process visualized for treating a waste such as Purex Tank Farm condensate is illustrated in Figure 5. The waste containing ammonia and organic matter along with a number of radioisotopes is fed to a steam stripper tower. The overhead vapors, representing about 5 percent of the waste, contain most of the ammonia and organic matter. Some radioiodine and radioruthenium are also present. After condensing and decanting to separate the two phases formed, we find that the organic, which represents about 0.02 percent of the waste, contains most of the ruthenium and iodine present in the overhead stream. The remainder is an aqueous phase containing most of the ammonia but relatively little radioactivity, and thus it can be disposed to the environment without further treatment.

The bulk of the waste leaves the stripping tower and is cooled before passing through a precoat type filter using finely divided (200×300 mesh) cesium selective adsorbent such as clinoptilolite as the filter aid. This step of the process removes particulate matter and radiocesium from the liquid. The adsorbent cake is discharged for burial whenever its capacity for cesium has been utilized, or whenever the pressure drop across the filter has reached a predetermined point. The filtered waste is then passed through a strong base anion bed which removes an appreciable amount of the ruthenium along with nitrate and nitrite ions. Periodically, this bed is regenerated with caustic soda. The regenerant solution is discharged to underground storage. Since alkali in excess of the stoichiometric amount must be used, the regenerant solution could be used for neutralizing high-level acid waste, if desirable. The waste leaving the anion bed is acidified to a pH of 4 before entering the cation bed which removes strontium, cerium, zirconium, and other radioisotopes in the cationic form. Having an extremely high capacity for these radioisotopes, the cation resin can economically be discharged for burial. The effluent leaving the cation bed is sufficiently low in radioactivity that it can be safely discharged to the environment. If the residual acid needs to be neutralized, the effluent can be combined with the aqueous overhead stream containing ammonia.

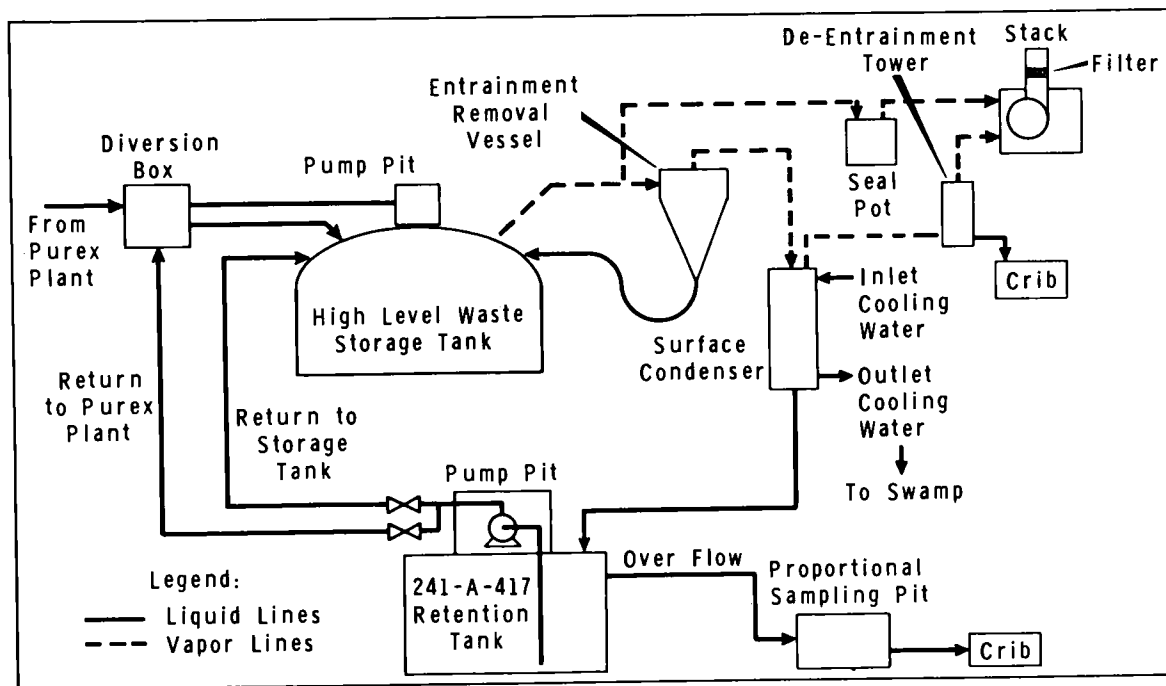


Figure 1. Simplified Flow Diagram Purex Tank Farm Waste Facility

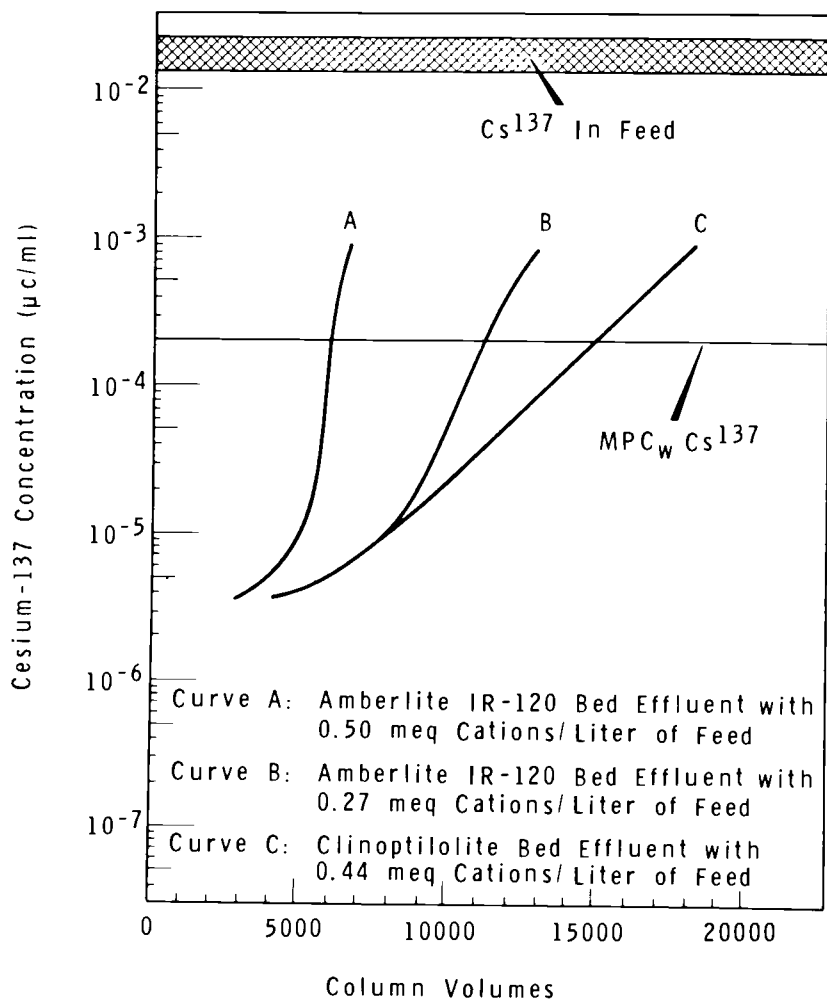


Figure 2. Cesium-137 Removal from Steam Stripper Bottoms

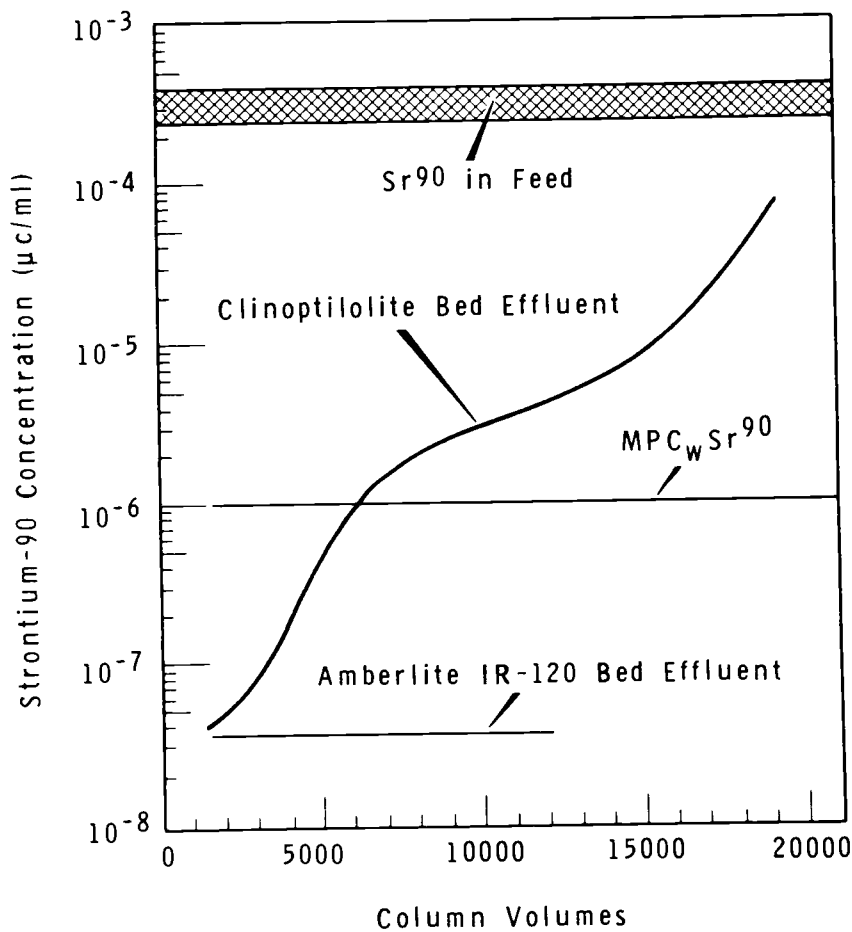


Figure 3. Strontium-90 Removal from Acidified Steam Stripper Bottoms

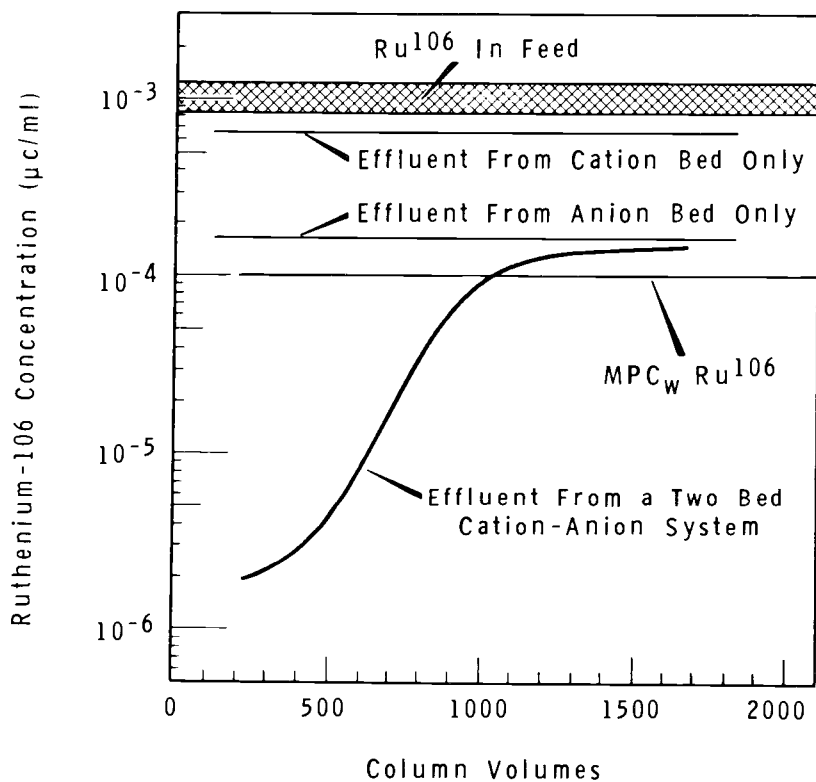


Figure 4. Ruthenium-106 Removal from Steam Stripper Bottoms

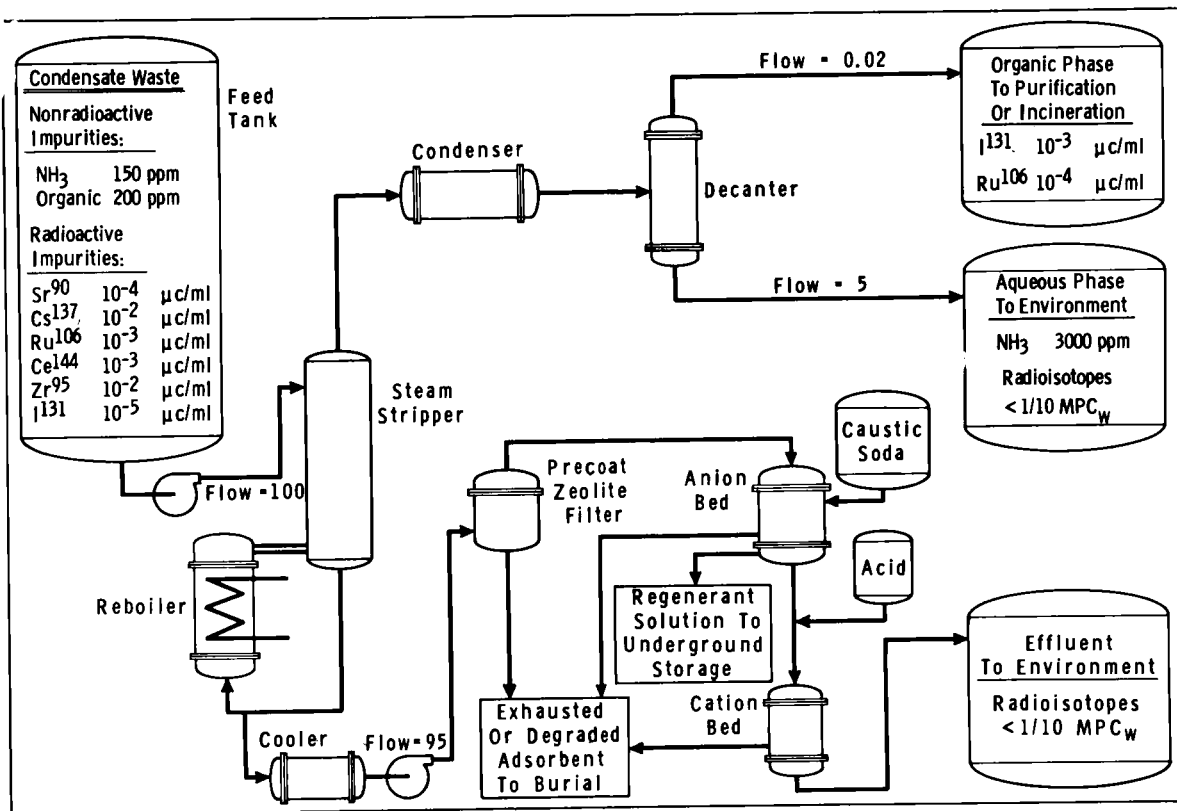


Figure 5. Condensate Decontamination Flow Diagram

THERMODYNAMIC ASPECTS OF GROWTH AND OXIDATION DURING BIOLOGICAL WASTE TREATMENT

J. A. Servizi and R. H. Bogun

INTRODUCTION

It is generally held that a portion of the waste organic matter removed during aerobic biological treatment is converted to sludge and that the remainder is oxidized to provide energy for synthesis and cell maintenance. There is a great deal of speculation and apparently some confusion about the quantitative relationship among oxygen consumption, sludge formation, and the nature of the waste undergoing treatment. As a result, the design of aerobic processes for biological treatment has been based on empirical assumptions relating to oxygen requirements and sludge production.

In this paper theoretical equations are presented relating oxygen requirements and synthesis to the free energy of oxidation of the substrate. Experimental verification is offered for simple systems consisting of single and multiple organic compounds and both pure and mixed microbial cultures. Data have been obtained from the literature and from experiments conducted in our Sanitary Engineering Laboratory.

LITERATURE SURVEY

In describing activated sludge accumulation, a number of engineers have used equations similar to the following proposed by McCabe and Eckenfelder⁽¹⁾:

$$\Delta S_{\text{net}} = y - 1 K_3 S_a$$

where y = lb 5-day BOD removed per day, S_a = lb of volatile suspended solids in the mixed liquor, ΔS = net sludge accumulation - lb VSS/day, a = fraction of y converted to VSS, and K_3 = endogenous or autooxidation rate constant. Though this formula is accepted in principle, there is disagreement about the value of "a." Heukelekian, et al⁽²⁾, Heukelekian and Gellman⁽³⁾, and Sawyer⁽⁴⁾ have found 0.5 grams VSS/gram BOD removed for sewage and various industrial wastes, whereas McCabe and Eckenfelder⁽¹⁾ have found this yield coefficient to range from 0.38 to 0.93 (as shown in Table I).

In general, two conflicting viewpoints are evident in a

review of the engineering literature. One point of view is that the amount of sludge produced during biological treatment varies with the chemical nature of the waste; the other is that the relationship between synthesis and oxidation is fixed and independent of the organic matter being assimilated.

Oxidation and synthesis by microorganisms have been studied extensively by microbiologists. Siegel and Clifton⁽⁶⁾ examined the aerobic assimilation by *E. coli* of succinic, fumaric, lactic, and pyruvic acids and of glycerol, arabinose, glucose, and lactose. In these experiments each organic was employed as the sole source of substrate carbon, and the amount converted to new cell tissue was determined by carbon analysis. This study found the proportion of substrate carbon converted to cell carbon unrelated to the free energy of substrate oxidation. Lamanna and Mallette⁽⁷⁾, in reviewing the work of Siegel and Clifton, concluded that the chemical nature of a substrate rather than its free energy of oxidation controls synthesis.

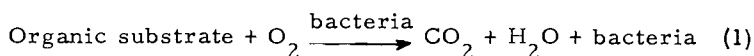
Bauchop⁽⁸⁾ and later Bauchop and Elsdon⁽⁹⁾ related cell growth to the theoretical quantity of ATP formed from the energy source during its catabolism. Anaerobic cultures of *S. faecalis*, *S. cerevisiae*, and *Ps. lindneri* were grown in complex media containing essential amino acids, vitamins, etc. Glucose, D-ribose, or arginine served as energy source, and it is significant that practically none of the cellular carbon was derived from these compounds. Experimental results gave molar growth yields from 8.3 to 11 g. cells per mole of ATP synthesized (dry weight basis).

Theoretical Considerations

It has been well established that chemoorganotrophic bacteria growing under aerobic conditions obtain energy for synthesis* from the oxidation of substrate. Since free energy change is a measure of the maximum work which a process may do, it seems logical to postulate that the quantity of cell

*The term synthesis will be used throughout this paper to signify gross synthetic yields or gross production of cell mass. That is to say, synthesis is taken to mean conversion of substrate to cell tissue exclusive of endogenous metabolism.

tissue synthesized (work done) per unit of substrate utilized should be related to the substrate free energy of oxidation. The biological process to which the postulate refers is described as



Energy is transferred from the catabolic to the anabolic processes in the cell via chemical bonds, principally the phosphate anhydride bonds of adenosine triphosphate (ATP). Now, if an organic compound serves the dual role of energy and carbon source, as shown in (1), then synthesis of cell tissue must occur from both the substrate and the intermediates formed during its catabolism.

The initial steps in different catabolic pathways are principally hydrolytic in nature, as shown in Phase I of Figure 1, and little energy is released in them. However, in later steps where the pathways converge into a system of common intermediate compounds, most of the free energy of substrate oxidation is released; about one-third in Phase II and two-thirds in Phase III⁽¹⁰⁾. It is assumed therefore that since synthesis and energy production will begin with intermediates which are common to most substrates, that in general the yield of cell tissue should be proportional to the amount of energy available for synthesis from oxidation of a unit of substrate. Assuming ATP production as a measure of this energy

$$Y = k_1 N_{\text{ATP}} \quad (2)$$

where

Y is the synthesis in grams of cell tissue per mole of substrate utilized

k_1 is a constant of proportionality having units of grams per mole of ATP

N_{ATP} is energy made available during catabolism of one mole of substrate expressed as moles of ATP

If ATP production is proportional to the free energy released from substrate oxidation, that is

$$N_{\text{ATP}} = -k_2 \Delta F_{\text{ox}}^{\circ} \quad (3)$$

then synthesis yields could be related directly to free energy, as

postulated, by the following equation

$$Y = -k_1 k_2 \Delta F_{ox}^o \quad (4)$$

Note: ΔF_{ox}^o was used because it varies only slightly from ΔF_{ox} for physiological concentrations of CO_2 , H_2O , O_2 , and substrate. For example, with 0.2 atm. O_2 , 0.05 atm. CO_2 , 0.01 M glucose; $\Delta F_{ox} = -688.5$ k-cal, while $\Delta F_{ox}^o = -686$ k-cal.

Equation (4) says that the more energy obtainable from a substrate, the more synthesis which can be performed.

Whether or not Eq. (3) is a reasonable hypothesis may be found by calculating k_2 values as shown in Table II for organics whose catabolic pathways are known. For purposes of illustration, the oxidative phosphorylation quotient was taken as three; thus three ATP are formed for each DPNH.

Limited evidence ⁽⁹⁾ indicates that Eq. (2) holds for some pure yeast and bacterial cultures grown anaerobically on complex media with a single compound serving as energy source.

Substrate Oxidation

As represented in Eq. (1), some of the substrate carbon will be oxidized to CO_2 and H_2O . The fraction oxidized (f_o) is related to the fraction utilized in cell synthesis (f_s) by

$$f_o = 1 - f_s \quad (5)$$

while

$$f_s = \frac{1}{C} \frac{C_c Y}{MW \text{ carbon}} \quad (6)$$

where

Y is the synthetic yield in grams cells/mole substrate

C_c is the fraction by weight of carbon in cells

C is the moles of carbon per mole of substrate

Substituting (4) for Y and putting (6) in (5)

$$f_o = 1 + \frac{C_c k_1 k_2}{12} \left[\frac{\Delta F_{ox}^o}{C} \right] \quad (7)$$

Assuming C_c as nearly constant for activated sludge, it is seen that the fraction of substrate oxidized is dependent upon its free energy of oxidation and carbon content.

Multiple Substrates

Seldom in sanitary engineering practice is a waste encountered which consists of a single organic compound. If it is hypothesized that each compound in a waste consisting of several organics causes a growth yield equal to that when it is alone, Eq. (4) takes the form

$$Y = -k_1 k_2 \frac{\sum M \Delta F_{ox}^o}{\sum M} \quad (8)$$

Likewise, Eq. (7) becomes

$$f_o = 1 + \frac{C_c k_1 k_2}{12} \left[\frac{\sum M \Delta F_{ox}^o}{\sum CM} \right] \quad (9)$$

Equations (8) and (9) are the general forms of (4) and (7).

Free Energy of Oxidation and Chemical Oxygen Demand

Although Eqs. (8) and (9) relate growth and oxygen demand to ΔF_{ox}^o , seldom is free energy of oxidation known for a waste. Fortunately, ΔF_{ox}^o and the theoretical chemical oxygen demand (Z)* are proportional for many compounds, as shown in Table III, thus

$$\Delta F_{ox}^o = -116 Z \text{ (Group I, carbohydrates, etc.)} \quad (10)$$

$$\text{and } \Delta F_{ox}^o = -104 Z \text{ (Group II, aromatics, etc.)} \quad (11)$$

Equation (10) applies to carbohydrates and Kreb's Cycle intermediates, while (11) applies to aliphatics and aromatics. By substitution of the above equations into (8) and (9), Y and f become dependent upon Z. Of course, the more familiar COD^o

*Theoretical chemical oxygen demand is the moles of molecular oxygen required to oxidize one mole of a compound to CO_2 and N_2O . Amino nitrogen is assumed converted to ammonia and nitrogen to HNO_3 .

(g. O_2 /mole) could be employed by substituting $COD = 32Z$.

RESULTS

If biological synthesis is primarily a function of substrate ΔF^{ox} , there should be a consistent relationship between synthesis and ΔF^{ox} as described by Eq. (8). In order to check this hypothesis, experiments were conducted wherein activated sludge growth and oxygen uptake were measured during metabolism of different organic compounds. In addition, the literature was examined for data describing the synthesis resulting from metabolism of known amounts of specific compounds.

Experimental Results

Activated sludges started from soil and sewage inoculums were grown on each of the substrates to be tested until substantial quantities of sludge were obtained. This sludge, harvested by centrifuging, was used to set up simultaneously two or more identical culture dilutions, each fed a different amount of substrate. Growth was followed by means of a Fisher photometer (Figure 2) and, when complete aliquots were analyzed for sludge concentration, a millipore filter or gooch crucible with asbestos mat being used. Differences in sludge concentration when growth was completed represented synthesis due to differences in initial substrate concentration (9)(11)(12).

The fraction of substrate oxidized was determined by a Warburg respirometer using 20 ml aliquots taken from the growth cultures. The ratio of net oxygen uptake to theoretical COD was taken as f_o . Experimental results are recorded in Table IV, and the relationship between Y and $\Sigma M \Delta F_{ox}^{ox} / \Sigma M$ is shown in Figure 3, while f_o and $\Sigma M \Delta F_{ox}^{ox} / \Sigma CM$ are in Figure 4. Regression analysis of the data in Figure 3 gave a slope of 0.108 g. cells/k-cal for the line of best fit.

The values of C_c reported in Table IV were computed from Eq. (9) using the measured values of f_o and Y for each experiment. The average value of C_c is 0.52, and it agrees well with those reported in Table V. The data in Figure 4 show some scatter, as might be expected since not all points were on the line in Figure 3. The slope of the line drawn in Figure 4 was determined by using $k_1 k_2 = 0.108$ g. cells/k-cal and an average C_c of 0.52.

Published Results

Siegel and Clifton⁽⁶⁾ studied the metabolic response of *E. coli* to several substrates. Each substrate was employed as the sole source of organic carbon, and cultures were allowed 16 hours for adaption before the experiment was performed. Data were reported as the ratio of carbon converted to cell tissue versus total carbon utilized. Therefore, in order to examine the relationship between Y and ΔF_{ox}^o defined by these data, the yields of cell tissue carbon had to be converted to cell mass and the total carbon utilized converted to moles of substrate.

A cell carbon content of 50 percent (dry weight)¹²⁻¹⁶ was assumed. Although accuracy in selecting a carbon content values does not affect linearity between ΔF_{ox}^o and Y , it can, of course, influence comparison with other investigators' results. In order of increasing $-\Delta F_{ox}^o$, the substrates were pyruvic acid, fumaric acid, succinic acid, glycerol, arabinose, glucose, and lactose.

McKinney, et al⁽¹⁷⁾ have reported on the metabolism of a large number of compounds by an activated sludge grown on phenol. Each compound was employed as the sole source of organic carbon, and the metabolism was followed by means of a Warburg respirometer. Except for phenol the activated sludge had no prior contact with the organics studied. Most of the substrates were readily metabolized; a few showing the effect of insufficient adaptation were slowly or partially degraded and therefore were excluded from the following analysis.

Molar growth yields were computed from McKinney's Warburg data by assuming that oxygen consumption represented the fraction of the initial substrate oxidized to CO_2 and H_2O . The unoxidized substrate fraction was considered converted to protoplasm. The total mass synthesized was calculated on the basis of substrate carbon converted to activated sludge and on the estimated carbon content of the activated sludge. A number of empirical formulae have been published describing the macro-chemical composition of activated sludge, as shown in Table V. According to these data the average carbon content of dried activated sludge may be taken as 51 percent. The relationship between Y and ΔF_{ox}^o is shown in Figure 6. Fatty acids, Krebs' Cycle intermediates, aromatics, carbohydrates, and amino acids are represented.

Agreement of Results

Synthesis yields calculated from the data of Siegel and Clifton (an E. coli culture) agree well with those measured in this laboratory (acclimated activated sludges). In addition, other reports from the literature indicate good agreement. Herbert (21)(22) found molar growth yields on glycerol of 48.2 and 45 g. cells/mole, respectively, for aerobic cultures of A. cloacae and A. aerogenes. Hoover and Allison⁽¹⁶⁾ obtained 142 g. cells/mole when Rhizobium was grown aerobically with sucrose as carbon and energy source.

By contrast, McKinney's data indicate apparently higher yields and also a difference in yields from carbohydrates and glycolysis products on the one hand and acids and aromatics on the other. The absolute value of these data is uncertain because the substrate was added to the activated sludge before measurement of O_2 uptake commenced, thereby introducing an uncertain variable in O_2 consumption data.

In spite of any differences between sets of data, there was a consistent linearity between growth yield and ΔF_{ox}^0 . The available evidence supports the hypothesis advanced earlier that synthesis Y is proportional to the free energy of substrate oxidation ΔF_{ox}^0 .

DISCUSSION

The results can be helpful in explaining some of the activated sludge design parameters which have been presented in the sanitary engineering literature.

COD and Substrate Metabolism

Using Eqs. (10) and (11), $k_1 k_2 = 0.108$ g. cells/k-cal and the fact that $COD = 32Z$, the following relationships are obtained from Eq. (4):

$$Y = 0.39 \text{ COD (Group I, carbohydrates, etc.)} \quad (12)$$

$$Y = 0.35 \text{ COD (Group II, aromatics, aliphatics, etc.)} \quad (13)$$

where y is g. cells/mole substrate and COD is the theoretical chemical oxygen demand of the substrate in g. O_2 /mole. Equations (12) and (13) indicate yields of 0.39 and 0.35 g. cells/g. COD. In contrast to these values, McKinney⁽²³⁾ asserts that

the value of 0.47 g. VSS/g. COD should apply to the metabolism of substrates by activated sludge. However, he assumed in his computation that one-third of the substrate COD was exerted. Such an assumption requires f_o to be constant. But, as seen in Figure 4 and Table IV, f_o is a variable. By substituting Eqs. (10) and (11) into Eq. (7), expressing COD as 32Z, and setting $C_c = 0.515$, the following definitions of f_o were obtained:

$$f_o = 1 - 0.017 \frac{\text{COD}}{C} \quad (\text{Group I, carbohydrates, etc.}) \quad (14)$$

$$f_o = 1 - 0.015 \frac{\text{COD}}{C} \quad (\text{Group II, aromatics, aliphatics, etc.}) \quad (15)$$

and for most application in practice f_o should be adequately defined as

$$f_o = 1 - 0.016 \frac{\text{COD}}{C} \quad (16)$$

Synthesis and BOD

As mentioned earlier, some investigators have related activated sludge synthesis to waste BOD by a sludge yield coefficient. It can be shown that a yield coefficient based upon substrate BOD would not be a constant, as Eckenfelder and McCabe (1) found by experiment. To illustrate, if BOD/COD were constant, substitution for COD in (12) and (13) would show Y as a constant proportion of BOD. However, BOD/COD is actually f_o , which is a variable fraction of the COD as shown in Eqs. (14) and (15). Therefore a yield coefficient based upon BOD would be a variable.

It is important to note that the range of $-\Sigma M \Delta F_{ox}^o / \Sigma CM$ in Figure 4 is limited to an approximate minimum of 83.3 (fumaric acid) and a maximum of 136 (glycerol). Most compounds studied by investigators of activated sludge metabolism fall near the middle of the range (110 to 115) and of course most mixtures would fall near the middle. It is for this reason that many investigators have found apparently constant sludge yield coefficients (based upon BOD) and fractions oxidized. For example, casein and lactose, quite different compounds from which Hoover, et al⁽²⁴⁾ concluded that nearly one-third of the COD was exerted, have $-\Sigma M \Delta F_{ox}^o / \Sigma CM$ equal to about 115.

SUMMARY

The purpose of this paper was to develop a rational basis for understanding the conversion of substrate to cell tissue in activated sludge. Considering free energy change as a measure of the maximum work which a process may do, activated sludge synthesis was shown to be dependent upon the free energy of oxidation of the substrate. The concept was extended to show how synthesis and the fraction of substrate oxidized varied with theoretical COD. The relationships obtained were used to explain various cell growth and substrate oxidation values reported in the sanitary engineering literature.

CONCLUSIONS

1. Synthesis of bacteria and activated sludge is directly proportional to the free energy of oxidation of the substrate; that is, $Y = -k_1 k_2 \frac{\sum M \Delta F^{\circ}}{Q_x} / \sum M$, and the constant of proportionality is on the order of 10^{-1} g. cells/k-cal.

2. Synthesis also is proportional to COD and can be defined by an equation of the form $Y = k \text{ COD}$.

3. The fraction of substrate oxidized to carbon dioxide and water is proportional to its COD, carbon content, and chemical nature, and is defined by the equation $f_o = 1 - k \frac{\text{COD}}{C}$ where the constant is on the order of 10^{-2} .

4. A sludge yield coefficient based upon substrate BOD would not be a general constant and, in addition, exertion of a constant fraction of the substrate theoretical COD is not generally applicable.

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Table I. Substrate Yield Coefficients

Waste	Lb VSS/Lb BOD	
	Removed	Investigator
Sulfite waste liquor	0.5	Sawyer ⁽⁴⁾
Cotton Kiering liquor	"	"
Reg rope	"	"
Brewery	"	"
Domestic sewage	"	Heukelekian, et al ⁽²⁾
Jute cook liquor	"	Heukelekian & Gellman ⁽³⁾
Yeast waste	"	" "
Gum waste	"	" "
Boardmill white water	"	" "
Domestic sewage and glucose	0.35	Wuhrman ⁽⁵⁾
Spent sulfite liquor	0.55	Eckenfelder & McCabe ⁽¹⁾
Synthetic fibre	0.38	" "
Pulp and paper*	0.76	" "
Refinery [†]	0.70	" "
Brewery	0.93	" "
Pharmaceutical [‡]	0.77	" "

*Wastes from waste-paper repulping and semichemical processing.

[†]Phenolic waste water.

[‡]Penicillin and fine chemical wastes.

Table II. N_{ATP} , $\Delta F_{\text{ox}}^{\circ}$, and k_2 for Various Organics*†

Organic	N_{ATP}	$\Delta F_{\text{ox}}^{\circ}$ k cal/mole	k_2	Ref for N_{ATP}
Glucose	38	- 687	0.055	26
Fumaric acid	18	- 333	0.054	27
Pyruvic acid	15	- 282	0.053	26
Butyric acid	28	- 514	0.055	26
Glutamic acid	26	- 475	0.055	27
Lactic acid	18	- 340	0.053	27
Succinic acid	20	- 369	0.054	27
Lactose	76	- 1,381	0.055	7
Glycerol	22	- 407	0.054	28

*Production of ATP and $\Delta F_{\text{ox}}^{\circ}$ are for oxidation by O_2 to CO_2 , H_2O , and NH_3 .

†The phosphorylation quotient of DPNH was taken as 3; thus $\text{DPNH} = 3 \text{ ATP}$.

Table III. Free Energy and Oxidation Data
for Several Compounds*†

Compound and Standard State	ΔF_f°	ΔF_{ox}°	Z moles O ₂	ΔF_{ox}° Z
	k cal/mole	k cal/mole	mole	Z
<u>Group I</u>				
Sucrose (S)	-371.6	-1382	12	115
Mannitol (S)	-222.2	- 740	6.5	114
Glucose (S)	-216	- 687	6	115
Arabinose (S)	-180.5	- 573	5	115
Glycerol (l)	-113.6	- 407	3.5	117
Fumaric acid (S)	-157	- 333	3	111
Lactic acid (l)	-124	- 340	3	114
Malic acid (S)	-211	- 336	3	112
Pyruvic acid (S)	-114.1	- 282	2.5	113
Methyl formate (l)	- 71	- 231	2	116
Formaldehyde (aq)	- 31	- 120	1	120
Formic acid (l)	- 85.1	- 66	0.5	132
<u>Group II</u>				
Napthalene (l)	+ 45.9	-1216	12	101
Octanoic acid (l)	- 84.6	-1124	11	102
m-xylene (l)	+ 27	-1065	10.5	101
Heptanoic (l)	- 86.2	- 973	9.5	
Toluene (l)	+ 26.5	- 914	9	102
Benzene (l)	+ 29.8	- 765	7.5	102
Nitro benzene (l)	+ 36.4	- 733	7.5	98
m-nitrobenzoic acid (S)	- 54.2	- 738	7.5	99
Benzoic acid (l)	- 59.2	- 773	7.5	103
Aniline (l)	+ 35.4	- 717	7	103
Phenol (S)	- 11.0	- 729	7	104
Pyrocatechol (S)	- 51.4	- 684	6.5	105
Resorcinol (S)	- 53.2	- 682	6.5	105
N-butyl alcohol (l)	- 40.4	- 621	6	104
Butyric acid (l)	- 91.5	- 514	5	103
Glutamic acid (S)	-170.4	- 475	4.5	106
Propionic acid (l)	- 92.1	- 360	3.5	103
Succinic acid (l)	-178.8	- 369	3.5	105
Alanine (S)	- 88.9	- 311	3	104
Acetaldehyde (l)	- 31.9	- 270	2.5	108
Acetic acid (l)	- 94.5	- 208	2	104
Glycine (S)	- 87.8	- 161	1.5	105

*Amino nitrogen converted to NH₃; nitro nitrogen converted to HNO₃

†Terminal oxidant, O₂.

Table IV. Activated Sludge Yields and Substrate Oxidation

Substrate	$-\Sigma M\Delta F_{ox}^{\circ}$	Y	$-\Sigma M\Delta F_{ox}^{\circ}$	f_o	C_c
	ΣM		ΣCM		
	k-cal mole	g. cells mole	k-cal mole carbon		
Glycine	160	14			
Acetic acid	208	22			
Alanine	312	31			
Fumaric acid	333	43	83.3	0.53	0.53
Glycerol	407	42	136	0.395	0.52
Glycerol	407	43			
Benzoic acid and alanine	443	46			
Glutamic acid	475	52			
Citric acid	512	56			
Citric acid	512	64	85.4	0.55	0.51
Benzoic acid, alanine, citric acid, glycerol, and sucrose	525	66	107.8	0.425	0.51
Benzoic acid, alanine, and sucrose	585	66	110	0.452	0.53
Benzoic acid, alanine, sorbic acid, and sucrose	621	71	113.9	0.42	0.54
Glucose	686	73			
Anthranilic acid	715	74			
Sorbic acid	748	76	124.7	0.44	0.53
Benzoic acid	771	80	110	0.52	0.50
Benzoic acid	771	82			
Benzoic acid	771	77			
Hydrocinnamic acid	1070	111	119	0.48	0.51
Hydrocinnamic acid	1070	118			
Sucrose	1381	142			

Table V. Carbon Content of Activated Sludge

Empirical Formula	Carbon Content of Formula %	Ash Content Dry Sludge %	Carbon Content Dry Sludge %	Refer- ence
$C_5H_7O_2N$	53.1	8.6	48.4	(18)
$C_7H_{10}O_3N$	53.9	1.3	53.2	(19)(4)
$C_5H_8O_2N$	52.9			(20)
$C_9N_{16}O_5N$	49.6			(20)

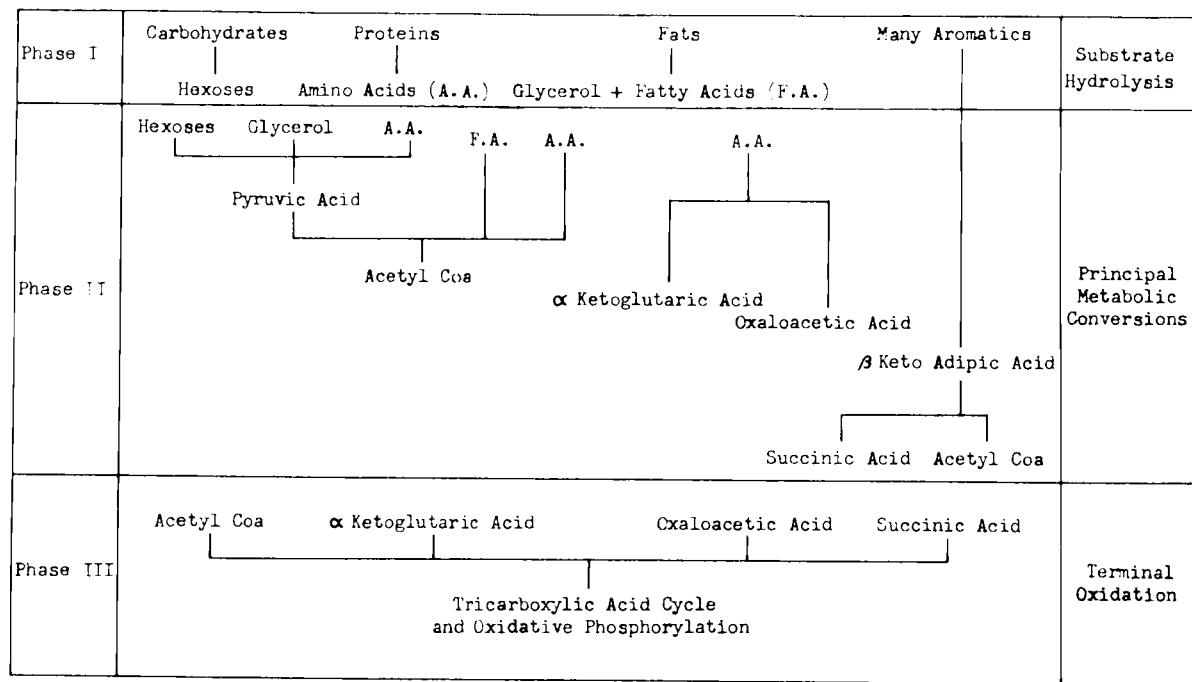


Figure 1. Major Metabolic Phases after Krebs (10) and Umbreit (25).

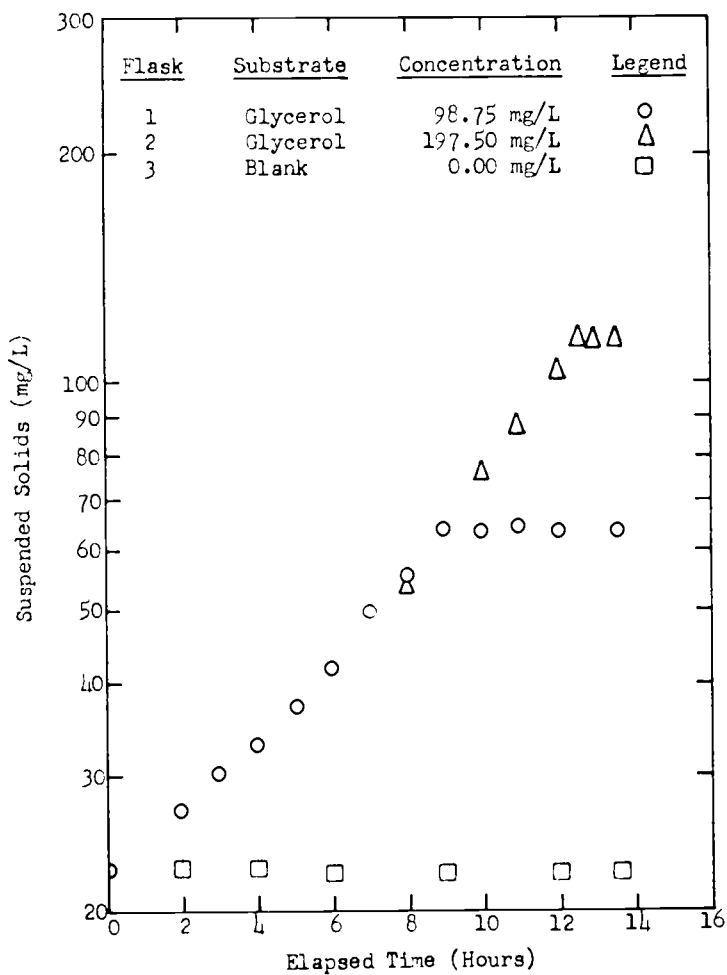


Figure 2. Activated Sludge Growth Curve.

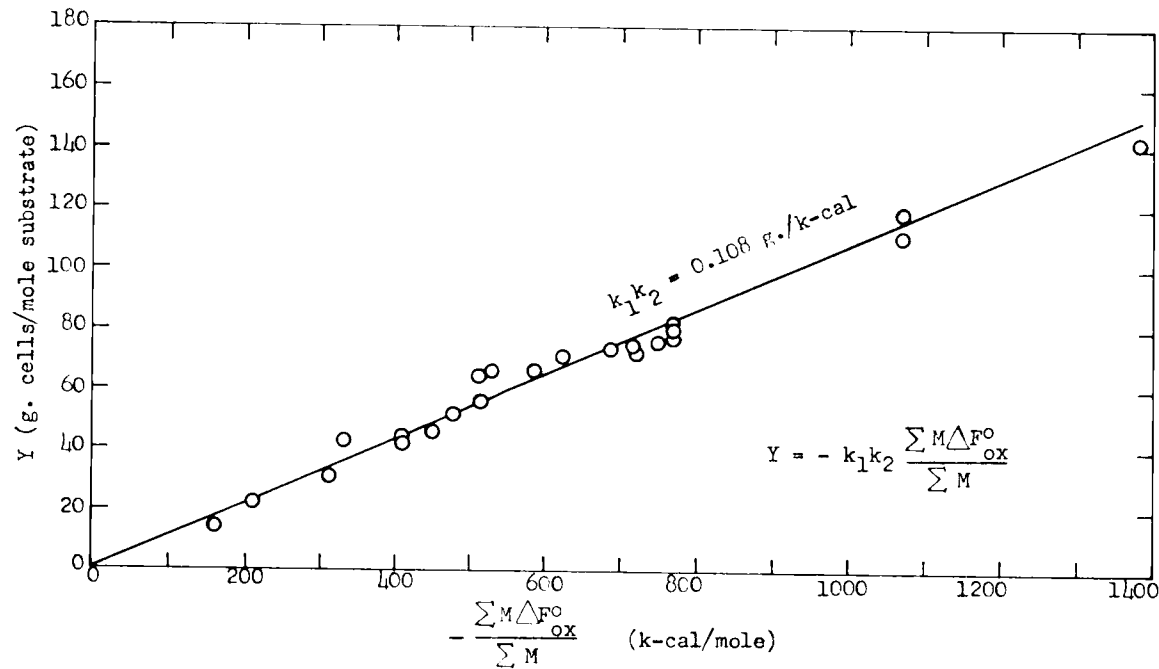


Figure 3. Molar Growth Yield of Activated Sludge as a Function of Substrate Free Energy of Oxidation.

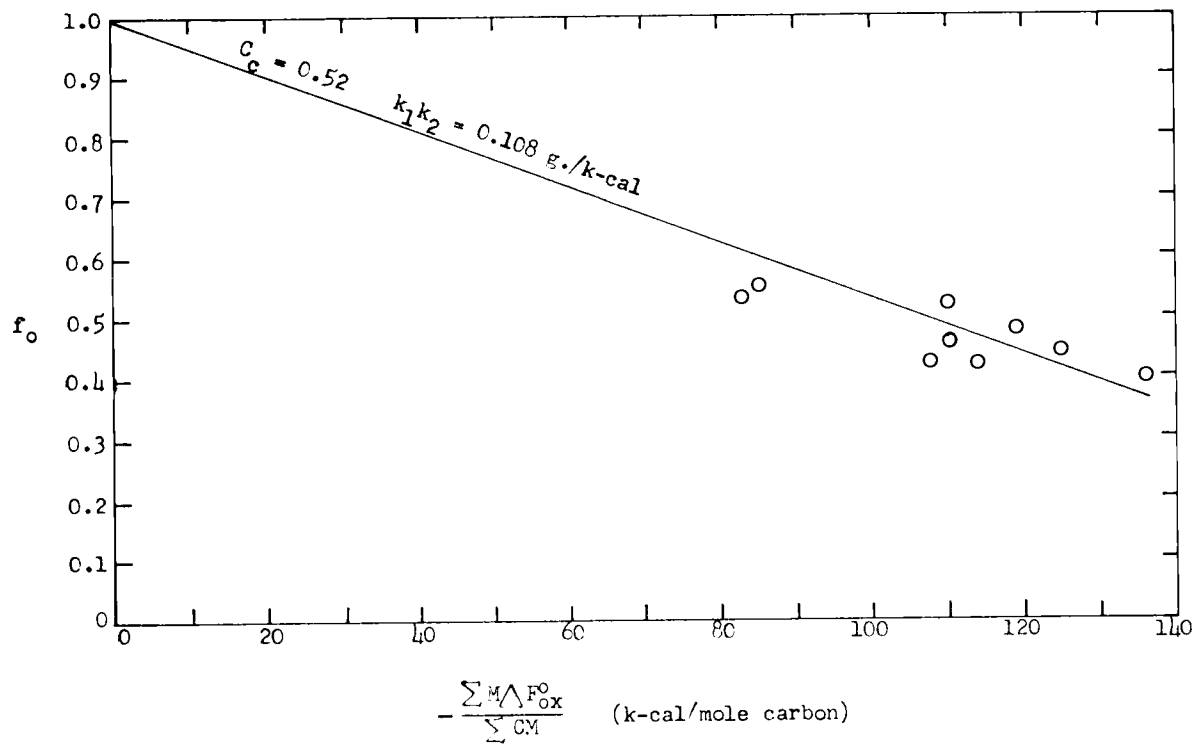


Figure 4. Fraction of Substrate Carbon Oxidized by Activated Sludge as a Function of Substrate Free Energy of Oxidation and Carbon Content.

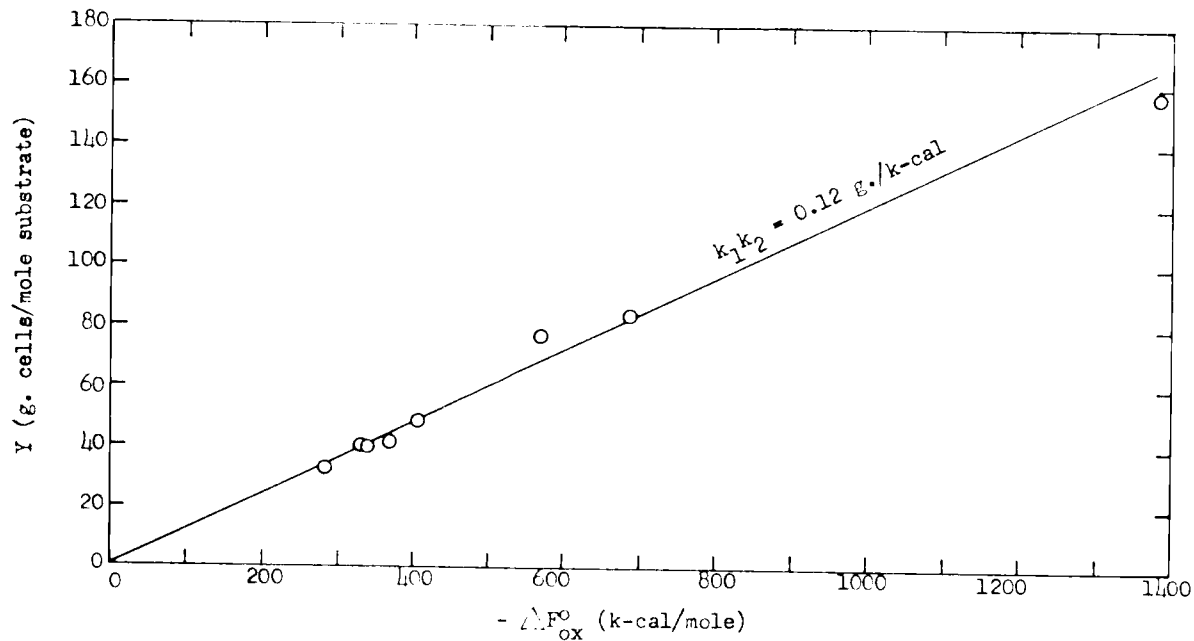


Figure 5. Molar Growth Yield of *E. Coli* as a Function of Substrate Free Energy of Oxidation. Calculated from Data of Siegel and Clifton (6a, b).

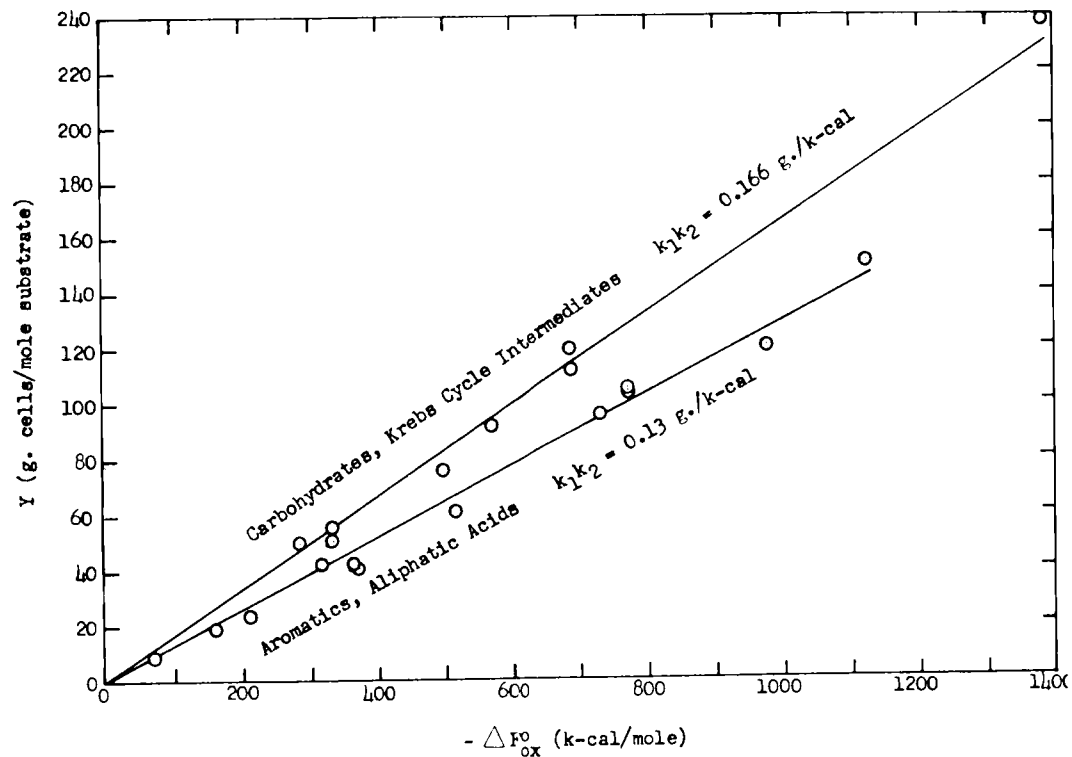


Figure 6. Molar Growth Yield of Phenol Acclimated Activated Sludge as a Function of Substrate Free Energy of Oxidation.
Calculated from Data of McKinney, et al (17).

RECOVERY OF CHLORINE FROM CHLORINE PLANT VENT GASES

Harry W. Bryson

The electrolysis of brine for the production of chlorine has developed into a big business here in the Northwest. There are five producing plants in the area, including British Columbia, and a sixth will go on stream next year.

Electrolytic chlorine cells produce a hot, wet gas. In order to transport this chlorine to the consumer the gas must be cooled, dried, and liquefied. As the cell gas contains a small percentage of other gases besides chlorine, complete liquefaction is not possible. This results in a stream of gas from the condensing equipment containing an appreciable percentage of chlorine. In industry this stream of gas is known as blow gas or sniff gas. Blow gas has been disposed of or used for the manufacture of bleach, for making muriatic acid, to chlorinate organic and inorganic compounds, and for the production of chlorine saturated water. In many areas the market for products that can be made from blow gas are limited, and it must be vented.

Today, I will discuss an economical system developed by the Hooker Chemical Corporation for the recovery of chlorine from blow gas. The process has been patented and licensed to several companies. By this system the removal of chlorine is almost complete, and the remaining gases can be neutralized or vented. The system becomes economical when there is no on-site use for the blow gas and when direct contact coolers are used. This recovery system makes it possible to build a chlorine plant anywhere in the country and meet strict air and water pollution regulations.

The hot chlorine gas direct from the cells enters the center of a direct contact cooler. This unit is a packed cooler consisting of two sections, one on top of the other. The chlorine gas flows up through the tower countercurrent to a flow of cooling water. From the cooling tower the chlorine flows to the drying towers where it is dried by strong sulfuric acid. The dry gas is next compressed and then cooled by refrigeration. At Tacoma, we operate the compressors at a pressure between 35 and 40 psig. As the chlorine is cooled under pressure it condenses and flows to storage tanks.

Besides chlorine, the stream of gas from the electrolytic cells contains small amounts of nitrogen, oxygen, hydrogen, and carbon dioxide. As the chlorine condenses the percentage of other gases in the unliquefied portion increases. The blow gas leaving the refrigerating system will run 10 or more percent chlorine, depending upon the temperature and pressure. It is the recovery of the chlorine content of this blow gas which I wish to discuss today.

The blow gas absorbing tower is a rubber-lined steel tower completely filled with ceramic packing. A tower to handle blow gas from a 250- to 300-T/D chlorine plant would be approximately 3-1/2 feet in diameter by 33 feet high. The blow gas is piped to the bottom of the packed tower recovery unit. It then works its way up the tower against a countercurrent flow of cold water. The chlorine and some carbon dioxide is absorbed in the cold water flowing down the tower, and the remaining gases are vented or neutralized.

The vent line at the top of the tower is fitted with an automatic valve which controls the tower pressure. While this valve may be set at any pressure below that of the liquefaction system, high pressure favors the complete recovery of chlorine. A typical blow gas from the chlorine condensing system might contain 15 percent chlorine, 18 percent carbon dioxide, and 4.6 percent hydrogen. The balance is nitrogen and oxygen. A typical vent gas from the scrubber contains from 0.5 - 1 percent chlorine, 18 percent carbon dioxide, and 4 percent hydrogen. The balance in this case is nitrogen, oxygen, and water vapor, most of which is added as air to dilute the mixture and limit explosion risks.

As chlorine is removed from the blow gas, the concentration of hydrogen in the remaining gases increases. An explosive mixture can result. For this reason the following safety features have been incorporated in the design of the blow gas scrubber: (1) The walls of the tower are thick enough to withstand a maximum explosive pressure which might develop. (2) The tower is completely filled with raschig rings so there are no large void spaces. This would reduce to a minimum the violence of any explosion that did start. (3) Explosion discs are installed on the unit (50 lb psi). (4) Air is introduced to the blow gas scrubbing system to dilute the gas mixture.

The scrubber or system pressure is used to force the

chlorine water out of the recovery unit and through a pipe to the top of a direct contact cooler. The cooler operates at approximately atmospheric pressure, so some of the dissolved gas flashes off as the water enters the cooler.

As mentioned before, the cooler body is divided into a cooling section and a stripping section. A disentrainment section is provided at the top of the tower. The entire tower is rubber-lined, with the cooling and stripping sections also brick-lined.

Chlorine at about 80°C enters the cooler between the cooling and stripping sections and passes upward through the cooling section. It rises upward against a countercurrent flow of cooling water or, in this case, blow gas scrubber effluent. The cooling section of the tower is packed with Intalox saddles supported by porcelain bars. The gas leaves this section and passes through the disentrainment section, leaving the tower at 15-20°C on its way to drying and compression.

As the water flows down the tower it is heated and gives up most of its chlorine picked up in the recovery unit. When chlorine is dissolved in water some of it reacts with the water to form acid. This combined chlorine cannot all be removed by heating. To liberate this combined chlorine an additive is added along with the water at the top of the cooling tower.

The bottom section of the direct contact cooler is a stripping section for final removal of the chlorine from the cooling water. Steam is injected directly into this section and heats the water to between 99 and 100°C. Under these conditions the water leaving the tower contains about 5-20 ppm chlorine. This water can then be mixed with plant cooling waters and discharged through the sewer system. The amount of water needed for dilution will depend upon its chlorine demand.

In operating the recovery unit a balance must be made between the allowable chlorine content vent, cooling water needed to cool the chlorine, and steam required to heat the effluent water. The main cost of operating the system is for steam, so it is desirable to keep this at a minimum.

The chlorine recovery system I have just described has proven very successful in our plants at Montague, Michigan;

Tacoma, Washington; and Vancouver, B.C. These units pay themselves off in chlorine saving and virtually eliminate air and water pollution problems which might be associated with chlorine manufacture.

STANDARDS BY GOVERNMENT FOR AIR AND WATER
POLLUTION AS RELATED TO THE
SMELTING AND REFINING INDUSTRY

Louis V. Olson

In many years of experience I have heard expressions of two extremes of opinion regarding the quality of our air and water. On the one hand there are advocates of a theory—or perhaps a hope—that even in our industrial age the air could be absolutely free of all objectionable contaminants, all odors except the aroma of flowers, and could be so clear that visibility would be restricted only by natural meteorological phenomena, and that all water in streams could be as pure and clear as that from a high mountain brook, if only the management of our modern industrial institutions had the public welfare foremost in mind, instead of an unremitting urge for maximum profit.

Such opinions may be expressed by men as they cook on their backyard barbecues, or ignite the trash in their incinerators, or burn dry leaves, or while driving their automobiles with cigarettes in their mouths. Housewives may express such views while pouring detergents into their washing machines or automatic dishwaters to contribute to the 4 billion pounds poured into the sewers of the nation annually to foul the treatment plants. Each is blissfully oblivious to the fact that he, too, is contaminating the air and water he believes only others, especially industrial leaders, should protect for him.

On the other extreme we are forced to admit that we had a few ruthless men in industry who would ordinarily give little thought to their contributions to the pollution of the environs without some compelling force superimposed upon what little conscience they may have possessed. For years some dissipated the valueless wastes from their processes without limit into the air or the streams, depending on the character and the convenience. They felt that they had acquired by habit the equivalent of prescriptive rights to do this and, even now, some make reasonable and necessary corrections only by force. These few cannot be convinced of the growing magnitude of the problems.

All of us who have lived a long time remember that our old swimming holes have been defiled to the extent that they are no longer attractive to the boys. This is just as well, because they certainly would not be healthful, even if the swimmers

could find a clean shower nearby to wash off the adhered filth. The fact is that some industries, especially slaughter houses, were deliberately located adjacent to streams into which their wastes could conveniently be deposited. Sewage from towns was discharged into the adjacent streams at increasing rates, evidently without fear of consequences. From many such streams fish and other aquatic life have disappeared. Potable water has become more precious, and the cost of treatment is increasing.

We know that neither of the extremes just cited can be either achieved or tolerated, but we can and should strive for the former within the limits of practicability. As long as we have our modern civilization, based to the degree that it is on metals and chemicals—as exemplified by the automobile, the television, and the airplane—and on our increasing use of energy, we cannot approach a Utopia in these respects.

Between these two extremes there are divers opinions regarding the quantity of wastes our air and streams should carry from the immediate environs. We know within reasonable limits the amounts of many types of pollutants each of these cleansing media can transport under several conditions without material degradation or physiological effects on plant and animal life. Studies in the past 25 years have increased at an accelerated rate until we have narrowed the limits of our thinking to an intermediate course of action. We are far from unanimity, but we have arrived at some agreement of practical plans of action with regard to both air and stream pollution in which we are considering the needs of the particular community, the density and growth of its population, the meteorological aspects, and the long range use of the resources "downstream."

All proposed plans and rules for the control of pollutants are bound to provoke disagreement as to what the exact criteria or standards should be. The opinions on standards, the debates on who should do the controlling—the local or the federal government—and to what degree in each case will always be subject to some disagreement. These debates, these arguments, and these studies should keep us apace with our growing technology and, therefore, our pollution potential. When we consider the vastness of these problems and the money and interests involved, we soon come to the realization that mere laws are not the complete answer or alone the solution of scientific problems.

Last summer a group of about 60 men who had spent the

larger part of their active careers in the studies of air pollution problems, met at the University of Michigan for a conference, following considerable correspondence and preparation. The purpose was to write standards to reduce and control air pollution. It soon became obvious that the most sensible way of approaching the problem was to divide into groups or committees of specialists according to their respective interest and experience, or their knowledge of the medical, agricultural, and meteorological aspects, or for their engineering ability in controls. After two days it was concluded that standards, if written, would have to be extremely broad, such as those published for the State of California. After a week the conclusion was reached that only two standards, as such, could be written in the light of present knowledge. We are still working by correspondence with the hope of substantial agreements. A publication probably will appear soon, but it will not be a manual with specific answers.

Those who attended the National Air Pollution Conference last December will, of course, remember that a large majority of the thousand who attended were opposed to federal intervention in local air pollution problems, except for the already authorized research and technical advice, and the control of some interstate aspects. There was only one speaker bold enough to enthusiastically advocate that the federal government set up standards or rules and enforce them on the federal level, although most suspected the purpose of the conference was to enhance that goal. Naturally, the solution of all local problems should be the responsibility of the community in which they originate to protect itself and its neighbors.

It is pertinent to recall that the control of both water and air pollution began—not in the legislatures, as is the tendency today—but in the courts, based on the judicial interpretation of the nuisance laws in various states. The courts tended to limit by injunction the quantity of effluents shown to be baneful or offensive to individuals or to the community. On the judge-made rules were superimposed those passed by legislatures, especially designed to protect public health. The first state laws were mostly concerned with water quality. The penalties were usually inconsequential. There followed the stricter legislation by the states, and now by the federal government, practically none of which dates back further than the end of the Second World War. Usually, commissions or districts are set up within the states and, in some cases, interstate commissions are now functioning. These have power to

limit quantities of effluents at the source, or to prescribe methods for the discharge of certain materials, such as dilutions, high stacks, temperatures, etc.

Legislation on the federal level, which had its modest beginning back in 1948, is growing into a giant, backed by the arguments of influential advocates that the states are not able to cope with their own problems, or that they don't know what is good for their citizens. It is claimed besides, that with respect to streams especially, some local problems transgress state boundaries, or are mutual in two or more states. Air pollution problems are receiving increasing regional consideration because of these mutual aspects. I heard one airline pilot in Washington make the statement that air pollutants from Salt Lake City can be visibly traced all the way to Detroit. I should say that is stretching even a smoke stream plenty far. Such exaggerations notwithstanding, the place to abate such a gross nuisance, imaginary or real, is at the source and on the local level.

With the new laws, as we would expect, come additional realms of government and greater expense to the taxpayer. Theoretically, the federal government can intervene in the pollution problems of any state only by invitation of its governor. In practice, however, federal teams have been sent into several states over the specific objection of the governors. There is an increasing tendency for federal technicians or planners to sit in on state staff meetings to advise, in order to lessen the danger of "misguidance" of state agencies or local governing bodies by local interests.

Since the 1956 amendment to the Water Act, "...there have been 18 enforcement actions, concerning 24 states, involving some 250 municipalities and about the same number of industries, as a result of which remedial action is in progress which will require the expenditure of an estimated one-half billion dollars and will affect 5,500 miles of streams."

Now, as to the numerous and particular industrial problems about which I was invited to talk: There was a time when the mining industry in the United States discharged practically all waste water without treatment into nearby streams. The products of combustion and volatile materials, together with much particulate matter in the form of ore dusts, were emitted into the ambient air. The contamination of waterways was never, until recently, considered a major problem.

Sometimes, however, tailings and copper in solution were the basis of complaint. Lead and zinc ores were washed into streams, seemingly without harm, other than the occasional clogging of some waterways.

Into the atmosphere in the United States at one time were emitted daily approximately 9,000 tons of sulfur in the form of sulfur dioxide and acid aerosols. Concurrently, there were discharged over a thousand tons of solids, principally metallic oxides and dusts from ores and fluxes. Accumulated depositions of arsenic and lead became sufficient in some local areas to be toxic to grazing animals. Sulfur dioxide released from points near the ground often bleached susceptible vegetation to distances of several miles, or even destroyed it in limited areas. Odors were often offensive in communities adjacent to smelting operations. Some lawsuits for the recovery of damages were provoked. The owners and managers of these metallurgical plants have for many years given primary consideration to the effort to develop devices and methods to prevent the escape of annoying effluents, motivated by a desire to save the by-products for the market and to prevent injury to vegetation or loss of livestock, as well as to obviate offensive odors at ground level.

So successful have been these endeavors that the discharge of sulfur dioxide from all primary smelters in the United States has been reduced to much less than half of that during those peak years, and more than 90 percent of the particulates are now recovered from the flue systems. The particulates and gases that do escape are eliminated in a much more acceptable manner. Adverse effects are now minor or absent. But there is still considerable agitation for further reduction of both the gaseous and solid effluents, especially in those areas where the populations are growing rapidly or aesthetic desires are increasing.

There are practical economic limits below which these emission rates cannot presently be reduced. In practice, quite weak sulfur dioxide cannot be economically converted to sulfuric acid under the present process and market conditions. Nor is it practical to produce liquid sulfur dioxide from weak gas for the same reasons. Therefore some sulfur dioxide must be discharged into the atmosphere, diluted as it is to but a few hundred parts per million by the time it flows from the stacks, often 600 feet above the adjacent ground level, and at temperatures several hundred degrees Fahrenheit. In some cases over 99 percent of

the solids are recovered from the flue systems of smelters. Some smoke stack "plumes" are almost invisible most of the time. To recover even a fraction of that which now escapes would require prohibitive capital investments.

The federal government has no rules or standards, *per se*, for specific air pollutants, but a few states have attempted to set limits. Standards are being developed quite rapidly for water in streams by classification, especially in the State of Pennsylvania. You are, of course, familiar with the maximum limits of various metallic pollutants which may be in potable water, if it is approved for public use. (Cu 1.0 ppm; Fe 0.3 ppm; Cd 0.01 ppm; Pb 0.05 ppm; Ag 0.05 ppm; Zn 5.0 ppm.) A few states have also set limits in the latter category.

California has developed a few broad standards by which various pollutants are categorized according to their probable adverse effects. ("California Standards for Ambient Air and Motor Vehicle Exhaust," State of California Department of Public Health, December 4, 1959.) The authorized state regional boards are, by resolution, setting precedents for permissible concentrations of various materials which may be discharged into the several bodies of water in the state, but these are far from standards; they are more of an effort to reduce or eliminate pollutants in the receiving waters within the bounds of practical economic limits.

An approach to the control of sulfur oxides has been to limit the concentrations in the stack effluents, regardless of the total volume, to 0.2 percent (e.g., Los Angeles). A more sensible approach has more recently been to limit the gas to specified ground level concentrations within restricted periods of time, with or without companion controls at the source. These limits are enforced by the use of a network of automatic monitoring devices maintained by the emitter. (Bay Area Air Pollution Control District.) There is no limit on concentrations below 0.2 ppm, and a maximum of over 1.51 ppm is permitted for not more than three minutes of each day (daylight hours). The duration of the respective periods varies with the concentration. The objective is to keep the exposure below that which might produce lesions on the most susceptible vegetation.

Restrictions of fluorine emissions have not yet been accepted as rules. However, courts have imposed limits in certain specific cases, usually determined by either recording

devices in districts surrounding industrial plants, by samples collected over long periods of time by aspiration of ambient air, or by actual analysis of the water or of vegetation which is an accumulator. These monitoring systems are sometimes combined. One part per million in potable water is acceptable—even desirable—but the level in air should be below 3 parts per billion, on the average, although there is still considerable disagreement on this. Forage is considered safe, in general, when the content is less than 35 parts per million on a dry basis, even when that forage comprises the exclusive diet of the animal over a long period of time.

The solids are, for the most part, now recovered from both smelters and refineries by the use of scrubbing devices, cyclones or multiclones, bag filters, and electrolytic precipitators, with preconditioning of the particulate matter. In many cases these devices, used singly or in combination, will remove over 99 percent of the dust burden from the flue gases. Some government agencies have set a limit for solids in the effluent gases of 0.3 grain per dry standard cubic foot, although there are a few localities in which this has been restricted to 0.2 grain. Usually, with the exception of some small operations within primary smelting plants, this limit is easily met. Superimposed on this standard is an old device—the Ringelmann chart—for estimating shades of gray, designed as it was for coal smoke. Since this indicates a percentage of opacity or obscuration, it can be used for other colors, but it is difficult to interpret in the case of white smoke, especially in fog or against clouds as a background. A shade of No. 2 is usually specified as the limit, with some exceptions. Then, as a final attempt to set standards, it is becoming the practice to limit the solid emissions to a proportion of the weight of the materials used in the various processes.

Most of the water pollution problems, especially of the copper industry, can easily be solved. They are usually minor. It so happens that most of the water taken from streams or available bodies of water is returned in the same condition after merely passing over heat exchangers. Usually such water is 5° to 10°F warmer at the outfall. The quantity and quality of the water discharged are often specified. In the State of Washington, restrictions are in general terms. Usually, the outfall depth below the surface of bodies of salt water is stated as a requirement for quick dilution.

The Selby smelter is an example of a small customs lead smelter which is now operating under quite restrictive rules to reduce air and water pollution. This plant is located on San Pablo Bay north of San Francisco, with the north side on the water's edge. Under the recent restrictive rules the many outfalls have been combined into a limited few, with installations of settling tanks. Primary sewage treatment facilities have been installed in all cases where water from toilets or bath houses is included, with adequate sewage disposal fields. Some small quantities of water are used for scrubbing operations. At certain specified points near these discharges the various metals have been limited to 0.3 ppm, with a comparable restriction for combinations of several metals. The discharges into the atmosphere are limited by the recent restrictive rules of the Bay Area Air Pollution Control Board. In spite of large expenditures and extreme care on the part of the local management, there have been minor, but unavoidable, violations. It is doubtful that a much larger primary smelter could be operated in districts where rules quite as restrictive are made and enforced.

An interesting new problem is the use of nitrates for blasting purposes. However, there is less chance of contamination of the nearby drainage water than from the same quality of ammonium nitrate used almost universally for fertilizer, and usually with few precautions. Nevertheless, there have been claims of animal poisoning when cattlemen have learned of its use and when dead animals have been found in the vicinity of mining operations. Ranchers are quite keen in their realization that excessive nitrates can be lethal to cattle and that the mining companies can be blamed for some losses. Some types of forage can accumulate sufficient quantities of nitrates to poison cattle under certain grazing conditions. This is true of forage grown on soils in which legumes have left excessive nitrate, or of limited areas into which nitrates from commercial fertilizers have accumulated in available drinking water. One and five-tenths percent nitrate on a dry basis can be lethal.

In conclusion, I should like to state that the control of pollutants in the atmosphere must be the concern of everyone. The task of promulgating rules and their enforcement should be left to local governments, because only the local residents are able to decide in accordance with their particular conditions what types of industries they wish to encourage, and to what degree they are willing to tolerate some incidental adverse circumstances to provide for their community needs—not some agency across

the continent. It is senseless to close an industry, or to impose economically impeding rules, merely because someone living in another state has found it necessary to enforce certain regulations for the purposes of that specific location.

We must remember that by two amendments to the Water Pollution Acts in 1956 and 1961, Congress granted the money and the enforcement powers to abate pollution of interstate waters. In this regard it might be of interest to some to call attention to remarks made by an assistant secretary of the Department of Health, Education, and Welfare at a recent meeting in Montreal:

"But let me make something else clear: While I use the word 'invitation' deliberately, you should be warned that I define it rather broadly. We might, for example, consider ourselves invited to start an enforcement action in your area without ever receiving a communication on the engraved stationery of the governor of your state. We might, on occasion, consider ourselves invited if we heard nothing from your state, especially when that lack of communication is matched by an equal lack of state action to meet a long-standing pollution problem of major proportions.

"So that there can be no misunderstanding, let me state it clearly: The best way to keep us out of your state is to get that pollution out of your water. If you can't, and want us to help, we will be happy to try. If you don't, we may be forced to try, even though you don't want us to."

While this is an expression of determination by a single official, it further illustrates the trend toward control from Washington. Pollution must be curtailed to the degree that we can depend on the quality and the safety of the water we drink and the air we breathe. Both must be free of contaminants baneful to health or offensive to the senses. That does not mean that we should be alarmed by every unpleasant odor that may momentarily be perceptible in our modern way of life, or that we may expect to safely drink from every stream.

Controls are expensive; they should be patterned by the community or district to fit the needs of the community or district, and to protect neighboring communities from their wastes. Individual and collective indifference to these problems can no longer be tolerated in our rapidly growing cities and towns. The responsibility must be that of every citizen. There is no

question but that industrial management is very much concerned with the public welfare and is sensitive to public opinion, and that it accepts its responsibility to reduce air and water pollution in every practical way in every community in which it has operations. Its employees and its neighbors must also realize that they must not indiscriminately put their "garbage" into the air or streams and then try to console themselves with the delusion that industry is responsible for it all.

A PROGRAM TO REDUCE THE KRAFT EFFLUENT ODORS IN RECEIVING WATERS

C. Edward Taylor

In the production of kraft pulp we normally associate odor problems with the gaseous emissions at the plant site. However, the Georgia-Pacific mill at Toledo, Oregon, encountered a very unique odor problem arising from the liquid effluent discharge about 8 miles from the mill. Although we have some unusual circumstances governing effluent disposal, we believe that our work in minimizing odor will find application in other areas.

First let me review our geographical location and the salient features of our water system. The mill is located on the Yaquina River approximately 8 miles from the Pacific Ocean and the town of Newport. Because of the aquatic life in Yaquina Bay and the very low river flow during the summer, we are not permitted to discharge any contaminated effluent into the river. An effluent line was installed all the way from the mill across country to Newport, through the center of the town, across the beach, and into the ocean beyond low tide. Just before expansion of the mill to our present 600 tons/day capacity in 1960, a second pipeline was installed, the outfall was extended about 250 feet, and a diffuser attached at the end of the lines. The surf in the discharge area is extremely rough, and the cost of further extension was prohibitive. The entire pumping system cost approximately 1-1/2 million dollars. We maintain a tight water system and discharge only about 5-1/2 million gallons per day, containing all the various mill contaminants, or about 10,000 gallons per ton of pulp.

We believed that a possible water pollution problem in Yaquina Bay was avoided by the installation of the effluent line to the ocean and that there would be no problems. Much to our consternation, however, when the warm effluent hit the cold, concentrated salt water the wave action released all the malodors into the air blowing through the residential and tourist areas of Newport. By normal standards our effluent losses were low—equivalent saltcake loss was 40 to 60 lb per ton of pulp, and the 5-day BOD was about 17 to 25 lb per ton of pulp; yet the concentration of the sulfur components released at the outfall was high enough to cause objectionable odors.

Our initial approach toward reducing the odors was to

employ some of the conventional methods utilized by other kraft mills:

1. We had in operation a 10-acre lagoon at the mill site to allow for maximum dilution of liquor spills, cooling, and some absorption of oxygen from the atmosphere. Retention time was roughly 2 to 3 days. The "cooling" of the effluent was out of consideration for the second waste line which could tolerate a water temperature of no more than 100°F.

2. A turpentine recovery system was installed to keep the turpentine from the pulping process out of the effluent.

3. The green liquor dregs were retained in the system to reduce the sulfide content.

4. Wherever possible, floor drains around the washers and other vulnerable areas were connected to process tanks to keep liquor and stock out of the sewers.

5. Chlorine injectors were installed in three locations to oxidize the odor components. We use surface condensers on the multiple effect evaporators to pull vacuum, and the condensates from the last effect have a high odor level. These condensates are mixed with the overflow from the blow heat accumulator and chlorinated before flowing to the sewer. (As a means of identification in our mill, the condensate from the last effect is termed "tail water" while the accumulated condensate from bodies 6 through 2 is called "contaminated hot water." The contaminated hot water is used as wash water in the causticizing process.) Chlorine can be added also to the total effluent entering the ocean pumps at the mill and to the total effluent in the lines at Newport just before discharge. Up to 100,000 lb of chlorine per month were used for odor reduction.

After all these steps were taken the objectionable odors were reduced some in Newport, but the problem was still far from being satisfactorily solved. We could have resorted to either stabilization of the effluent or extension of the effluent line to deep water, but either step would cost roughly 1 million to 1-1/2 million dollars.

We knew that there were unstable sulfur components in the effluent, and we suspected that anaerobic bacterial action in the lagoons magnified the problem through generation of hydrogen

sulfide. At this point we decided to take a new approach.

Our own laboratory and pilot plant tests proved to us that aeration could dramatically reduce the odor of the effluent.

We endeavored to develop a combination of aeration systems which would not require operators, would be reliable, and would be economical. Rather than relying on complete oxidation in a single operation, we have employed three types of installations to treat the effluent in steps.

One effective means of obtaining good oxygen transfer is through the use of an open cooling tower, which also reduces the effluent temperature (Figure 1). These units can be used whenever the water is discharged from an elevated tank, and pumping costs are not encountered. We installed two cooling towers, one 40-foot unit on the overflow from the blow heat accumulator and one 15-foot unit on the excess evaporator condensates not required for mud washing.

A second type of unit is an aeration trough which can easily be made at any mill. Salvage stainless steel washer wire is used to form a false bottom on a trough, air is introduced uniformly beneath the wire, and water flows above the wire. The air is broken into fine bubbles passing through the wire and up through the water. Since there is only a head of a few inches of water, a fan or other source of low pressure air can be used. We utilized the air discharged from Nash vacuum pumps, which are constantly operating on other installations. Aeration troughs were installed on the tail waters from the evaporator hot wells and the excess contaminated hot water not required in liquor making.

The third aeration unit employed is the Infilco Vortair. We have two 40-hp units located in our lagoons (Figures 2 and 4). These surface aerators can be mounted on a stationary platform or on a raft for flexibility. Basically, the unit consists of a 9-foot diameter steel turbine type agitator mounted horizontally at the water surface. There are 2-inch holes behind each turbine blade. As the rotor turns, air is drawn down through the hole, where it is broken up into very fine bubbles. Our ponds are well agitated. The aerators are rated to introduce 2 to 4 tons of dissolved oxygen per day to the effluent.

As mentioned earlier, we suspected that our lagoons were adding to the odor problem. Tests proved that we had a

significant increase in sulfides during the three days while the effluent passed through the lagoons. However, the cooling towers lowered the effluent temperature to about 100°F, which was below the design limit on our pipe line, and the lagoons were no longer required for cooling. We were then able to cut down our lagoon system to two small ponds, with an aerator in each pond. We are now aerating for about 8 hours, and anaerobic bacterial activity is avoided.

In dealing with odor problems associated with effluent, special analytical techniques are required to characterize the important chemical constituents. Rather than go into any detail, I would like to cite a few methods we have found useful:

1. Odor evaluated at minimum effluent concentration at which odor can be detected in sea water.
2. Oxygen demand by iodine titration.
3. Sulfides and mercaptans determined by potentiometric titration with silver nitrate.
4. Sulfides by bromide-bromate titration.
5. Sulfides by precipitation from zinc acetate solution.

We found that a combination of the tests was required in order to obtain significant results, rather than relying on a single method. The aeration equipment we have installed has cut the concentration of the odor components to a fraction of their original value, as evidenced by the fact that the apparent oxygen demand of the effluent leaving the mill has decreased from about 40 ppm to almost 0.

Of course the important question was the reduction of odor release at Newport because the state controlling agency set a deadline of June 1, 1962, to abate the odor nuisance. Our results were more dramatic in Newport than indicated by our analytical procedures. Since completion of our equipment, only occasional trace odors have been detected in the immediate area of the outfall.

You may be interested in our monitoring program. We have maintained an "odor patrol" in the Newport area at least three times daily to make personal observations. In addition, we have employed two lead-tape-odor-recording instruments operating continuously north and south of the outfall. A metered amount of air is drawn through lead acetate-treated paper

which reacts with hydrogen sulfide, methyl mercaptan, and possibly other sulfur compounds. The darkening of the tapes is a measure of the gas concentration which can be determined in parts per billion. The best index of the success of our odor control program is the reduction in the number of hours indicating odor on our instruments. During August 1961, 295 hours of odor exposure were recorded, in August 1962, zero hours of exposure were recorded. (Note: The very costly addition of chlorine to the effluent was discontinued last October without adverse effects, and has not been resumed.)

We have had many complimentary comments from Newport residents on the success of our program. We even received a letter of congratulations from the Newport Chamber of Commerce.

You may wonder if we have merely transferred the odor problem from Newport to our mill site and the adjacent town of Toledo. We are sure this is not the case. Granted, some odor is detectable in the vapors next to the cooling towers and aeration troughs, but a few feet downwind the increase in odor level in comparison to the general background odors is negligible. Around our lagoons the odor is most likely reduced because there is no release of hydrogen sulfide from bacterial action. We believe that the odor compounds are predominantly oxidized and not merely stripped from solution.

Our objective was to reduce our kraft effluent odors in the receiving waters. We found that dissolved oxygen derived from the air is very effective and economical in stabilizing the complex combination of odor compounds. Lagoons are effective in mixing effluent and providing some stabilization of the BOD, but they must be kept aerated to avoid odor buildup. Our problem has been solved through a combination of exploratory studies, installation of adequate equipment, and finally, good operation and supervision, geared toward minimum chemical losses.

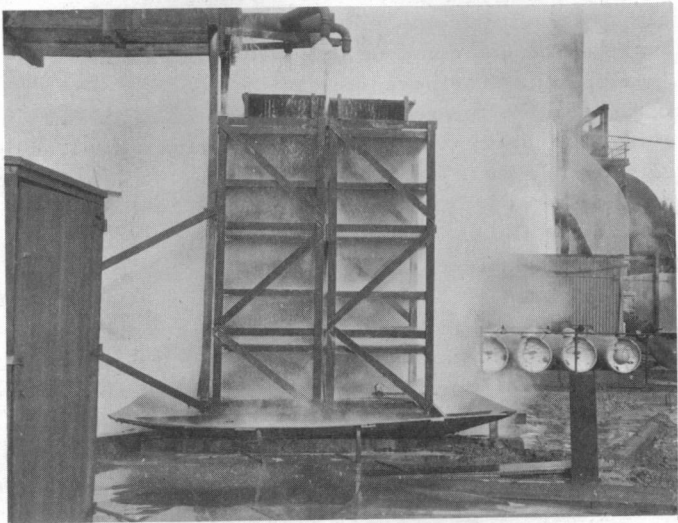


Figure 1. Cooling Tower



Figure 2. Platform-Mounted Aerator



Figure 3. Platform-Mounted Aerator



Figure 4. Aerators Located in Separate Small Lagoons

HYDRAULIC BARKER EFFLUENT CLARIFIER
AT WOOD PRODUCTS DIVISION
WEYERHAEUSER COMPANY, EVERETT, WASHINGTON

R. E. Draper and F. S. Mercier

When the Weyerhaeuser Company built the Everett kraft mill to better utilize the waste wood from Mills "B" and "C," it was found economically desirable to install hydraulic barkers at both of the sawmills. Since these mills are located on the mouth of the Snohomish River, a tidal estuary, the most logical place to receive the effluent from the barkers was the river. These waters, of course, are under the jurisdiction of the Washington State Pollution Control Commission and, as it was desired in 1957 to obtain a permanent permit to dispose of the effluents, a system had to be designed to reduce the suspended solids to the acceptable limits of 225 ppm SCS before the effluents reached the river. This paper discusses the design of such a system.

It should be noted at this point that, while the systems for the two mills are completely separate, they are identical in all but one respect. Therefore, this will deal mainly with the system installed at Mill "C."

Figure 1 shows the flow of the effluent and wastes through the Mill "C" clarifier system.

The hydraulic barker, which is a Bellingham type, uses 900 gpm of fresh filtered river water for debarking the logs. The water and debris from the barker operation drops directly into a herringbone grizzle screen bottom hopper through which a bar chain conveyor runs. The screens have 3/8-inch slots, and the larger wood and bark pieces that will not pass through them are conveyed out of the hopper into the hog and used for fuel. The effluent which passes through the grizzle screens is flumed to a head box and distributed over three Link-Belt Company horizontal vibrating screens.

Each of the vibrating screens is covered with a 16-gauge, type 302 stainless steel plate. The plate has 0.085-inch diameter holes staggered on 5/32-inch centers. The screenings are dropped off the ends of the screens into a waste conveyor which takes them directly into the powerhouse fuel system, while the effluent is piped by gravity flow to the clarifier. At this point the total suspended solids have been reduced to 2,000 parts per million or

less.

The Dorr-Oliver clarifier is 45 feet in diameter and has a volume of 12,700 cubic feet. This gives a retention time of approximately 120 minutes at the rate of 900 gpm of effluent. The effluent is discharged directly in the center of the clarifier. The concrete bottom has a 12 to 1 slope from the outer perimeter to the center. In one section of the bottom, near the center, is a sludge basin. Mounted on the center feed column is a motor-driven arm extending from the center to the edge of the clarifier. This arm has four pieces welded to it at 45° angle to act as a worm and rake the sludge into the sludge basin as it settles out. The arm rotates at about three revolutions per hour. The same drive mechanism also powers a skimmer blade on the surface. This moves all the buoyant particles to a scum trough and into the scum pit. The clarified effluent is allowed to overflow over a launder with weir-shaped openings into a circumferential trough from where it flows to the river.

The sludge is removed from the sludge pit continuously, using an air-and-vacuum operated diaphragm pump. This is controlled by a timing circuit, and the capacity of the pump can be adjusted to the volume of sludge to be filtered. The sludge is discharged into the vat of a dewatering filter.

The handling of the skimmings is the one point where the systems at the two mills differ. At Mill "B" the skimmings are pumped with another diaphragm pump directly into the main sludge line, while at Mill "C" they are carried by a conveyor over a dewatering screen and dumped into the disposal conveyor. The water in the scum pit is controlled by level and periodically is automatically pumped back into the clarifier feed line.

The dewatering filter is a three-element vacuum disc type with approximately 65 square feet of filtering area. Each element is divided into eight sections and the faces of each section are covered with 100-mesh stainless steel screen. The elements are rotated through the sludge effluent in the vat by an electrical variable speed drive with a 3 to 1 speed adjustment. A vacuum of approximately 15 inches of water is provided by a Roots-type vacuum pump driven by a 15 hp motor.

About 45 percent of the elements are submerged in the sludge effluent. As the discs rotate, the vacuum draws the suspended solids against the screens, forming a cake. The water that is drawn through the filter is separated in a vacuum

receiver and returned to the clarifier feed line by a 1-1/4 inch centrifugal filtrate pump. The caked solids adhering to the rotating filter discs are continuously removed by scrapers and drop into a box link conveyor to be taken to the disposal area. The material as it comes off the filters is approximately 30 percent solids, and at this consistency can be moved easily by either belt or chain conveyor.

As previously stated, the effluent from the horizontal vibrating screens contains about 2,000 parts per million of suspended solids. Sedimentation tests run repeatedly on the effluent at this point have given the sedimentation rates shown graphically in Figure 2.

This shows a rate of 76 percent in 5 minutes, 85 percent in 20 minutes, and 88 percent in 60 minutes. These results indicate that the retention time of 120 minutes which has been provided is more than adequate to provide the necessary reduction in solids. Tests taken on the clarified effluent show consistently an average of under 200 parts per million suspended combustible solids, which is lower than the 225 parts per million maximum set by the Pollution Control Commission.

These clarifier systems have been in service at the Wood Products Division of the Weyerhaeuser Company in Everett for the past five years. They have proven to be an efficient means of reducing the solids content of the hydraulic barker effluents to a satisfactory level for disposal in the adjacent waters. In addition, they have required a minimum of operational attention and have provided virtually maintenance-free operation during this period.

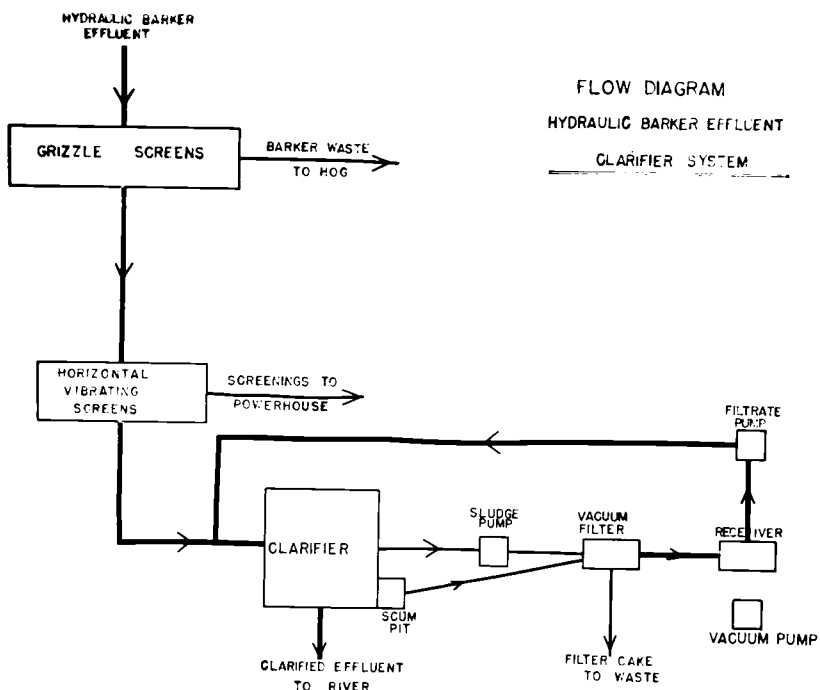


Figure 1.

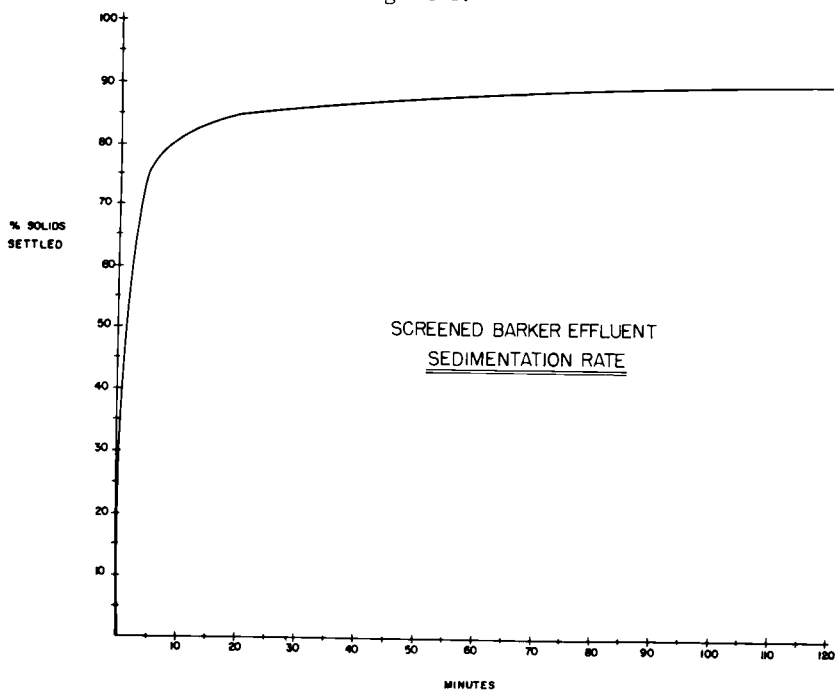


Figure 2.

AN OCEANOGRAPHIC SURVEY OF PORT ANGELES HARBOR

J. E. Stein, J. G. Denison, G. W. Isaac

ABSTRACT

An oceanographic survey of Port Angeles Harbor was carried out to ascertain if industrial wastes from pulp mills was unduly polluting the harbor. It was found that, in regard to any possible effect of industrial waste, the water quality was excellent. The biota of Port Angeles compared favorably with that of Hood Canal, where no industries are extant. The results showed that per unit area, even in the immediate vicinity of the mill, there was a greater abundance of animals.

INTRODUCTION

Port Angeles, as shown in Figure 1, is located on the Strait of Juan de Fuca. In Figure 2 it can be seen that the harbor is formed by a depositional spit (Ediz Hook) which extends from the mainland and is oriented in a west-east direction. The harbor, as seen in Figure 3, is approximately 2.5 nautical miles long and 1.4 nautical miles wide. Figure 4 is a bathymetric chart of the harbor floor. Note that the slope of the floor dips toward the north and the deepest portion is found in a trough located along the southern shore of the spit. Figure 5 shows sections along which bottom profiles were taken. These profiles are shown in Figure 6 and demonstrate the gentle sloping of the harbor floor toward the north.

The total effluent volume of the Rayonier mill is only 35 million gallons per day. In an area circumscribed by a 1000-yard radius arc about the mill, the receiving volume of water is almost 2 billion gallons. Assuming total mixing, the mill effluent constitutes only 1.8 percent of the immediate dilution volume of this area. At mean low tide the volume within the harbor is in excess of 54 billion gallons; consequently, the effluent comprises only 0.065 percent of the total dilution volume within the harbor. When these waters mix with that of the nearby Strait, it is easy to see that the amount of waste contributed by the Rayonier mill is truly infinitesimal.

The results of the survey will show, from a biological and chemical point of view, that as heretofore stated the quality of the water throughout the Port Angeles Harbor can be truly

characterized as excellent.

METHODS AND PROCEDURES

Standard chemical, physical, biological, and oceanographic procedures were used. All surveys were undertaken during flooding tides. The surveys were thus designed so that the conditions observed would be those prevailing during times of maximum effluent concentrations. To confine this report to a reasonable length, we shall not give an extensive analysis of the results of the entire survey. Only the more pertinent and significant factors will be presented. However, to give you an idea of the magnitude of the survey, the work required the services of 9 trained men for a period of 2 weeks in the field, 53 stations were visited not less than 4 times each, an average of 7 water samples were taken in depth at each station, over 4,000 chemical determinations were made, more than 1,000 biological specimens were examined, and about 3,000 man-hours were required to reduce and analyze the data. This was accomplished in approximately 3 months.

The following are some of the results and conclusions drawn from this survey.

RESULTS

Figure 7 shows the cruise plan and station locations. Of paramount interest was the distribution of spent sulfite liquor (SSL) within the harbor. Because most of the effluents entering the harbor have densities less than sea water, the most significant impact of pollution, if it does occur, should be encountered at or near the surface. Consequently, only the surface samples representing the various chemical parameters will be discussed. All of these samples were obtained on a single flooding tide. Figure 8 is an isogram showing the general distribution of SSL within the harbor. Notice that most of the SSL is confined to the southern half of the harbor where two major source areas can be detected: one at Rayonier Incorporated and the other near the western portion of the harbor, where Fibreboard and Crown Zellerbach are situated. A portion of the values in the northern part of the harbor are, in all probability, due to stored logs. It is well known that the Pearl-Benson method for the detection of SSL is not specific and that tannins, bark leachings, domestic sewage effluent, and other materials will give positive values. It is interesting to note that in the southern portion of the harbor

the changes or gradient in SSL values decrease from south to north. On the other hand, in the northern half of the harbor the readings increase in an east-west direction. This general orientation of gradients, that is at right angles to each other, was found to be a consistent pattern, and will be discussed later.

Figures 9 through 11 show the pattern of SSL distribution at depths of 10, 20, and 30 feet, respectively. These figures demonstrate the striking decrease of SSL concentration with depth. The confinement of the material at the surface affords an excellent opportunity for aeration by wind and wave action, and enhances the transport of this material into the adjacent Strait by wind and tidal currents.

Figure 12 shows the oxygen distribution. Here, again, we have a similar pattern. At the surface the oxygen concentrations are generally lower in the southern portion of the harbor than in the northern portion. Also note that the numerical values of adjacent isolines in the southern portion increase from south to north, and in the northern portion decrease in an east-west direction.

Figure 13 compares a series of oxygen profiles from inner harbor stations with a control station located in the Strait of Juan de Fuca. The six inner harbor stations, starting with station 1 at the end of Rayonier dock, were spaced approximately 400 yards apart and were located along a line connecting the Rayonier dock and the end of Ediz Hook. From these profiles it can be seen that the subsurface waters of the inner harbor compare favorably with the control station. This similarity in the subsurface-oxygen concentration demonstrates, beyond any reasonable doubt, that dissolved oxygen is not being depleted by sludge deposits. The average surface dissolved oxygen of the six inner harbor stations is 1.3 parts per million lower than that measured at the control station. However, it will be shown that in spite of slightly depressed surface-oxygen concentrations, the area was found to support a teeming biota.

Figure 14 shows the salinity distribution within the harbor. Here, as in the preceding figures, we see the same general pattern; namely, lower salinities in the southern portion of the harbor and higher values in the northern half. Also note, again, that the gradient in the southern portion still runs from south to north and in the northern portion is more or less oriented east to west.

Figure 15 shows the distribution of the pH values. This isogram, as with all the others, shows the same patterns.

Figure 16 shows the percent transmission of blue light through samples of surface water. Blue light was selected because of the low absorption of this wave length by sea water. On the other hand, discolorations frequently associated with pulp mills, such as yellow, brown, and red, are readily absorbed by blue light. Notice in this figure that the pattern is generally the same as in the preceding isograms. The waters to the north are clearer than those to the south. Also, the gradients show a similar pattern. It should be mentioned at this time that the average vertical visibility, as measured by a Secchi disc, is approximately 30 feet. This value compares favorably with Hood Canal, a body of water along which no industries or large cities are located.

A complete study of tidal currents within the harbor was not carried out. However, even with the limited data at hand, certain statements can be made concerning the movement of materials within the area. For example, based on the distribution of SSL shown in Figure 8, one may conclude that the northerly movement of effluent within the harbor is not very prominent. If there was a distinct northerly transport, materials would not be confined to the southern half of the harbor as indicated in this figure. In still water the effluent would spread out over the surface much like a plume of smoke in the air. However, where tidal currents occur the shape of the plume is masked and the effluent is spread out in accordance with the oscillations of the tidal currents. Notice that this is what has occurred in the southern half of the harbor. Also from Figure 8, it is indicated that the net flow of materials in the harbor is generally counterclockwise. If the net flow was in the other direction (i. e., clockwise), there would be relatively high concentrations of liquor toward the north and west portion of the harbor which, as can be seen, is not the case. Furthermore, if the net flow is more or less counterclockwise, deposits associated with the Rayonier effluents must extend in an easterly direction. That this is true is shown in Figure 17. This figure is a scale drawing of the exact location, shape, and size of the Rayonier sludge deposit. The extension of this deposit in an easterly direction reinforces the conclusion that the net flow of material from the mill is eastward rather than toward the inner harbor.

The size and shape of the sludge beds were ascertained by the utilization of technically trained divers. Three divers were used in the underwater survey; each diver was equipped with Self Contained Underwater Breathing Apparatus (i.e., SCUBA gear). After a few preliminary dives the outer edge of the sludge bed was found. The divers then followed the outermost margin and periodically released anchored marker floats. The positions of the floats were fixed by triangulations with transits. The eastern deposit, its outline is shown in Figure 17, consists of an overlay of very fine, light, fibrous material beneath which there are underlying strata of oxidized matter. The maximum depth of the sludge bed is approximately 30 inches. This maximum is located near the mill outfall. Toward the periphery of the sludge bed the deposits are less than an inch in depth. In this zone the deposition is not continuous throughout; instead, it is characterized by isolated patches of material ranging from a few inches to a foot in diameter. The area of the eastern sludge bed is 39.1 acres, or approximately 1.7 percent of the entire harbor floor.

The western sludge bed consists of wood litter and bark emanating from the barker effluent. Underlying the surface layer is woody material in varying stages of oxidation. The depth of this sludge bed is the same as the eastern deposit. It is an area of 24.5 acres which comprises only 1.2 percent of the entire harbor floor. The combined east-west deposits constitute 63.6 acres, which is only 2.9 percent of the total area of the inner harbor bottom.

At mean low tide the water depth in the vicinity of the most eastern portion of the sludge bed varies from 3 to 18 feet. Consequently, when waves pass over this area, the bottom is disturbed and the deposits are lifted into suspension. The suspended material is then carried off into the Strait by wind and tidal currents. During the survey divers reported that occasionally they could feel wave action along the bottom in this area. Turbulence of the bottom sediments occurs when the depth of water is nearly equal to one-half the wave length as measured from crest to crest or trough to trough. As a result of diving observations made on succeeding days, it was definitely established that the most eastern edge of the sludge bed was unstable and showed a considerable degree of fluctuation. By contrast, the northern boundary of the sludge bed has become limited by the net eastward transport of materials emanating from the outfall. From these data we conclude that, although

there are minor fluctuations, the size and shape of the sludge beds are stabilized. This stabilization is brought about by the action of waves and currents.

Biological data were collected by means of underwater photography, square foot piling samples, speared specimens, and beach seining. The location of each seining operation is shown in Figure 18. The technique employed in laying-out the net is demonstrated in Figure 19. One end of the net was held on the beach and balance payed out from the end of a skiff at an approximate 45-degree angle from the shore. Upon reaching the end of the net, the skiff was swung in an arc toward the shore while a constant tension was maintained on the line. In this manner an arc of approximately 110 degrees was circumscribed, and slightly more than 98,000 cubic feet of water was fished at each location. Figure 20 shows the results of a haul made over the eastern sludge bed at a distance of 150 yards east of the mill outfall. In this haul sea-run cutthroat, herring, flounder, sculpin, stickleback, and crabs were taken. The lower edge of the net showed evidence of contact with the sludge bed and, from this observation, it is obvious that the bottom deposits were in no way harming fish. No patterns or relationships between abundance of fish and distance from the mill were observed. However, in one case more fish were taken at a station 150 yards from the mill than at one located 1400 yards away. Table I is a tabulated summary of the numbers, species, and the total quantity of fish taken at each station. Locations 2 and 4 contained prodigious quantities of herring. Eldridge⁽¹⁾ alleged that herring were extremely susceptible to pollution. Furthermore, Chapman⁽²⁾ found that herring are territorial and their migration habits are minimal. This means that most of the herring taken in the harbor were native to the area and had spent most of their lives at this place. Gross inspection of the fish at the time of netting failed to disclose any indications of stress. Moreover, microscopic examination revealed that there were no apparent lesions. Table II is a tabulated summary of the different species and the number of each species which were taken by net. From a biological point of view, this wide diversity of organisms indicates that the water quality is excellent. Had there been undue pollution, many of these 17 different species of fish would not be represented. Other organisms were seen but not taken by net. These will be discussed shortly.

Extensive underwater sampling and photography was conducted in the vicinity of the Rayonier dock. The pilings were

exceedingly interesting because they supported a wide variety of organisms along the entire length of the dock. Twenty-five different species were collected from a single piling located near the northeast corner of the dock. All of these organisms lived their entire lives attached to or in close vicinity of these pilings. Consequently, all of these species would be continuously exposed to any of the wastes discharged by the mill. Underwater photographs taken by our SCUBA divers showed present of barnacles, anemones, snails, crabs, sponge, and tube worms.

In addition to piling observations, swimming forms were also noted. Herring, greenling, starry flounder, skate, and many others were noted. Table III is a tabulated summary of the different forms of fish which were observed by the divers. Some of these fish were taken with a speargun. Analysis of the stomach content of the speared fish revealed that they were feeding on a wide variety of organisms; thereby indicating that an adequate food chain was present to support the teeming marine life noted in the area. On one occasion technicians from the Washington State Pollution Control Commission (PCC) were accompanied by our divers, and they too observed the wide variety of organisms found on and adjacent to the Rayonier dock.

Port Angeles has been a mecca for skin divers and sport fishermen for many years. Many specimens were taken from this harbor during a recent skin diving fish derby. This international tournament has become an annual affair at Port Angeles.

Up until recent years an active octopus fishery was carried out in the Port Angeles harbor. A 35-pound specimen was captured by divers. Because of market difficulties, the commercial octopus fishery is no longer extant. However, these organisms are still present in considerable numbers. Due to the extreme susceptibility of octopus to chemical changes in the water, their abundance in the Port Angeles harbor attests to the excellent quality of the water.

The biota of Port Angeles was compared with that of Hood Canal, a popular diving and sport fishing area where no industries or large cities exist. The results showed that per unit area, even in the immediate vicinity of the mill, there is a greater abundance of animals.

CONCLUSIONS

1. Burning and recovery facilities would have little or no effect on chemical factors and, in all probability, no effect on the biota.
2. The wide variety of organisms found in stomach contents of fish indicates the presence of an excellent food chain.
3. Because of the amount and diversity of marine organisms, one can only conclude that variations in surface water quality are insignificant.
4. The presence of sludge beds within the vicinity of the mill outfall in no apparent way affected the biota.
5. Materials from the Rayonier effluent are carried out of the system in an easterly direction and not toward the inner harbor.
6. The size and shape of the sludge deposits have been stabilized by wave action and tidal currents.
7. Hood Canal was used as a control area, and it was found that there were relatively more organisms in Port Angeles Harbor.
8. From a biological and multiple use point of view, the quality of water within the Port Angeles Harbor is excellent.

REFERENCES

1. Eldridge, E.F. and G.T. Orlob, "Investigation of Pollution of Port Gardner Bay and Snohomish River Estuary, " Sewage and Industrial Wastes, Vol. 23, No. 6 (1951).
2. Chapman, W.M., M. Katz, and D.W. Erickson, "The Races of Herring in the State of Washington, " Dept of Fisheries, State of Washington Biological Report No. 38A, November 1941.

TABLE I.
BEACH SEINING - PORT ANGELES - OCT. 12, 1961
INDIVIDUAL SEINE HAULS

DISTANCE FROM MILL	BOTTOM COMPOSITION	NO. OF FISH TAKEN	PER CENT OF TOTAL	NO. OF SPECIES TAKEN
150 yds.	Mud with pulping fibers	75	7.7%	6 species of fish 1 specie of crab
450 yds.	Mud and eel grass	344	35.4%	7 species of fish 1 specie of crab
575 yds.	Gravel and eel grass	104	10.7%	8 species of fish 1 specie of crab
750 yds.	Gravel and eel grass	386	39.7%	10 species of fish
1400 yds.	Gravel and a little eel grass	64	6.6%	5 species of fish

TABLE II
BEACH SEINING - PORT ANGELES - OCTOBER 12, 1961
SPECIES TAKEN AND PERCENT COMPOSITION
OF THE COLLECTION

No.	Per- cent	Species	
799	82.12	Pacific herring	<u>Clupea harengus passasi</u>
103	10.59	Shiner perch	<u>Cymatogaster aggregata</u>
19	1.95	Tube-snout	<u>Aulcrhynchus flavidus</u>
16	1.64	Starry flounder	<u>Platichthys stellatus</u>
12	1.23	Edible crabs	<u>Cancer magister</u>
5	0.52	Tidepool sculpin	<u>Oligocottus maculosus</u>
3	0.31	Buffalo sculpin	<u>Enophrys bison</u>
3	0.31	Pacific staghorn sculpin	<u>Leptocottus armatus</u>
2	0.21	Surf smelt	<u>Hypomesus pretiosus</u>
2	0.21	Cutthroat trout	<u>Salmo clarki</u>
2	0.21	English sole	<u>Parophrys vetulus</u>
1	0.10	Padded sculpin	<u>Artedius fenestralis</u>
1	0.10	Northern anchovy	<u>Engraulis mordax</u>
1	0.10	Pacific sand lance	<u>Ammodytes hexapterus</u>
1	0.10	Striped seaperch	<u>Embiotoca lateralis</u>
1	0.10	Pacific tomcod	<u>Micorgadus proximus</u>
1	0.10	Threespine stickle- back	<u>Gasterosteus aculeatus</u>
1	0.10	Crescent grunnel	<u>Pholis laeta</u>
973 = Total organisms			

TABLE III
SCUBA DIVING - PORT ANGELES - OCTOBER 5-19, 1961
Free-Swimming Forms Observed During Diving Operations

Black Rockfish	<u>Sebastes melanops</u>
Yellowtail Rockfish	<u>Sebastes flavidus</u>
Giant Marbled Sculpin	<u>Scorpaenichthys marmoratus</u>
Lingcod	<u>Ophiodon elongatus</u>
Chinook Salmon	<u>Oncorhynchus tshawytscha</u>
Starry Flounder	<u>Platichthys stellatus</u>
Greenling	<u>Hexagrammos</u> sp.
Buffalo Sculpin	<u>Enophrys bison</u>
Pacific Herring	<u>Clupea harengus pallasii</u>
Tube-Snout	<u>Aulorhynchus flavidus</u>
Ratfish	<u>Hydrolagus coliei</u>
Skate	Unidentified
Octopus	<u>Octopus</u> sp.
Broken-Back Shrimp	<u>Spirontocaris</u> sp.
Krill	<u>Euphausia pacifica</u>

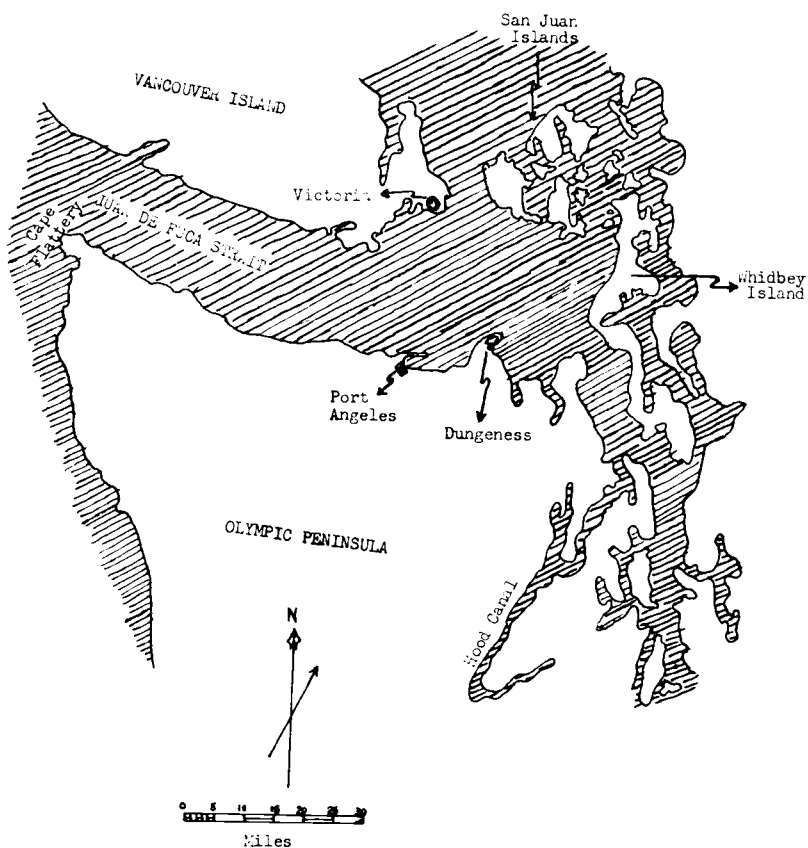


Figure 1. Map Showing Port Angeles Area and Environs



Figure 2. Aerial Photograph of Port Angeles Harbor

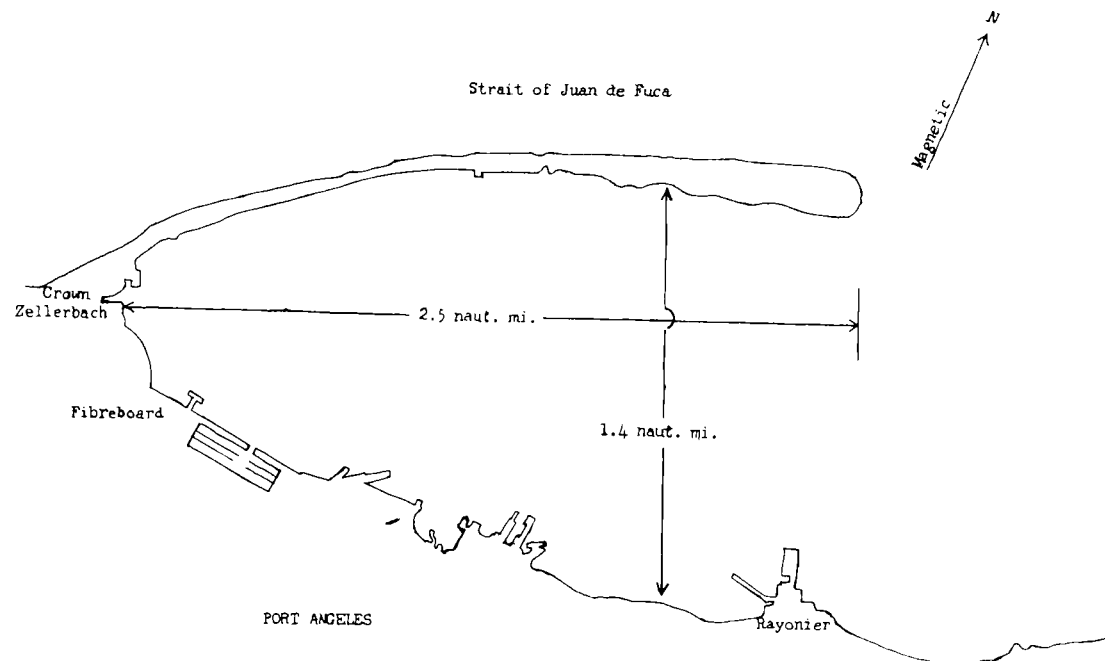


Figure 3. Diagram Showing Dimensions of Harbor

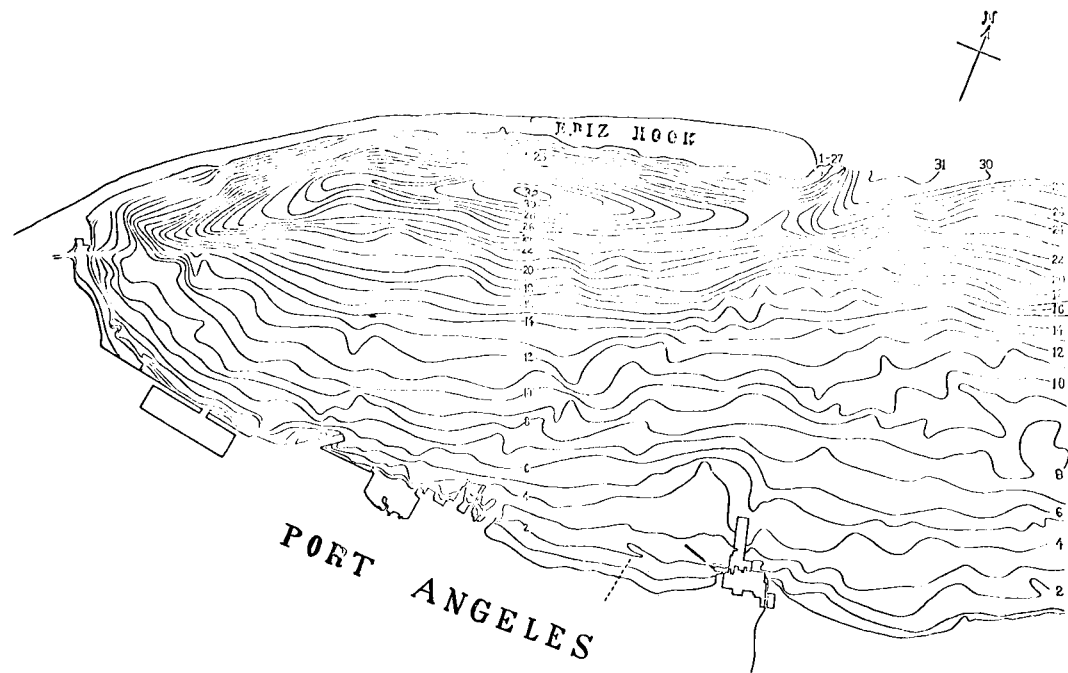


Figure 4. Bathymetric Chart of Port Angeles Harbor

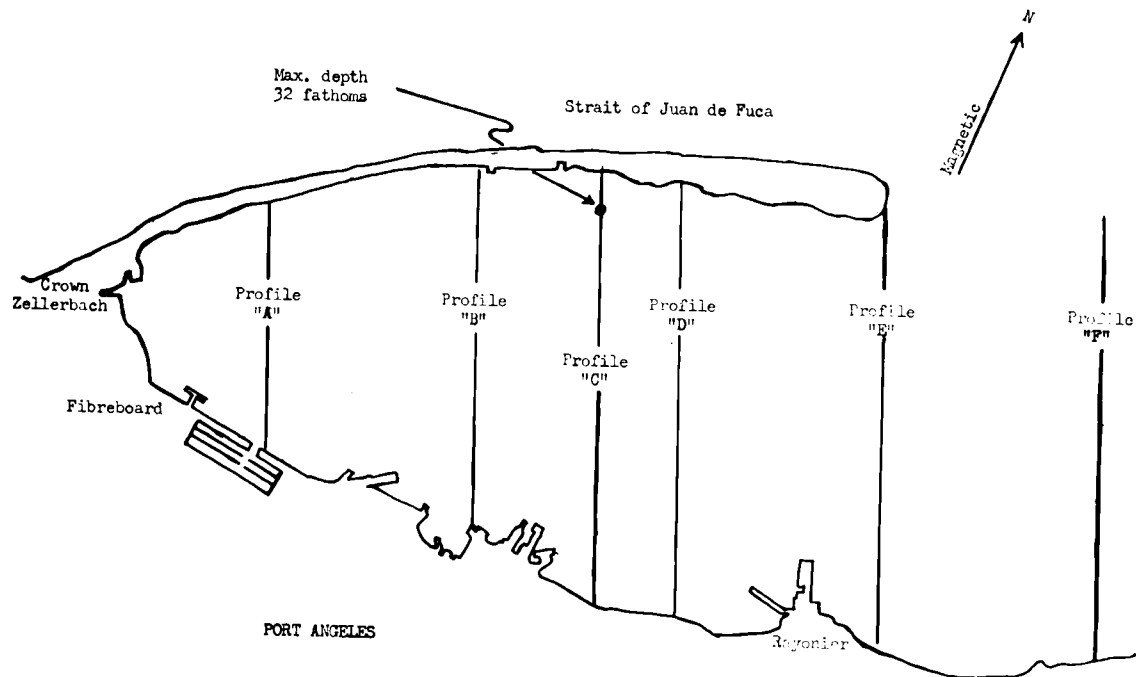


Figure 5. Sections Along Which Bottom Profiles Were Taken

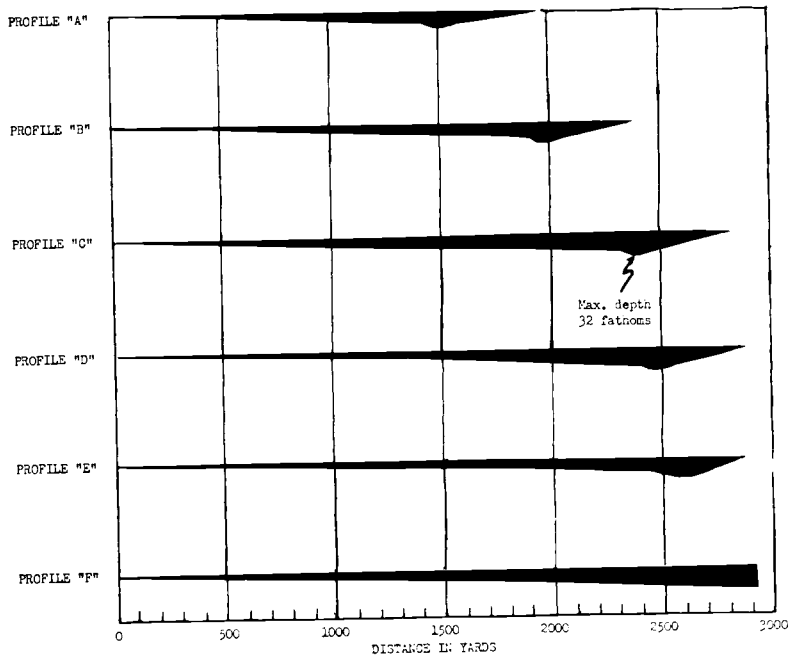


Figure 6. South-North Profiles of Port Angeles Harbor
Profiles Taken Along Section "A" to "F" of Figure 5

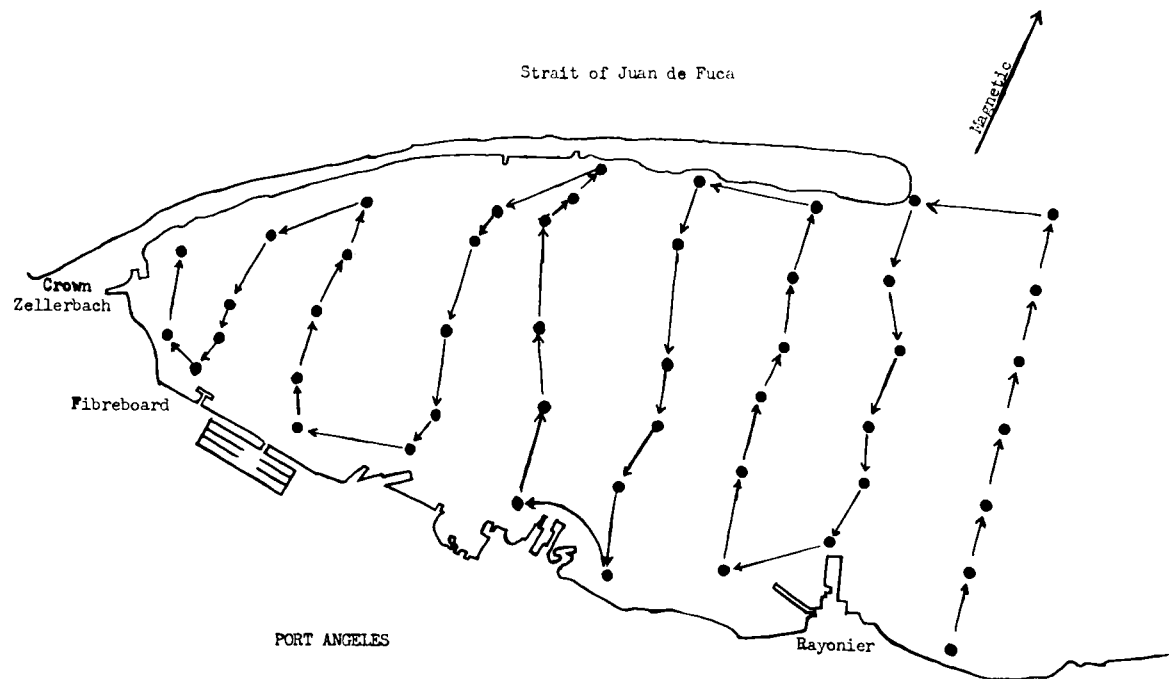


Figure 7. Cruise Plan and Station Locations of the Port Angeles Survey

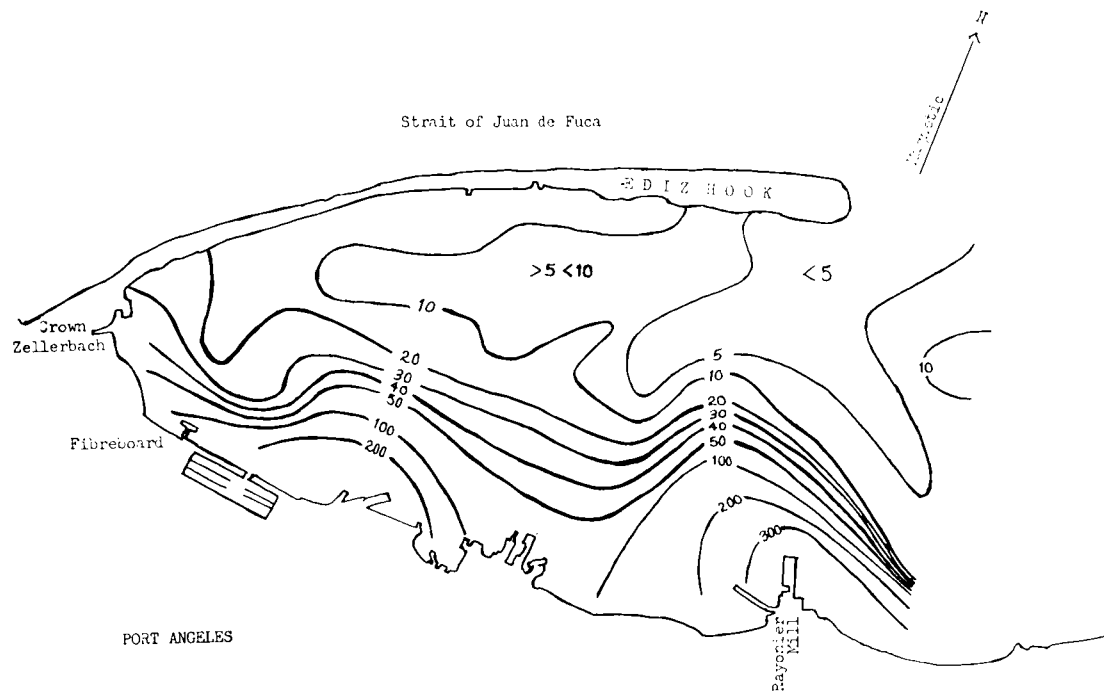


Figure 8. Isogram Showing Distribution of Spent Sulfite Liquor Within Harbor

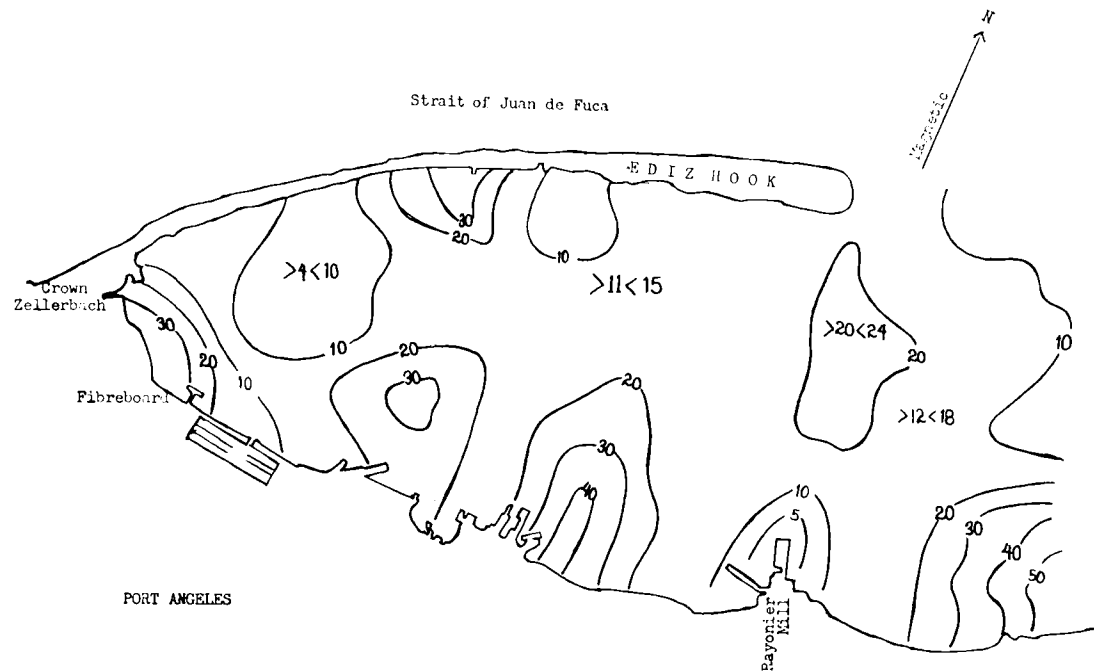


Figure 9. Isogram Showing Distribution of Spent Sulfite Liquor 10 Feet Below Surface

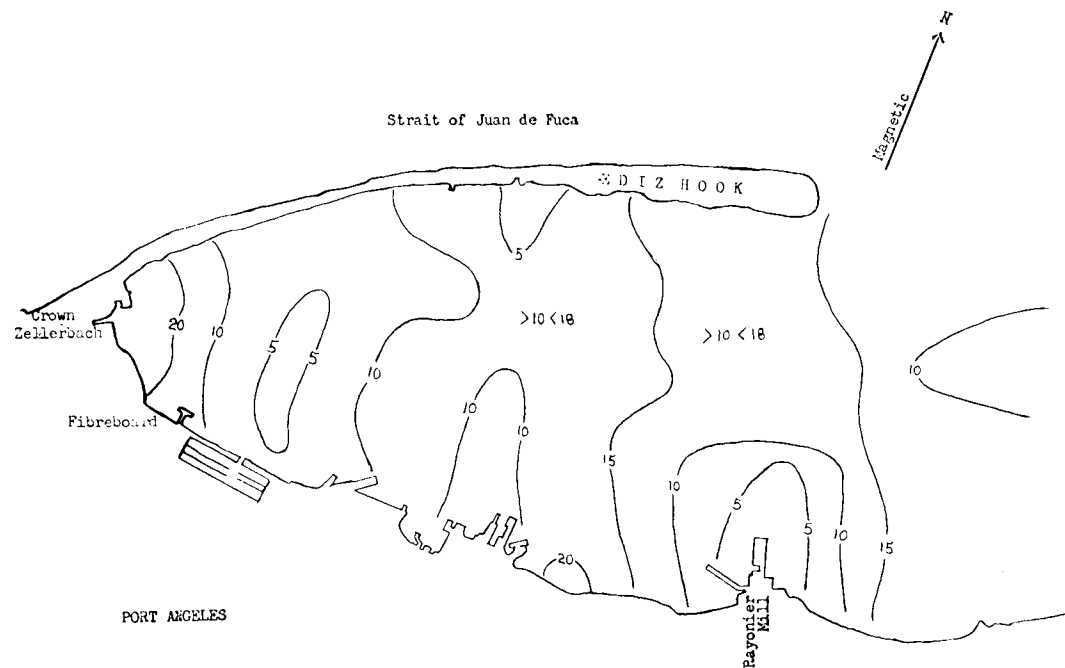


Figure 10. Isogram Showing Distribution of Spent Sulfite Liquor 20 Feet Below Surface

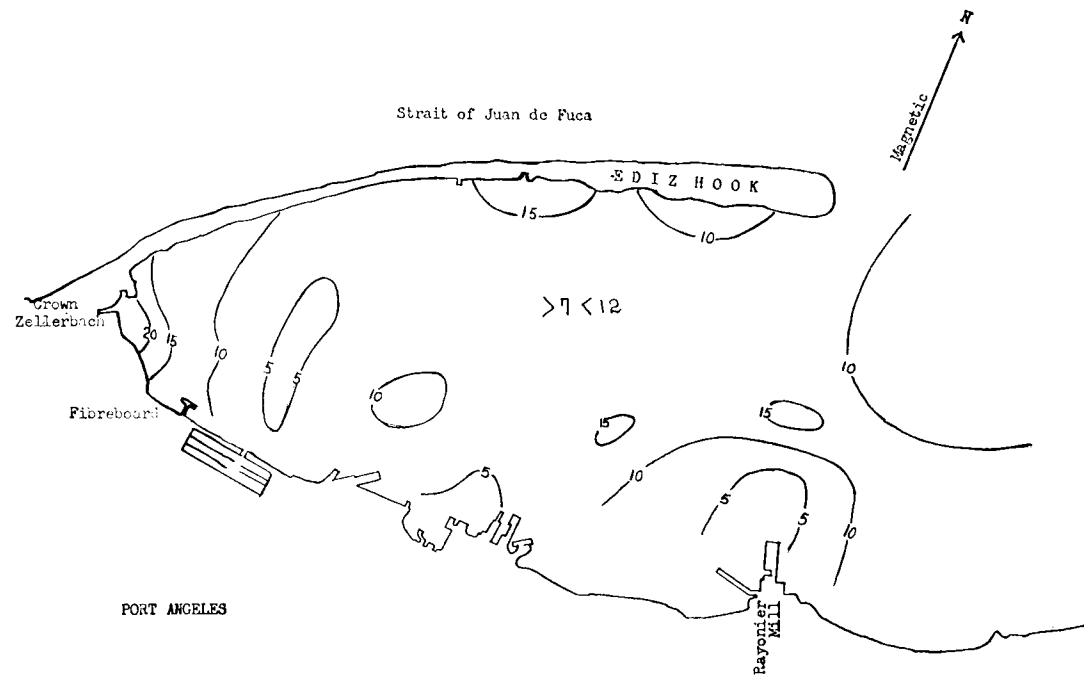


Figure 11. Isogram Showing Distribution of Spent Sulfite Liquor 30 Feet Below Surface

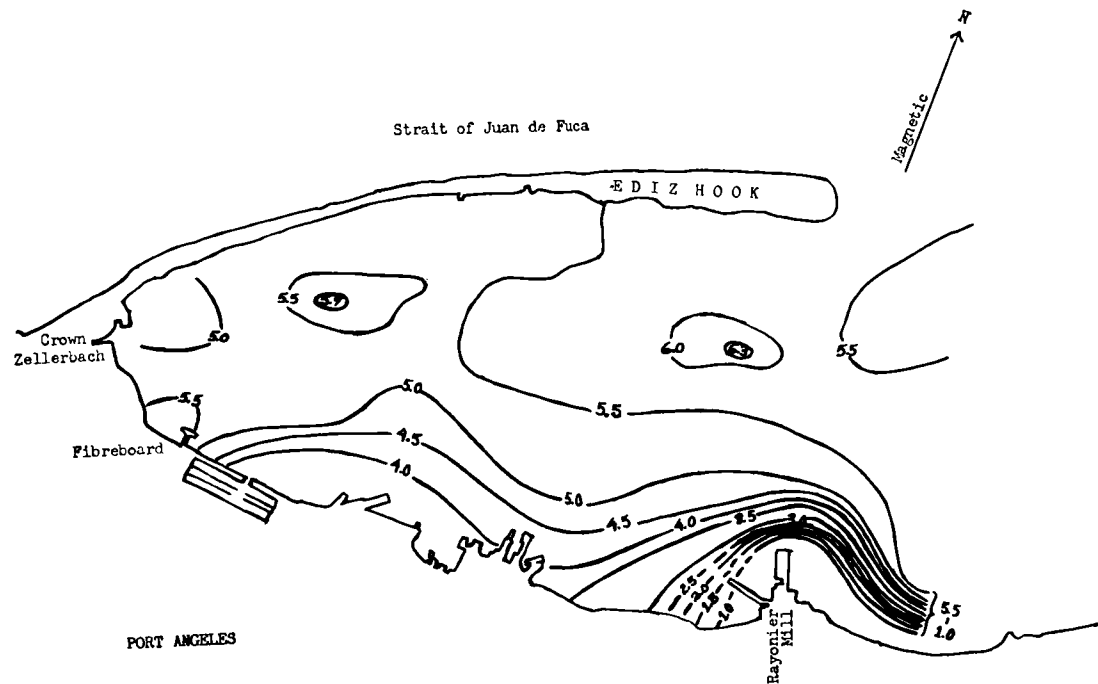


Figure 12. Isogram Showing Surface Distribution of Dissolved Oxygen Within Harbor

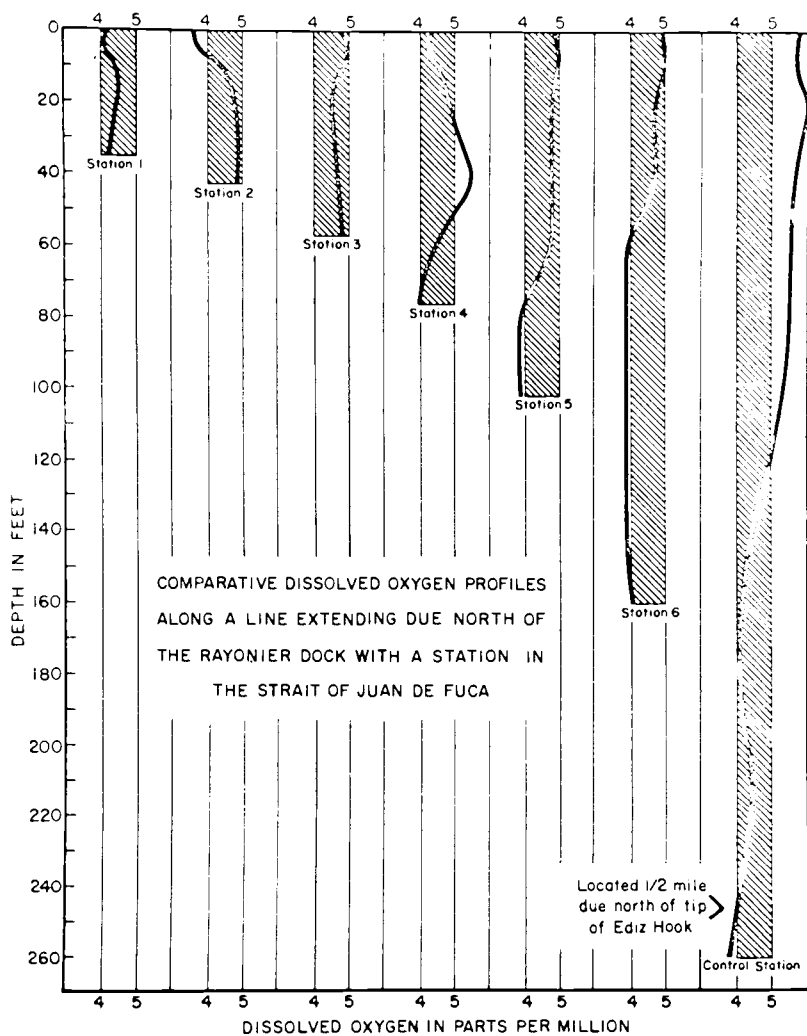
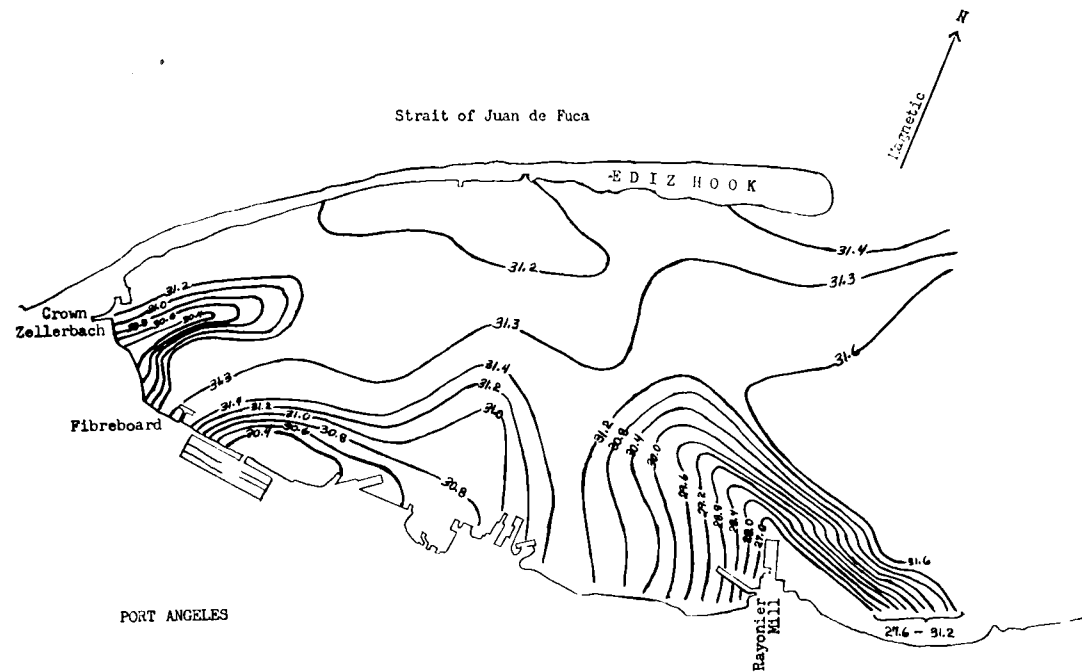


Figure 13. Oxygen Profiles of Inner Harbor Station Compared with a Control Station Located 0.5 Miles Due North of Tip of Ediz Hook



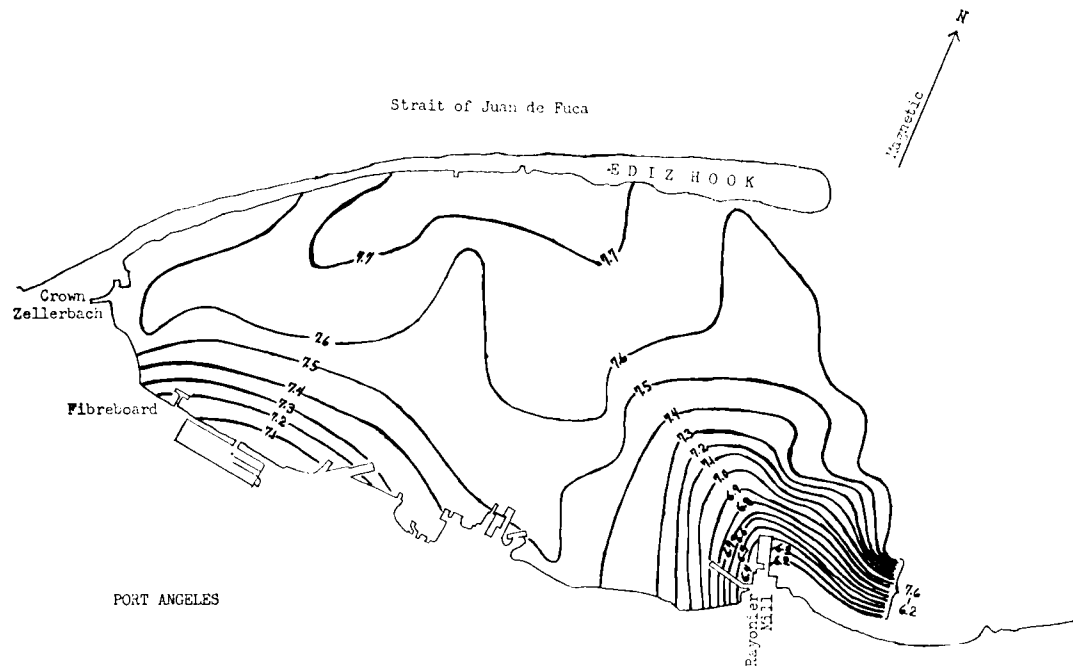


Figure 15. Isogram Showing Variation of Surface Hydrogen Ion (pH) Concentration Within Harbor

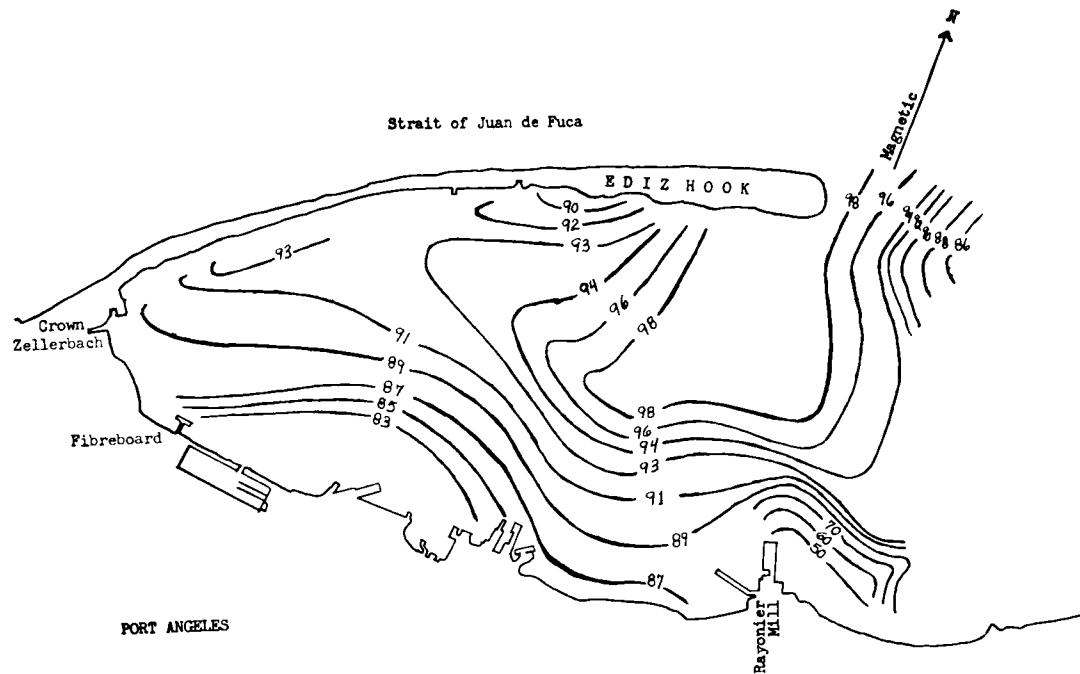


Figure 16. Isogram Showing Percent Transmission of Blue Light Through Surface Water Samples

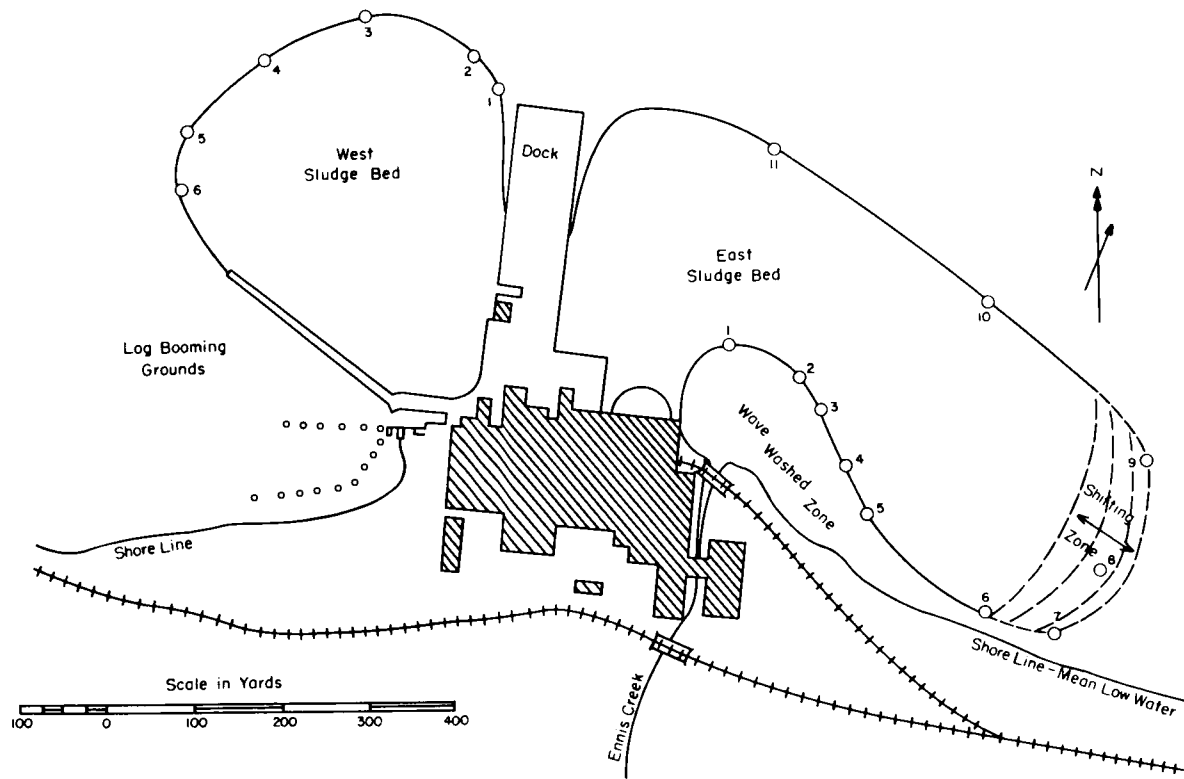


Figure 17. Scale Drawing Showing Exact Location, Shape, and Size of Rayonier Sludge Deposits

<u>Seine Haul</u>	<u>Distance From Outfall</u>
No 1	150 yds
No 2	450 yds
No 3	575 yds
No 4	750 yds
No 5	1400 yds

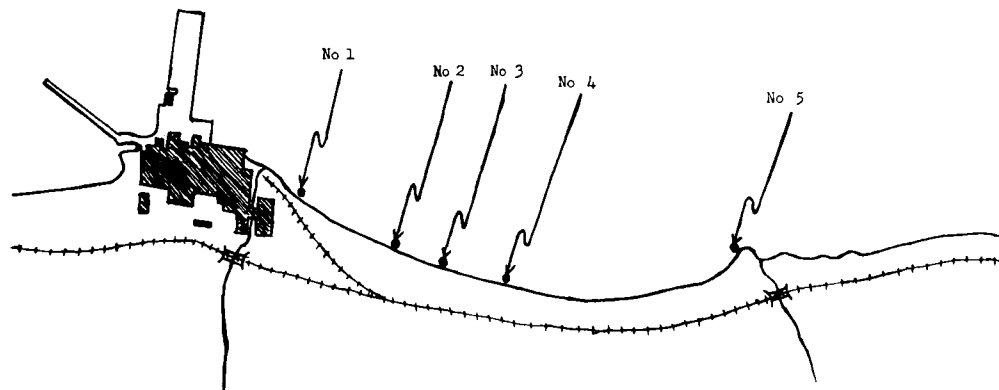


Figure 18. Scale Drawing Showing Seining Locations of Port Angeles Survey



Figure 19. Photograph of Beach Seine as it is Being
Payed-Out From Stern of a Skiff



Figure 20. Results of a Seine-Haul Made 150 Yards East of the Rayonier Outfall

LAND DISPOSAL OF PULP AND PAPERMILL EFFLUENTS

R. O. Blosser and E. L. Owens

In 1959, a survey of land disposal practices in the pulp and paper industry revealed that at least 14 mills had studied or were employing some form of soil filtration as a means of effluent disposal. It was also revealed that the industry was displaying increasing interest in this form of waste treatment since its application is well suited to seasonal disposal during stream low flow periods. That this interest continues is evidenced by the fact that at least 7 mills are known to have initiated, since that time, either laboratory studies, pilot field studies, or full-scale field installations to seasonally handle portions or all of the mill effluent by land application. Industry interest and the suitable geographical location of a number of mills for its employment, therefore, led to the establishment of a fundamental study of land disposal at the Council's Oregon State University project.

Based on earlier studies, relatively dilute mill effluent when applied in quantities common to crop irrigation practices could be assimilated by the soil, producing crops at least equal to those produced by conventional water supplies. Little knowledge was actually available, however, in such areas as to the effect of soil characteristics on its capacity for treatment of various effluents, the effect of cover vegetation on soil treatment capacity, the effect of effluent composition on soil characteristics, fertilizing or soil conditioning effects of effluents, if any, or possible adverse effect on ground water quality where concentrated or highly colored effluents are applied as irrigation water. These are areas in which investigations have been conducted, and this paper constitutes a progress report on the observations.

The laboratory studies have dealt primarily with changes in effluent characteristics, changes in soil characteristics, and changes in cover vegetation conditions when a wide variety of effluents are applied to the soil in simulated irrigation practice. The initial phases of the investigation dealt with changes occurring when effluents were applied to bare soil columns similar to those shown in Figure 1. The study was then expanded to investigate the role of cover vegetation on the land in irrigation disposal of pulp and papermill effluents. Figure 2 is a view of the greenhouse showing some of the laboratory columns used in

this portion of the study. The cover vegetation is *alta fescue*, a grass of high moisture resistance and reasonably high salt tolerance with an extensive root formation. These qualities make it well suited for use in irrigation disposal operations where maximum water application is desirable, and it has proven to be superior to Reed canary grass in the laboratory investigations.

Four representative soils have been used in these studies; a sand loam, a silt loam, and two clay loams, classifications which principally define particle size. Their ion exchange capacity, or capacity to chemically adsorb the cations, also differs, increasing with decreasing particle size, with the clays having the highest exchange capacity. Analyses employed have included BOD, color, pH, lignin, conductivity, and measurement of the cations and anions of major importance in soil management to include sodium, calcium, magnesium, potassium, sulphates, and chlorides. Percolate collection and measurement have afforded the opportunity to establish moisture loss by evapotranspiration, while clipping of the grass at regular intervals, where cover vegetation is employed, provides a measure of productivity which reflects the benefit or apparent harm to the cover vegetation by a specific effluent of set of conditions. Volumetric loadings of 5 to 11 inches per week, or 20,000 to 43,000 gallons per acre day, have been used where cover vegetation is employed. This hydraulic load is in excess of the consumptive requirements of the cover vegetation in the laboratory and simulates field conditions where application rates of about 9,000 gallons per acre day in the northern latitudes are in excess of evapotranspiration requirements and would result in percolation to the ground water.

Extended irrigation periods of 9 months or longer, representing in many areas the equivalent of 2 to 3 years seasonal effluent disposal, have been employed to assist in evaluating long-term effects. Subsequent to the irrigation period, the soils are leached with tap water to simulate a period of high precipitation following seasonal disposal. A number of effluents to include bleached kraft, unbleached kraft, kraft recovery condensates, caustic extract wash water, dilute solutions of kraft black liquor, insulating board mill, sulfite, kraft effluents fortified with sodium or wood sugars, and other synthetic effluents, as well as tap water, have been employed to cover the wide spectra of effluent characteristics encountered at field installations.

BOD REDUCTION

BOD has been one of the parameters of evaluation used to measure the change in mill effluent characteristics as they percolate through soil. When observing the soil percolate from columns loaded at different BOD levels it has been possible to identify significant changes in soil percolate quality. These changes are directly identifiable with the organic loading applied when expressed as a function of the soil surface BOD loading.

At loadings of up to 235 pounds BOD per acre per day, reductions of 95 percent or greater have consistently been recorded with no impairment of cover vegetation or soil permeability reduction assignable to rapidly decomposable organic matter. Removals of 60 to 84 percent were noted at loadings of 280 pounds per acre day with accompanying septic percolate. Both illustrate that insufficient oxygen was gaining entry at the soil surface to maintain aerobic conditions. Excessive cover vegetation damage finally resulting in complete kill, as well as reduced soil permeability, were also noted after 8 months of irrigation. BOD loads just over 400 pounds per acre per day also were reduced about 60 percent. Impairment of grass growth was more rapid and severe, however, finally resulting in reduced soil permeability and, hence, mandatory lower hydraulic loadings by the end of the third month of effluent application. These findings are illustrated in Table 1.

The high degree of treatment afforded at loadings less than 235 pounds per acre per day has been found to be independent of soil effluent type over the complete range of soils and effluents employed.

Based on these observations, with correction for difference in soil temperatures existing between the laboratory and field, sustained BOD loadings of 200 pounds per acre day on soils of 15 to 20 inches in depth could be expected to result in percolates of high quality, unimpaired growth of selected cover vegetation, and no reduction in soil permeability due to BOD loading. Employing loading parameters of 27,000 gallons per acre day and 200 pounds BOD per acre day, high degree BOD removal could be expected for effluents with an initial concentration of 875 ppm. Since most effluents exhibit BOD concentrations less than this, it appears that permissible hydraulic loading will hold organic loadings below the critical level in

most instances. There are certain cases, however, where organic loading would be a design parameter.

The storage of effluents in lagoons for biological treatment, intermittent discharge or, in specially planned units, depending on seepage to the ground water, as a disposal method, is a common practice. Since the seepage from these units ultimately finds its way to surface water, some knowledge of the treatment afforded during percolation through the soil was desired. Simulated ponds on 20 inches of soil similar to those shown in Figure 3 are employed in this study. A mineral oil seal at the air-liquid interface on one-half of the columns provides the true anaerobic conditions existing at the bottom of deep ponds, while the remainder simulate a shallow pond environment.

In Table 2 is shown a summary of the data on BOD reductions accomplished during percolation of kraft effluents through the soil under the simulated seepage beds. At seepage rates of 0.25 to 0.6 inch per day, the soil residence times of 23 to 54 days, BOD reductions averaging 72 percent or greater have been observed. When the seepage rate was increased and a coarse sand with substantially less volume of voids was employed as the filtration media, soil residence time was substantially reduced. BOD reductions likewise were reduced, falling to the 20 to 30 percent range. The simulated shallow ponds exhibited slightly higher reductions despite the fact that anaerobic conditions in the soil existed in both cases.

It is significant to note that at soil residence times of 12 days in the irrigation studies where aerobic conditions were maintained in the soil, BOD loads approximately 8 times as great were reduced 95 percent or more.

COLOR REMOVAL BY THE SOIL

While it has been observed that BOD removal from effluents by the soil during irrigation is independent of soil or effluent type over the range investigated, the same is not true for color removal when these effluents are applied as irrigants. Color removal varies both with effluent type and soil type. A summary of some of the more significant observations is shown in Table 3, where color reduction is expressed on a percentage basis for an irrigation period of 9 or 10 months. Where bleached kraft and insulating boardmill effluents, both with initial color

concentrations greater than 1000 ppm, were applied to clay loam soils, 99 percent color removal was noted, while sandy loam removed only 65 percent of the color. It was generally observed that for all the kraft and insulating boardmill effluents employed the clay loams were most effective in retaining the color, followed in effectiveness by silt loam and sandy loam in this order. Extensive color intensification, averaging about 100 percent net color increase, was consistently observed when both ammonia and calcium base sulfite effluents were applied to silt and sandy loam, despite the fact that 35 to 90 percent of the lignin present in the effluent remained in the soil during the period of effluent application. This increase was probably due to transformation of the lignin complex while percolating through the soil, resulting in a significant change in the light absorption capacity of the effluent. This phenomena may explain the apparent persistence of color in ground water where contamination with sulfite effluents has occurred.

When appreciable color passage was noted during the period of effluent application, leaching normally resulted in continued color passage. When the applied effluent color was above 1000 ppm or where sulfite effluents were applied, the leaching percolates from all except finely divided high calcium exchange capacity Olympic clay loam soil exhibited substantial increases in color content.

While it appears that the Olympic clay loam soil was capable of functioning as both a color remover and color retainer, the variability observed in the laboratory investigations dictates that proposed land disposal operations incorporate studies employing both the effluent to be applied and soil available at the site if ground water contamination might be detrimental.

BIOLOGICAL QUALITY OF PERCOLATES

The percolates from soil columns receiving effluents do not differ significantly in odor from that percolate from columns irrigated with tap water, both exhibiting the earthy odor of highly treated secondary effluents.

The percolates from columns to which kraft recovery condensates, sulfite effluent, and unbleached kraft linerboard mill effluent has been applied as irrigants were bioassayed using

the guppy as a test specimen. There were no mortalities nor were distress symptoms noted during a 96-hour exposure period to 100 percent concentrations of these percolates. This indicates that immediate discharge of percolates into a water course would have no effect on the aquatic habitat providing the high degree aerobic treatment provided by percolation through approximately 2 feet of soil is provided.

CHANGES IN SOIL CHARACTERISTICS

In the study of changes occurring in soil characteristics due to effluent application, changes in salt concentration in the soil have been employed as a parameter of evaluation. Of primary concern is the fate of sodium. Interest in the fate of sodium that may be found in some effluents stems from the role it plays in crop and soil management where conventional water supplies are used for irrigation. The field of soil science deals at some length with the subject and considerable knowledge has been accumulated relative to handling the problems associated with sodium accumulation.

Significant variations in sodium removal from the effluents by the four soils employed was observed. Concentrations in the soil at the termination of effluent application were dependent both on the concentration in the effluent applied and the amount of evapotranspiration occurring. Final concentrations were, however, closely associated with the cation exchange capacity of the soil; the finely divided Olympic clay loam with the highest cation exchange capacity of 31 meq/100 gms exhibiting the highest concentrations. In due turn, the sandy loam with lowest cation exchange capacity of 14 meq/100 gms exhibited the lowest concentration.

Leaching of these soils with water after the irrigation season, analogous to the leaching accomplished by natural rainfall, revealed that the major portion of the sodium is rather easily removed. It was also observed that individual soils exhibit specific leaching properties.

In Figure 4 is plotted on semilog paper sodium concentration in the soil at 4 inches from the surface versus inches of leachate collected for Olympic clay loam soil that had been irrigated with four different effluents. This family of curves can be represented by the general equation $y = y_1 10^{-KV}$, where V is in inches of leachate collected. The K or leaching reaction

rates for all four effluents are seen to fall into a rather narrow range. Similar relationships were noted for the other soils, indicating that the rate of sodium leaching is independent of the source of sodium accumulation.

A summary of the leaching rates observed is shown in Table 4. It can be seen that the leaching rates vary for different soils, with the silt loam exhibiting a leaching rate almost twice that of the Olympic clay loam. These data indicate that the degree of sodium removal is not only dependent on the amount of leaching water applied but is also dependent on the type of soil involved. With the cooperation of member mills now employing land disposal, we are attempting to determine if sodium leaching under field conditions exhibits similar soil-type leaching rate relationships.

Problems in soil management reflected in reduced soil permeability during the period of effluent application attributable to sodium accumulation during a single irrigation season have been confined to 1/30 dilutions of kraft black liquor and synthetic effluents, both exhibiting sodium adsorption ratios of 35 or greater and of extremely poor water quality by conventional irrigation water standards. We have observed what may be reduced permeability due to soil deflocculation during the leaching cycle in Olympic clay loam columns that received bleached kraft and insulating boardmill effluent, both of which exhibited high level sodium buildup during the irrigation season.

Our experience to date has shown that problems attributed to, but not at this time defined as, sodium accumulation when applying effluents of medium irrigation quality with a sodium adsorption ratio of 8 or less are confined to the finely divided, high cation exchange Olympic clay loam soil, and may well be the result of an abnormally long irrigation season prior to leaching. Since most whole kraft mill effluents where sodium may be encountered have sodium adsorption ratios less than 8, the sodium problem is probably minor for most soils.

A study is now in progress to determine if effluent-soil reactions differ substantially from conventional irrigation water-soil reactions when the irrigation liquid is of like salt concentration. A bleached kraft effluent and a synthetic irrigation water of similar content are applied to identical bare soil columns. Composite percolates are analyzed after each 10 inches of effluent application, while the soil is analyzed after 30 inches of

effluent application. In Figure 5 is shown the sodium concentration existing in clay loam soil during 90 inches of irrigation. Two items are significant here. First, is the fact that about 80 percent of the sodium accumulation occurred as a residual after only 30 inches of effluent application. Second, is the striking similarity of sodium concentration, both total and water soluble, existing in the soil during the irrigation period, which indicates that the organics present do not materially change the soil-salt exchange mechanism. A similar relationship was observed in percolate quality, as is shown in Figure 6.

Sodium concentrations approached a maximum after 20 inches of irrigation and remained about constant during the remainder of the irrigation period, confirming that the majority of the sodium accumulation occurred rapidly. The similarity of sodium concentration in the two percolates can also be observed. This similarity in calcium, magnesium, and potassium levels in the percolates, both during irrigation and leaching, was also observed, as shown in Figure 7. Soil analyses likewise exhibited similar concentrations of these ions during the irrigation season. Sulphate and chloride ion concentrations in the percolate exhibited the same similarity, indicating at this time that the knowledge accrued in the use of conventional irrigation water supplies is applicable to these effluents.

Other parameters used to evaluate changes in soil characteristics due to effluent application were changes in soil permeability and cover crop condition. Reductions in soil permeability were associated with both excessive sodium loads and BOD loads in excess of 235 pounds per acre per day. These experiences have been previously described. Favorable experience with highly colored effluents, such as caustic extract wash water with an initial color over 8000 ppm, and successful application for 18 weeks of 1/30 dilutions of kraft black liquor with a color over 10,000 ppm and a lignin concentration 40 times that of bleached kraft effluent, indicated that the buildup of color bodies in the soil is probably not significant in reducing soil permeability at field installations.

With the exception of delayed grass kill where sulfite pulp and papermill effluent was used as an irrigant, impaired grass growth has been accounted for by excessive organic loading or violation of well accepted soil and crop management practices. Examples of such violations are: high hydrogen ion concentrations in the irrigant creating acidic soils, excessive hydraulic

loadings, or the use of irrigants with unfavorable sodium adsorption ratios. Within these limitations, however, the effluents employed have been observed to produce grass equally as well or better than tap water.

One of the more significant observations of the investigations has been the merit of establishing, and need for adoption of, land disposal practices to maintain cover vegetation. Where maximum hydraulic loadings are desired, hence minimum land requirements such as is usually the case in waste disposal, the cover crop plays an important role. This was demonstrated by a twenty-fold increase in percolation rate on dense silt loam soil when a cover crop with an extensive root system was employed. Conversely, reduced percolation rates were consistently observed when conditions resulted in impairment or death of the cover crop during the irrigation season.

The alternate route of transfer for liquid afforded by evapotranspiration, and observed to lag between 50 and 90 percent in the laboratory during the summer months, reduces dependence on percolation as the sole source of water removal from the upper soil strata. Prevention of classification and dispersion of soil at the surface, which impedes filtration, are added benefits of the cover crop. It appears highly doubtful at the present time that the most economical land use for irrigation disposal can be accomplished unless the program is tailored around suitable cover vegetation.

GUIDES TO FIELD APPLICATION

In Table 5 are shown what are considered to be, based on the laboratory investigations to this time, the major areas of consideration in field application of land disposal and loading parameters in terms of effluent and soil characteristics. For high percolate quality, maintenance of cover vegetation, and good soil permeability, a BOD load of 200 pounds per acre per day is considered as approaching the upper limit. It does not appear at this time that there are sufficient color bodies present in effluents encountered in the field to be of significance in detrimentally changing soil characteristics. Potential ground water contamination may exist and individual site evaluations are warranted in these cases. Good soil and crop management practices dictate that the pH of applied effluents lie in the range of 6.5 to 9. We have observed no detrimental effects on salt tolerant vegetation or reduced soil filtration rates on rather permeable soils when the sodium adsorption ratio of the applied

effluent was less than 8. For high clay content soils the allowable sodium adsorption ratio may be less than 8.

SUMMARY AND CONCLUSIONS

The experimental work to date has pointed out an increased potential for, and some of the limitations of, pulp mill effluent disposal by irrigation. Some of the parameters of evaluation pertinent to its application have been developed from selected soils in the laboratory. The importance of the beneficial role of cover vegetation in land disposal has been demonstrated. Organic loading levels which produce high quality percolates insofar as BOD and aquatic biology aspects are concerned and which do not impair grass growth or soil permeability have been established for some typical soils. If ground water contamination by color might be detrimental, detailed studies employing the effluents and soil available at the site and a knowledge of underground water movement is to be advised. These investigations have demonstrated that many of the effluents from industry are suitable irrigants, producing grass in amounts at least equal to that produced by tap water.

Laboratory studies now in progress, or to be undertaken, will deal specifically with detailed changes in soil characteristics attributable to effluent application and a determination of suitable soil amendments that might be required. With the cooperation of member mills, these aspects are also being followed at field installations.

Table 1.
Effect of BOD Loading on Percolate Quality,
Cover Vegetation and Soil Permeability

BOD Loading Lb/Acre Day	BOD Reduction Percent	Cover Vegetation Condition	Soil Permeability
280	60-84	Poor	Impaired
< 235	95+	Good	Satisfactory

Table 2.
BOD Reduction in Kraft Effluent During Percolation
Through the Soil Under Seepage Beds

Simulated Pond Depth	Seepage Rate In./Day	Soil Residence Time Days	BOD Reduction Percent	
			Range	Mean
Shallow	0.25-0.5	27-54	73-89	81
Deep	0.25-0.6	23-54	51-90	72
Shallow	2.5-2.9	3- 3.5	25-41	32
Deep	2.8-3.7	2.4- 3.1	15-29	23

Table 3.
Effect of Soil Type on Color Transport

Soil Type	Effluent	Applied Effluent Color ppm	Color Reduction %
<u>During Effluent Application</u>			
Clay loams	Kraft & insulating board	1000 +	99
Sandy loam	Kraft & insulating board	1000 +	65
Silt loam & sandy loam	Sulfite	500	(-)70

Soil Type	Applied Effluent Color ppm	Percolate Color Change
<u>During Leaching</u>		
Olympic clay loam	1000 +	Negligible
Other soils	1000 + or sulfite	Increase

Table 4.

Summary of Sodium Leaching Reaction Rates by Soil Type

Soil Type	Median	Mean
Willamette silt loam	0.014	0.013
Olympic clay loam	0.0067	0.0068
Newberg sandy loam	0.010	0.010
Red Aiken clay loam	0.0079	0.0097

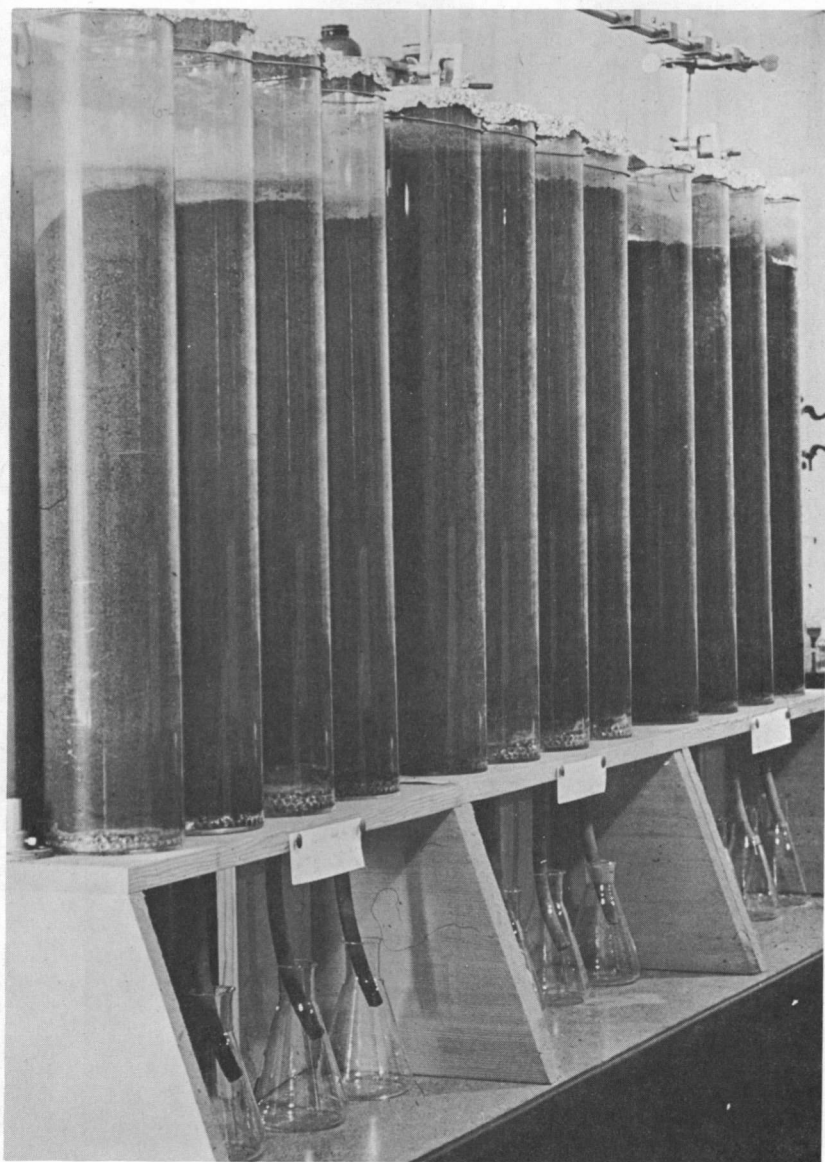


Figure 1.

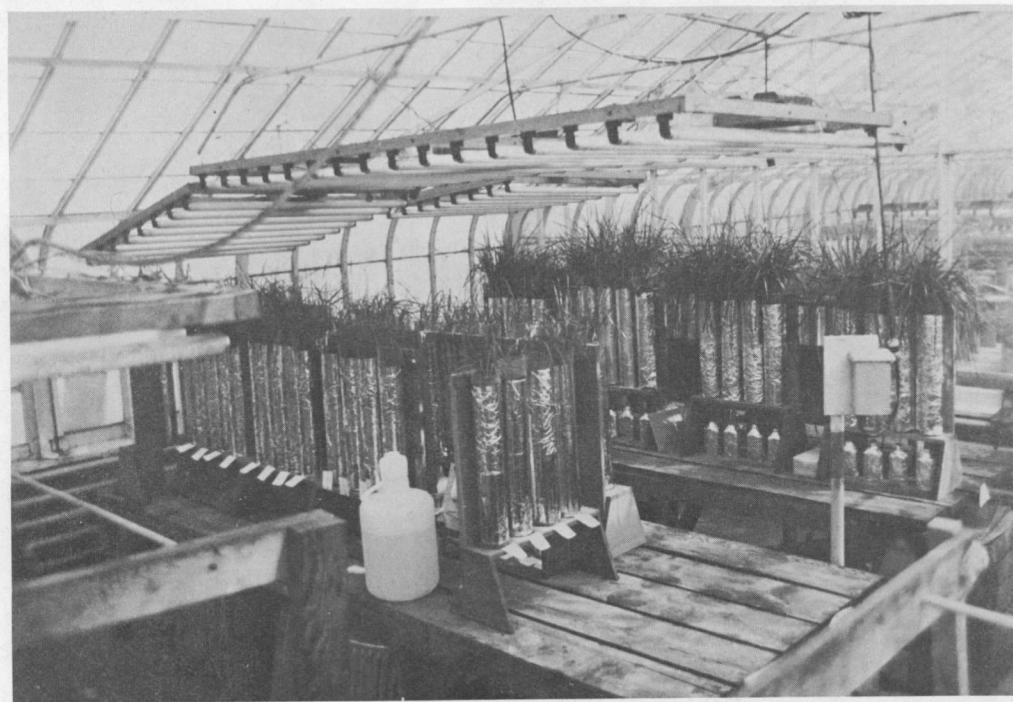


Figure 2.

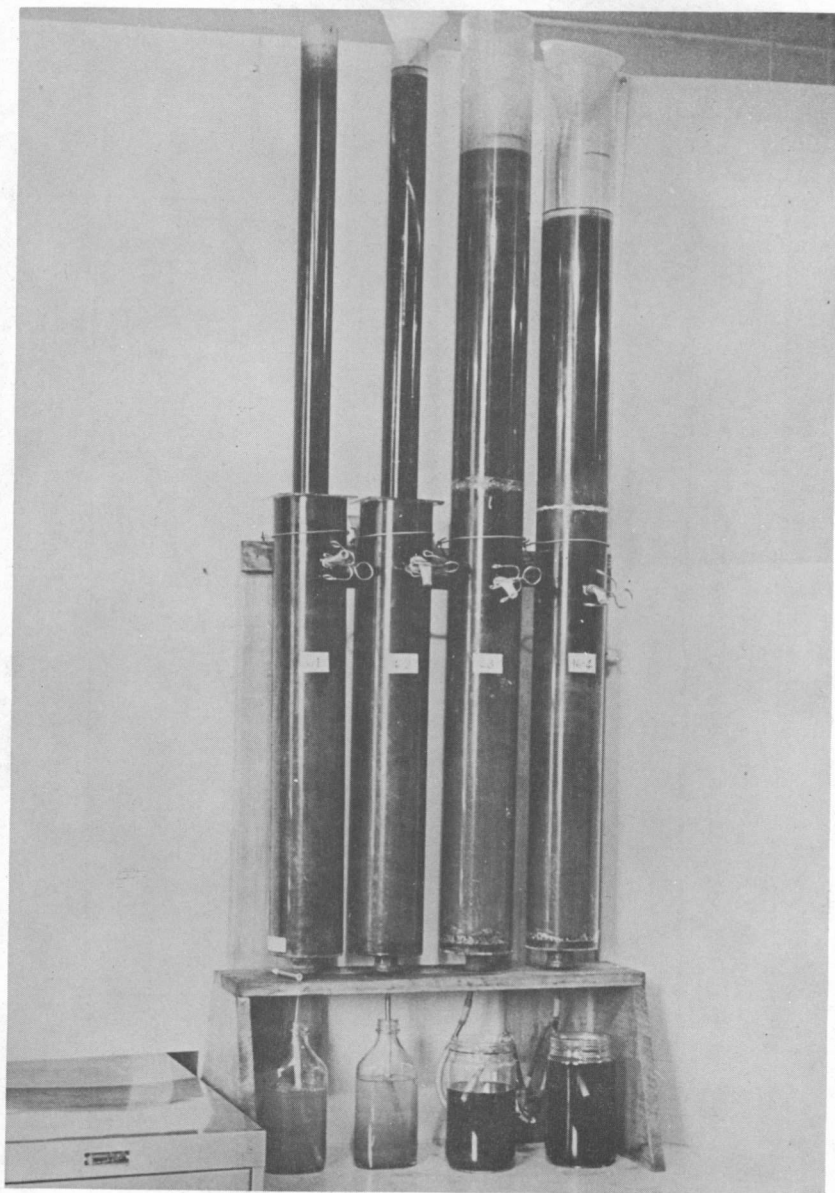


Figure 3.

FIGURE 4

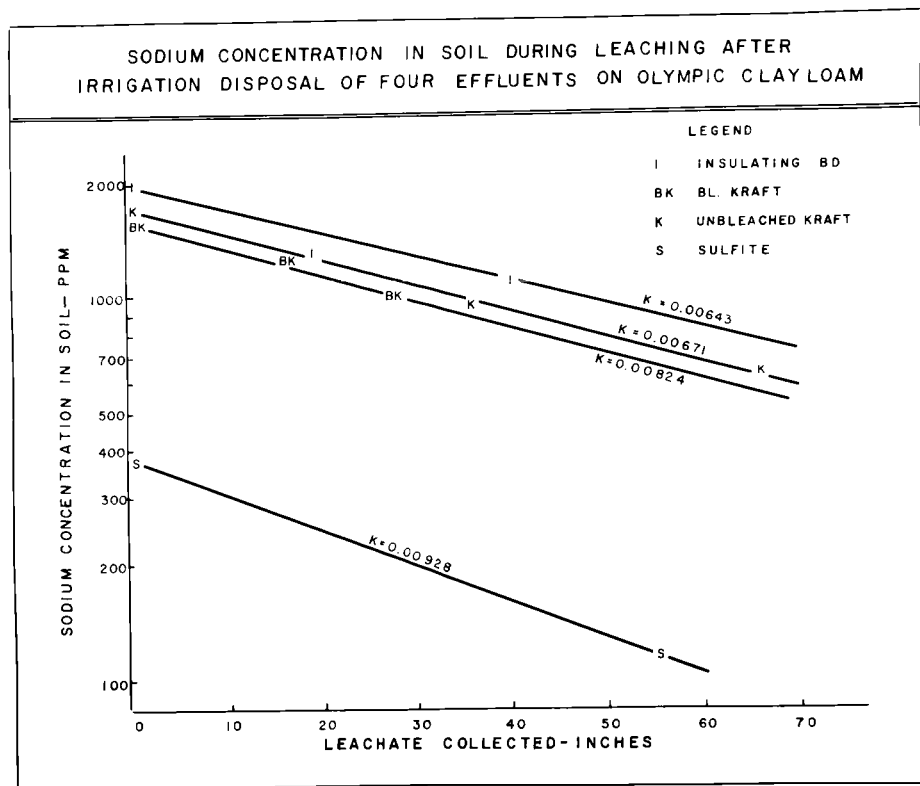


FIGURE 5

SODIUM ACCUMULATION IN CLAY LOAM SOIL
IRRIGATED WITH BLEACHED KRAFT AND SYNTHETIC
EFFLUENTS OF LIKE SALT CONCENTRATION

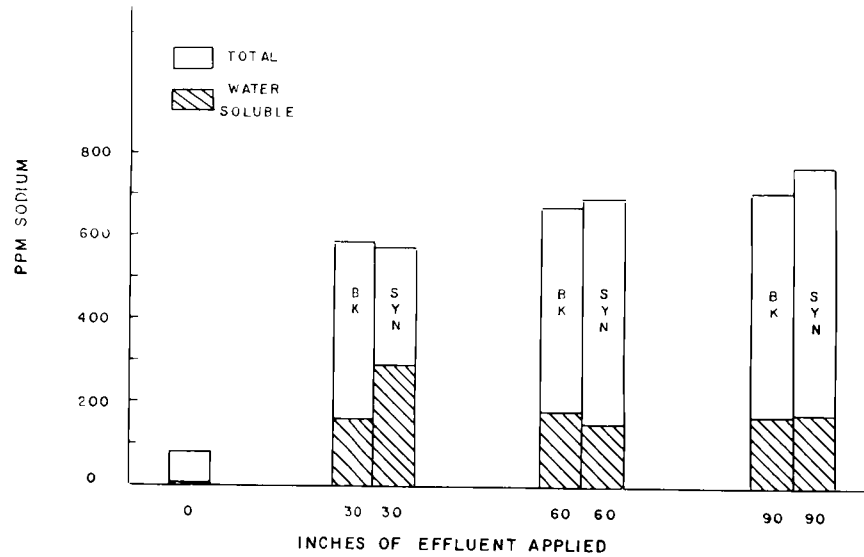


FIGURE 6

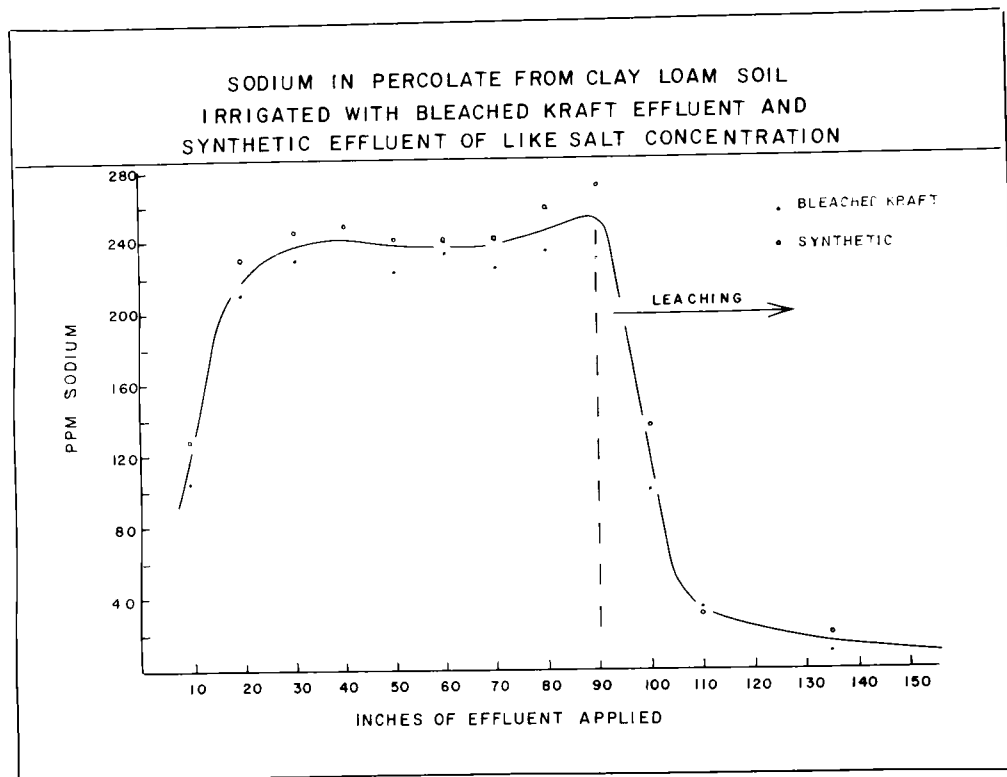
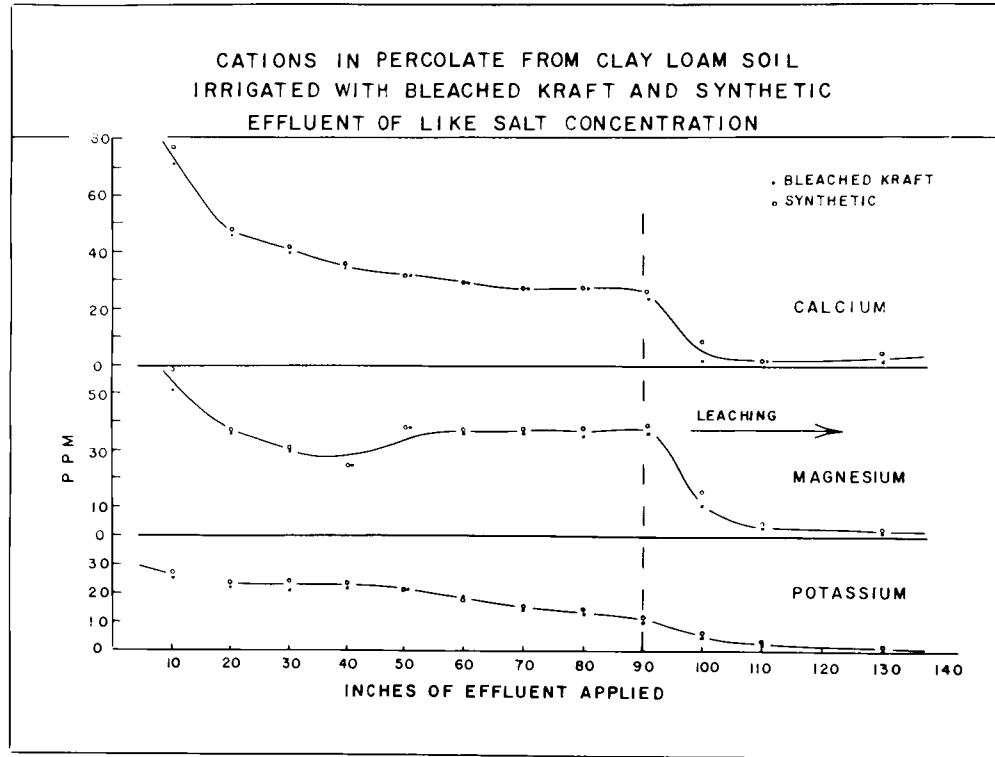


FIGURE 7



SYNTHETIC ORGANIC PESTICIDES AN EVALUATION OF THEIR PERSISTENCE IN NATURAL WATERS

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INTRODUCTION

In 1960, some 647,795,000 pounds of synthetic organic toxicants of various kinds were produced in the United States. Of this total, 90 percent were marketed during that year. If the entire production was used on land in the United States, a total use rate of approximately 215 pounds per square mile or just slightly more than one-third of a pound per acre is indicated.

The discharge of this vast tonnage of organic substance to the environment is a significant factor to those concerned with the presence and the long-range implication of exotic substances in the ground and surface waters. The size of the figure speaks as well for the need to understand the fate and behavior of this class of exotic organics in natural waters.

The chlorinated hydrocarbons which include the popular insecticides DDT, aldrin, and lindane are of greatest commercial significance. Also classed with this group are the phenoxyacetate herbicides and chlorinated fungicides. Combined, these chlorinated hydrocarbons make up slightly less than 80 percent of the total pesticides production of the United States. Also produced in significant amounts are the phosphorus containing insecticides.

Although these substances constitute less than 5 percent of the present production, their use is rapidly increasing and they will be of considerable significance in years to come. Of less, but still marked commercial significance are the dithiocarbamates which are used for fungicidal purposes. These substances constitute approximately 2 percent of the total pesticide production. The remaining 13 percent is made up of thiocyanates, carbamates, various heterocyclic forms, the nitrophenols, and heavy metal substances. Prominent members of these commercially significant groups are shown in Table 1.

The vast increase in use of the synthetic organic pesticides has occurred during the past decade. During this period considerable data regarding the acute toxicity levels for many substances have been determined. It is clear, however, from

reports such as that of Rosen and Middleton⁽²⁹⁾ that there is a need for the development of knowledge concerning the fate of pesticidal substances. It is a significant and somewhat revealing fact that little or no work pertaining to the long-range environmental persistence and the chronic toxicity levels of most of the commercially important materials has been reported.

This report deals with the extent of persistence of the commercially significant groups of pesticidal substances. It is essential, therefore, at the onset to define what is intended when the word persistence is used. A substance is termed persistent if it or its degradation products can be identified in an environment which can be shown to contain a biota of saprophytic capability. Persistence, then, is the result of a reduced rate of the essential catabolic steps leading to the complete conversion of the material to carbon dioxide and water. In the same fashion, a material can only be said not to be persistent from laboratory type studies unless it can be shown to support the growth of a microbial culture when offered as a sole carbon source.

The persistence of pesticidal substances, particularly the chlorinated hydrocarbons in normally saprophytic environments is attested to by several reports. There are also reports concerning the carry-over of pesticides to foods.

Martin⁽²⁾ reports that DDT, aldrin, chlordan, dieldrin, endrin, heptachlor, lindane, and toxiphen are not affected by or do not affect soil bacteria. Kiigemagi, et al⁽¹⁷⁾ report that the natural decrease in the field levels of aldrin, dieldrin, and heptachlor are not associated with the action of soil bacteria. MacPhee⁽¹⁸⁾ indicates from field studies that DDT, BHC, and chlordan persist for months and even years. The field persistence of these substances is borne out by such findings as that of Rosen and Middleton⁽²⁹⁾ who demonstrated the presence of several chlorinated insecticides in surface waters.

Ettinger and Ruchhofs⁽⁷⁾ report that low concentrations of the m- and p-monochlorophenols are destroyed by activated sludge. Ingols⁽¹³⁾ presents additional information on this subject, indicating that the monochlorophenols can be metabolized but cannot support a culture as a sole carbon source. Although Jönsson and Färaeus⁽¹⁶⁾ report the slow destruction of aldrin by soil bacteria in soil (10 percent per month), it is difficult to see how microbiological action could be proven, as no chloride was produced. Powers⁽²⁷⁾, in an unpublished memorandum, reports

the destruction of dichloro and pentachlorophenol. The latter work was apparently done in connection with one or several of the Dow Company's waste treatment plants.

Marth and Ellickson⁽¹⁹⁾ report the carry-over of DDT, BHC (benzene hexachloride), lindane, dieldrin, isotox, perthran, DDE, and methoxychlor in milk on treated crops and in other dairy products.

There appear to be no data concerning the destruction of the bridged biphenyl (DDT) compounds or, for that matter, none beyond that of Jönsson and Färaeus concerning the destruction of the methano bridged cyclodienes.

There are several reports of the biodegradation of many phenoxyacetate type weedicides in the literature. Johnson and Colmer⁽¹⁵⁾, Fernley and Evans⁽¹⁰⁾, Sleenon and Walker⁽³²⁾, Webley, et al⁽³⁴⁾, Audus⁽¹⁾, Byrde and Woodcock⁽⁵⁾, and Evans and Moss⁽⁸⁾, all report that microbial systems exist which can utilize 2,4-D and several homologous substances as sole carbon sources.

No reports were found concerning the destruction of the phosphorus containing insecticides by bacteria. In fact, there is a marked paucity of data concerning the destruction of phosphorus containing materials of any description. Slade⁽³¹⁾ and Rothstein⁽³⁰⁾ both report that phosphorylated intermediates are not metabolized by bacteria and yeasts. Mitchell⁽²³⁾ reports that phosphorus cannot enter the cell wall by simple diffusion processes. There are reports, however, of plant systems which can hydrolyze and apparently metabolize some fraction of the phosphorus containing insecticides⁽⁹⁾.

Two reports were obtained from the literature indicating the natural destruction of the urea-carbamate type of functional group. Jensen⁽¹⁴⁾ reports the destruction of thio-urea in farmyard manure, and MacPhee⁽¹⁸⁾, in a study of field persistence of a number of materials, observed that ferbam disappeared rapidly.

The literature reports, then, indicate a material variation in the persistence of pesticidal substances. The behavior of the materials appears to be closely related to the nature of the functional groups employed in producing a toxic substance.

RESULTS OF EXPERIMENTAL WORK

The metabolism studies were carried out with the Warburg microrespirometer at 20°C and with the conventional 5-day 20°C biochemical oxygen demand test. Cellular material was prepared for use in the Warburg by centrifugation and re-suspension in an ammonium phosphate buffer system which provided a COD/N ratio of 20. In some instances substrate depletion was followed directly with the infrared spectrophotometer, supernatant COD by the semi-micro method of Okey, et al⁽²⁵⁾, or a specific test for the substrate. The particularly insoluble insecticides were introduced into the Warburg flasks in petroleum ether solution and the solvent removed by gentle warming. All other materials were handled in water solution.

The experimental work was carried out in two principal phases. The first phase, employing unacclimated activated sludge grown on a combination of simple substrates, was designed to eliminate from further consideration those substances readily available for metabolic use. The second phase of the work was carried out with sludges adapted to specific carbon skeletons and designed to permit an evaluation of the effects of substitution.

For phase one it was desired to use a test system grown on a medium generally comparable in proportion of fat, protein, and carbohydrate to vegetable leachate, although no attempt was made to duplicate specific components of leachate. The synthetic sewage or growth medium employed for this work is shown in Table 2.

The test substances examined in the screening study are shown in Table 3. Because of the broad implications resulting from use of unacclimated cellular material and the problem of evaluating the effects of low solubility, the results of this study have been classed in broad activity categories in Table 5 on the basis of the standards set forth in Table 4. It is seen that, with minor exceptions, the materials fall into similar activity classifications based on the nature of their functional groups.

The bulk of the chlorinated materials are in the nil or slight response category with the exception of the chlorinated weedicides, which all appeared to undergo substantial degradation by the unacclimated activated sludge. The phosphorus containing insecticides all fall into the nil activity group. The dithiocarbamates were all materially attacked except those containing zinc.

According to Horsefall⁽¹²⁾, zinc is one of the more toxic metals, and it is suggested therefore that since identical carbon frames carrying other metals were readily metabolized, that the difference observed here was due to the metal itself.

From the screening studies four classes of compounds appear to be resistant to attack by unacclimated activated sludge. These substances were DDT, the methano bridged insecticides, the chlorinated phenols, and the phosphorus insecticides. Further studies were carried out to develop information as to the basic cause of this resistivity.

Four chlorinated insecticides were first examined in long-term acclimation studies. Four, 15-liter reactors were inoculated in settled sewage and soil effluent three times a week over a period of 6 months. During that period the insecticides were added in water dispersion employing a wetting agent of the triton series of low biodegradability. Sufficient material was added to result in a final concentration of 50 mg/l of the insecticide. After 6 months the entire reactors were extracted with carbon tetrachloride and the infrared spectra of the extracts obtained. In each instant the spectrum of the material recovered was identical with the spectrum of the pure insecticide. No bands indicating the presence of partially oxidized degradation products were observed. It was noted that a diverse biota including algae, protozoa, bacteria, and fungi flourished in the reactors, seemingly unaffected by the presence of the toxicant.

A series of Warburg examinations was carried out to evaluate the effect of extent, location, and orientation relative to other functional groups of chlorine substitution on a carbon frame to which the activated sludge test had been adapted. The results of this work are shown in Tables 6 and 7.

The 8-carbon and longer substituted materials were metabolized at the same rate as the nonsubstituted substrate. However, n-chlorohexane was metabolized at a substantially reduced rate and the chlorobutanes underwent little assimilation.

The metabolism of chlorinated cyclic materials also appears to be affected by size and spatial considerations. Monochlorobenzene was not attacked by a culture raised on benzene. However, a culture raised on naphthalene metabolized substantial quantities of 1- and 2-monochloronaphthalene. According

to Walker and Wiltshire⁽³³⁾, metabolism proceeds via an attack on the unsubstituted ring.

The presence of an oxidized group also appeared to affect the metabolism of cyclic chlorinated organics. The culture grown on phenoxyacetic acid was able to assimilate a material quantity of the dichloro homolog. In contrast, the culture grown on benzoic acid metabolized only a small quantity of the dichloro homolog, but substantial quantities of the monochlorinated substances. Monochlorobenzene underwent only slight attack by a benzene culture. However, 4-chlorocatechol was attacked at substantially the same rate as the unsubstituted homolog by both a benzene and benzoic acid culture.

The results of the study of the chlorinated phenols are not reported in Table 7. These materials have been shown to uncouple oxidative phosphorylation in higher animal systems⁽¹¹⁾. This phenomenon was observed in this work. The uncoupling phenomenon is accompanied by large increases in respiration without concomitant destruction of the substrate occurring. The results of the study of the monochlorinated phenols demonstrating this behavior are shown in Figure 1.

The metabolism of compounds of the DDT class was studied by an analysis of the metabolic behavior of a series of bridged biphenyl compounds. These materials, their structures and the results of the Warburg studies are shown in Table 8. A culture was obtained only on 4-methylbenzophenone. It was not possible to obtain a culture on or demonstrate metabolism of compounds containing a secondary or tertiary central carbon. Further, it was not possible to acclimate the benzophenone culture to any of the resistant substances.

The metabolism of the benzophenone series was reduced to nil by the presence of two chlorine atoms. *p*, *p'*-dichlorobenzophenone was substantially inert to metabolic attack.

Little appears to be known concerning the metabolism of methano bridged compounds similar to the cyclodiene insecticides. For the study of the biodegradability of the methano bridge an activated sludge was grown on camphor as a sole carbon source. Rapid growth of this culture and follow-up on Warburg studies demonstrated that the bridge, *per se*, was not a deterrent to microbial metabolism.

Development of an activated sludge with the capability

to assimilate the methano bridge provided a means of examining the effect of chlorination on the biodegradability of this class of compounds. Two high purity materials were obtained for this purpose from pesticide manufacturers. These substances, aldrin diacid and HET acid, which are shown in Figure 2, were subjected to Warburg examination and were used as substrates in unsuccessful attempts to develop cultures from small quantities of inoculum. This work was particularly significant in that the salts of both acids employed were extremely soluble in comparison to the analogous insecticides. Rejection by the camphor culture of these substances at concentrations of 150 mg/l indicated that the low solubility of the insecticides was not the primary reason for their resistance to metabolic attack.

To study the metabolism of phosphorus containing materials cross substrate studies were carried out with non-insecticidal phosphorus containing analogs. The materials studied, their structures, the analogous base or culture substrate of the test activated sludge and the results of the study are shown in Table 9.

It was not possible to demonstrate metabolism of any phosphorus substituted analogs. Further, it was evident that these materials did not interfere with the normal patterns of cell metabolism. TEPP is known to substantially irreversibly inhibit a broad spectrum of esterases, lipases, and peptidases in higher animals⁽²²⁾. In this study purified TEPP at 300 mg/l did not affect the microbial metabolism of ethylacetate, corn oil, or bactopectone. Finally, phosphorylated intermediates such as glucose and fructose phosphate were not metabolized by a culture grown on glucose, in general agreement with the report of Slade⁽³¹⁾.

Attempts to develop cultures from small inoculum on the phosphorus containing materials also were unsuccessful, as were attempts to acclimate cultures grown on benzoic acid and phenylacetic acid. Although activated sludge cultures were obtained on both TEPP and malathion, it was observed that cellular material from neither culture was able to metabolize freshly prepared substrate. This finding indicated acclimation to the products of hydrolysis, but not to the parent material.

The heterocyclic weedicide, aminotriazole, was found to be resistant to metabolic attack in the screening studies. Attempts to develop an activated sludge culture on this compound were not successful, nor were attempts to acclimate cellular

material derived from other cultures. In additional Warburg studies this substance did not appear to interact in any way with the activated sludge.

DISCUSSION

The experimental findings have demonstrated that the biochemical behavior of the pesticides and pesticide-like materials studied may be categorized on the basis of the functional groups present on the molecule and certain spatial molecular characteristics. Specifically, these controlling features appear to be:

1. The size and spatial relationship between the site of substitution and possible sites of metabolic attack
2. The nature of the functional group
3. The number of functional groups

It is significant that these are the same features which control chemical reactivity.

Substituents of greatest importance in reducing the rate of biodegradation of commercially significant pesticides are chlorine and phosphorus. Pesticides carrying the dithiocarbamate and the thiocyanate functional groups were readily metabolized.

The metabolism of nonaromatic chlorinated organic substances appeared to be impeded when the chlorine was located less than 6 carbon atoms from a site of attack. The metabolism of the cyclodiene insecticides such as dieldrin and aldrin was found to be nil. It is suggested that the resistance to metabolic attack is due to the proximity and number of substituted chlorine atoms. The biodegradation of the acyclic chlorinated fungicides is probably inhibited by the same mechanism. In accordance with the available data on the subject, it was assumed that the site of chlorine substitution was not the site of initial attack (33)(8).

The observation that chlorine appears to affect the behavior of substrates 4 carbons in length coincides with the report of Badger⁽²⁾ that the chemical effect of chlorine appears to extend a distance of 4 carbons away from the site of substitution. Badger's report was based on the finding that the ionization of

chlorinated monocarboxylic acids is affected a distance of 4 carbons away from the site of substitution.

The systematic increase in biodegradability with increasing numbers of substrate oxidized functional groups strongly suggests that the ease of total destruction is associated with the degree of completion of the oxidative phase of assimilation existing before the substrate is in contact with the micro-biota. That is, it appeared in the studies of the chlorinated cyclic compounds that the critical rate limiting steps were those preceding ring scission. When the oxidative steps preceding ring scission were completed, as was the case with 4-chlorocatechol, no significant deterrent to metabolism was observed. Regardless of the number of oxidized functional groups, the findings suggest, however, that substrate chlorination in excess of three is sufficient to substantially eliminate biological attack on the molecule. This observation is derived from the finding of partial metabolism of 2,4, 5-trichlorophenoxyacetate by the sludge raised on 2, 4-D as a sole carbon source and the lack of metabolism of the highly chlorinated but highly oxidized methanobridged acids.

The persistence of the DDT type compounds is apparently not due to the presence of chlorine alone. The primary deterrent to metabolism appears to be derived from the configuration of the carbon skeleton itself, specifically the configuration around the central or bridge carbon atom. The bridge carbon of DDT is seen to be secondary in nature. In the study of DDT metabolism, materials containing normal, secondary, and tertiary bridge carbons were examined. Growth was obtained readily on those substances containing no branching at the central carbon. On the other hand, when the substrate contained a secondary or tertiary central carbon, no assimilation was observed nor was it possible to develop activated sludges on those materials. It is suggested that this observation is similar to that of Bogan and Sawyer⁽⁴⁾ and McKinney and Symons⁽²¹⁾ concerning the biodegradation of the branched chain alkyl benzene sulfonates.

An analysis of the necessary configuration of the DDT molecule provides some insight as to the steric nature of the enzyme required to assimilate this form. Using Pauling's data for bond distances and angles⁽²⁵⁾, it is seen that the form of the molecule that is physically possible is that of an inverted 'v' with the trichloro group at the apex and the benzene rings providing the sides. The ortho hydrogen atoms of the benzene

rings can interfere if the benzene rings are placed in the same plane. It is likely, therefore, that the rings neither exist in the same plane nor as mirror images of each other. Therefore, if the bridge carbon must be attacked directly, the enzyme must approach through the opening in the 'v'.

The chlorinated phenols were observed to cause an increase in respiration without concomitant removal of substrate. This phenomenon is associated with the uncoupling of the enzyme systems which produce high energy phosphate (ATP), for the coupling mechanism appears to act as a governing device controlling the rate of endogenous respiration. That the halophenols enter into the uncoupling reaction has been reported also by Clowes and Krawi⁽⁶⁾ and others⁽¹¹⁾. Rich and Yates⁽²⁸⁾, in an analysis of the effect of 2,4-dinitrophenol on activated sludge also observed this phenomenon.

When an uncoupler is present in the medium synthesis of new cellular material is reduced or stopped altogether. Although these materials appear to undergo biodegradation at some limited rate, as observed in this work and has been reported by others⁽¹³⁾⁽⁷⁾, it is suggested that an uncoupler in high enough concentration could destroy an activated sludge culture simply by increasing the rate of self utilization.

The persistence of the phosphorus containing materials was complete; it was not possible to demonstrate the metabolism of any intact phosphorus containing molecule. The underlying cause of inertness of the phosphorus containing materials is not fully understood. It has been reported, however, that certain metabolic intermediates do not pass through the wall of a variety of cells⁽²³⁾⁽³⁰⁾⁽³¹⁾. It is suggested that the inertness of this group of substances is associated with a carefully controlled mechanism for the transport of phosphorus itself. Mitchell⁽²³⁾, in an analysis of phosphate movement in Staphylococci noted that there is no simple diffusion in or out of the cell and that the alteration in the physical or electronic makeup of the substrate resulted in a cessation of phosphate transport.

Although the activity of the saprophytic microorganisms would appear to be of primary importance in determining the fate of pesticidal substances, several of these materials enter into chemical reactions which are of extreme importance in determining their persistence and the nature of the residues.

The phosphates and thionophosphates hydrolyze at the pH values normally expected in surface waters. The bulk of the phosphorus insecticides have half lives of 1-3 days at pH 7⁽²²⁾. The notable exception to this general rule is parathion, which has a half life of 120 days and can, therefore, be a toxic threat for a considerable length of time.

The hydrolysis of the toxic esters yields an organic fraction and a diester which further hydrolyzes producing a monoester and an additional organic fragment. Only the first stage hydrolysis of the phosphate esters is well understood. From data supplied by O'Brien⁽²⁴⁾, it appears that the monoesters and diesters have widely varying half lives at stream pH values. The diester appears to be the most stable. It is anticipated, then, that the intact insecticide will disappear rapidly (with the exception of parathion), but will produce, by hydrolysis, a diester and a monoester. The di- and monoesters may then persist for an extended period of time. In some instances, as with the two parathions, the nitrophenol organic fraction may, in itself, be toxic.

Only three chlorinated materials of commercial significance undergo chemical reactions in the environment which will affect their longevity⁽²²⁾. These are chlordan, toxiphen, and lindane (BHC). Both chlordan and toxiphen appear to undergo dehydrochlorination with warmth and sunlight and produce as yet unidentified chlorinated degradation products. Lindane also undergoes dehydrochlorination in an alkaline environment to produce primarily 1, 2, 4-trichlorobenzene. The latter material appeared to be resistant to metabolic attack. Biokin⁽³⁾ reports that in sunlight and warmth, DDT undergoes oxidation to 4, 4'-dichlorobenzophenone. The reports of lengthy persistence of this material and the results obtained here do not support this contention, however.

The heterocyclic weedicide, aminotriazole, was observed to be resistant to attack in all studies carried out on this material. This finding appears to be consistent with the report of Horsefall⁽¹²⁾, indicating that the inclusion of nitrogen as a heteroatom profoundly affects the biological activity of cyclic compounds.

SUMMARY AND CONCLUSIONS

A study of the molecular features of pesticidal substances pertinent to their persistence in the environment has been carried out. An analysis of the chemical and biological degradability of pesticidal materials as a function of their molecular form has been used to evaluate the life of the substance or significant degradation products thereof in the biosphere. Studies were carried out to evaluate the effect of the type, number, and location of certain functional groups on the fate of the substance in the environment. An analysis of the biodegradability of the carbon skeleton of the commercially significant classes of pesticides was also carried out. The following conclusions are drawn:

1. The majority of the chlorinated pesticides were resistant to biodegradation. The significant exceptions to this general behavior pattern were the chlorinated weedicides of the 2,4-D series which appeared, for the most part, to undergo substantially complete degradation. The extent to which chlorine affects biodegradation was related to the number and location of the chlorine atoms, the presence and nature of other substituents on the pesticide.
2. In most instances the persistence of the chlorinated pesticides is due to the high degree of chlorine substitution. This applies to the methano bridged cyclodienes of the dieldrin series, chlorinated phenols, and probably to the acyclic chlorinated fumigants and fungicides, as well. The resistance of DDT to biodegradation appears to be due to the presence of a secondary carbon at the bridge location.
3. The weedicide, aminotriazole, was observed to be resistant to biological attack.
4. The presence of phosphorus in its oxidized state appears to severely deter the metabolism of an organic compound. It is concluded that the phosphorus containing insecticides and their hydrolysis products will persist for a material length of time. Fortunately, most of the materials have half lives of less than 2-3 days at normal stream pH values. Parathion, with a half life of 120 days at pH 7 is the notable exception to this general rule and can be expected to persist for extended periods in a neutral environment. Further, both parathion and methyl parathion produce, on hydrolysis, p-nitrophenol which is in itself resistant to biological attack and an uncoupler of

oxidative phosphorylation.

5. The increasing production and use of the acyclic or non-nitrated cyclic phosphorus containing insecticides appears to have considerable merit. These substances hydrolyze rapidly and produce degradation products which appear to be readily available as microbial substrates.

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TABLE 1

REPRESENTATIVE COMPOUNDS OF COMMERCIALY
SIGNIFICANT PESTICIDAL GROUPS

TRADE NAME	STRUCTURE	CHEMICAL NAME
DDT		2,2,BIS (P-CHLOROPHENYL) 1,1,1,-TRICHLOROETHANE
LINDANE		1,2,3,4,5,6-HEXACHLORO CYCLOHEXANE γ ISOMER
ALDRIN		1,2,3,4,10,10-HEXACHLORO-1, 4,4A,5,8,8A-HEXAHYDRO-1,4- ENDO,EXO,5,8-DIMETHANO NAPHTHALENE
2,4-D		2,4-DICHLOROPHENOXYACETIC ACID
PARATHION		O,O-DIETHYL O-P- NITROPHENYL THIONO- PHOSPHATE
ZINEB		ZINC ETHYLENE BIS DITHIOCARBAMATE

TABLE 2

NATURE AND QUANTITY OF MATERIALS EMPLOYED
IN SYNTHETIC CULTURE MEDIUM

MATERIAL	CONCENTRATION
$\text{NaNH}_2\text{HPO}_4$	50 MG/L
KH_2PO_4	25 MG/L
NH_4CL	50 MG/L
$(\text{NH}_4)_2\text{HPO}_4$	20 MG/L
MgSO_4	50 MG/L
FeCL_3	5 MG/L
CaCL_2	50 MG/L
GLUCOSE	400 MG/L
CASTILE SOAP	50 MG/L
BEEF EXTRACT	50 MG/L
CHEMICAL OXYGEN DEMAND	650 MG/L
BIOCHEMICAL OXYGEN DEMAND	300 MG/L

TABLE 3

PURITY AND SOURCE OF MATERIALS USED IN STUDY OF PESTICIDAL SUBSTANCES

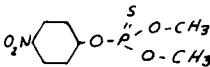
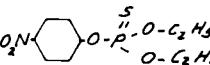
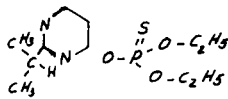
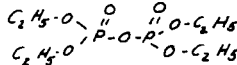
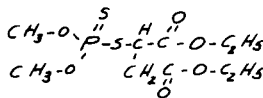
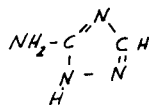
TRADE NAME	CHEMICAL NAME	STRUCTURE	SOURCE	GRADE
METHYL PARATHION	O,O-DIMETHYL O-P-NITROPHENYL THIONO-PHOSPHATE		MONSANTO CHEM. CO.	100%
PARATHION	O,O-DIETHYL O-P-NITROPHENYL THIONO-PHOSPHATE		MONSANTO CHEM. CO.	99.9%
DIAZINON	O,O-DIETHYL O-2-ISOPROPYL 4-METHYL-6-PYRIMIDYL THIONO-PHOSPHATE		GEIGY CHEM. CORP.	96.43%
TEPP	TETRAETHYL PYROPHOSPHATE		CALIF. SPRAY CHEM. CORP.	40%
MALATHION	O,O-DIMETHYL-S-(1,2-DICARBOETHOXYETHYL) DITHIO-PHOSPHATE		AMER. CYANIMIDE CO.	95%
AMINOTRIAZOLE	1-AMINO 2,3,5-TRIAZOLE		AMER. CYANIMIDE CO.	96.1%

TABLE 3 (CONTINUED)

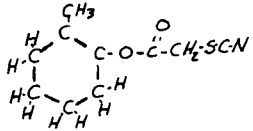
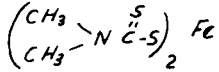
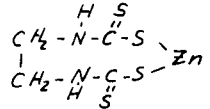
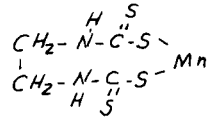
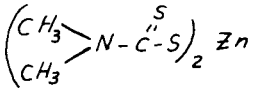
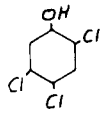
TRADE NAME	CHEMICAL NAME	STRUCTURE	SOURCE	GRADE
THANITE	ISOBORNYL THIOCYANO ACETATE		HERCULES POWDER CO.	97.2%
FERBAM	FE DIMETHYL- DITHIOCARBAMATE		DUPONT CHEM. CO.	PURIF.
ZINEB	ZN ETHYLENE BIS DITHIOCARBAMATE		DUPONT CHEM. CO.	PURIF.
MANEB	MN ETHYLENE BIS DITHIOCARBAMATE		DUPONT CHEM. CO.	PURIF.
ZIRAM	ZN DIMETHYL DITHIOCARBAMATE		DUPONT CHEM. CO.	PURIF.
TRICHLOROPHENOL	2,4,5-TRICHLORO- PHENOL		DOW CHEM. CO.	90%

TABLE 3 (CONTINUED)


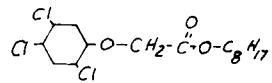
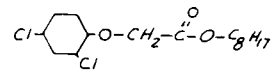
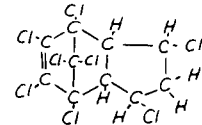
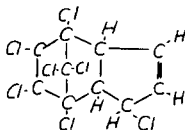
TRADE NAME	CHEMICAL NAME	STRUCTURE	SOURCE	GRADE
PENTACHLORO- PHENOL - PENTA	SAME		DOW CHEM. CO.	83%
ISOCTYL 2,4,5-T ESTER	ISOCTYL 2,4,5- TRICHLOROPHENOXY- ACETATE		MONSANTO CHEM. CO.	TECH.
ISOCTYL 2,4-D ESTER	ISOCTYL 2,4- DICHLOROPHENOXY- ACETATE		MONSANTO CHEM. CO.	TECH.
CHLORDAN	4,5,6,7,8-HEXA- CHLORO 3A,4,7,7A- TETRAHYDRO-4,7- METHANOINDENE		VELSICOL CHEM. CO.	REF.
HEPTACHLOR	1,4,5,6,7,8- HEPTACHLORO-3A,4,7, 7A-TETRA HYDRO- 4,7-METHANOINDENE		VELSICOL CHEM. CO.	REF.

TABLE 3 (CONTINUED)

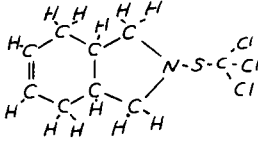
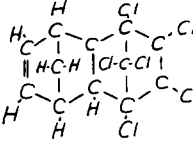
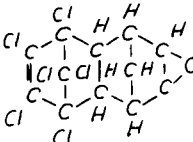
TRADE NAME	CHEMICAL NAME	STRUCTURE	SOURCE	GRADE
CAPTAN	N-TRICHLOROMETHYL- MERCAPTO-4-CYCLOHEXANE 1,2-DICARBONIMIDE		CALIF. SPRAY CHEM. CORP.	PURIF.
ALDRIN	1,2,3,4,10,10-HEXA- CHLORO-1,4,4A,5,8,8A- HEXAHYDRO-1,4-ENDO,EXO- 5,8-DIMETHANO NAPHTHALENE		SHELL CHEM. CO.	98.5%
ENDRIN	1,2,3,4,10,10-HEXA- CHLORO-6,7-EPOXY- 1,4,4A,5,6,7,8,8A- OCTAHYDRO-1,4-ENDO- 5,8-DIMETHANO NAPHTHALENE		SHELL CHEM. CO.	98.2%

TABLE 3 (CONTINUED)

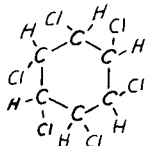
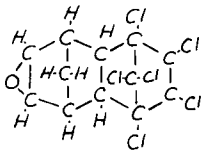
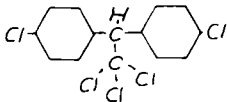
TRADE NAME	CHEMICAL NAME	STRUCTURE	SOURCE	GRADE
HEXACHLORO- CYCLOHEXANE	1,2,3,4,5,6-HEXA- CHLOROCYCLOHEXANE ISOMER		CALIF. SPRAY CHEM. CORP.	PURIF.
DIELDRIN	1,2,3,4,10,10-HEXA- CHLORO 6,7-EPOXY-1,4, 4A,5,6,7,8,8A-OCTAHYDRO 1,4,ENDO,exo-5,8- DIMETHANO NAPHTHALENE		SHELL CHEM. CORP.	99.9%
DDT	2,2,BIS (P-CHLORO- PHENYL) 1,1,1- TRICHLOROETHANE		MONSANTO CHEM. Co.	TECH.

TABLE 4
STANDARDS FOR REPORTING METABOLIC ACTIVITY IN
SCREENING OF PESTICIDAL COMPOUNDS

WARBURG EXAMINATIONS (150 μ g - 300 μ g)		BOTTLE BOD EXAMINATIONS (10 mg/L)	
EXTENT OF METABOLISM	OXYGEN UTILIZATION	EXTENT OF METABOLISM	OXYGEN UTILIZATION
MATERIAL	20% OF ULTIMATE BOD (COD)	MATERIAL	20% OF ULTIMATE BOD (COD)
SLIGHT	5-20% OF ULTIMATE BOD (COD)	SLIGHT	2% OF ULTIMATE BOD (COD)
NIL	LESS THAN 5% OF ULTIMATE BOD (COD)		
INHIBITING	10% BELOW BLANK @ 300 MIN.		

TABLE 5
CLASSIFICATION OF SCREENING STUDY RESULTS
ON THE BASIS OF METABOLIC ACTIVITY
OF TEST SUBSTANCES

INHIBITION	NIL RESPONSE	SLIGHT ATTACK	MATERIAL ATTACK
CAPTAN	METHYL PARATHION	ZIRAM	FERBAM
PENTACHLORO-PHENOL (@ 150 mg/L)	DIAZINON	ZINEB	THANITE
	TEPP	TRICHLOROPHENOL	MANEB
	MALATHION	CHLORDAN	2,4,5-T ACID (@ 75 mg/L)
	PARATHION	HEPTACHLOR	2,4-D ISOOCTYL ESTER
	PENTACHLORO-PHENOL (@ 75 mg/L)	2,4,5-T ACID (@ 150 mg/L)	2,4,5-T N-BUTYL ESTER
	DDT		
	AMINOTRIAZOLE		
	ENDRIN		
	DIELORIN		
	ALDRIN		
	LINDANE		

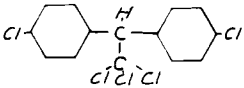
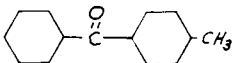
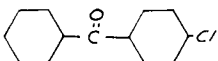
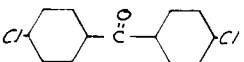
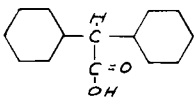
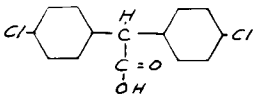
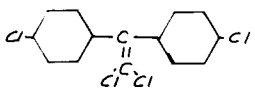
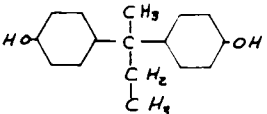
TABLE 6
METABOLISM OF ACYCLIC CHLORINATED COMPOUNDS

CULTURE SUBSTRATE	TEST SUBSTRATE	EXTENT OF METABOLISM	REMARKS
TETRADECANE	1-CHLOROTETRADECANE	COMPLETE	
DECANE	1-CHLORODECANE	COMPLETE	
OCTANE	1-CHLOROOCANE	COMPLETE	
	2-CHLOROOCANE	COMPLETE	
HEXANE	1-CHLOROHXANE	COMPLETE	METABOLISM OF CHLORINATED HOMOLOG SUBSTAN- TIALY REDUCED IN RATE
	1-CHLOROBUTANE	NIL (15% COMPLETE)	ACCLIMATION TO 4-CARBON COMPOUNDS
	2-CHLOROBUTANE	NIL (10% COMPLETE)	DEMONSTRATED BY SIMULTANEOUS ADAPTION TO N-BUTANOL

TABLE 7
METABOLISM OF CYCLIC CHLORINATED COMPOUNDS

CULTURE SUBSTRATE	TEST SUBSTRATE	EXTENT OF METABOLISM	REMARKS
BENZOIC ACID	4-CHLOROCATECHOL	COMPLETE	RATE MARKEDLY LESS THAN BENZOIC ACID
	m-CHLOROBENZOIC ACID	COMPLETE	
	p-CHLOROBENZOIC ACID	40 - 60% COMPLETE	
	o-CHLOROBENZOIC ACID	30 - 40% COMPLETE	
	2,4-DICHLOROBENZOIC ACID	15 - 20% COMPLETE	
PHENOXYACETIC ACID	p-CHLOROPHENOXY- ACETIC ACID	60% COMPLETE	
	2,4-DICHLOROPHENOXY- ACETIC ACID	60% COMPLETE	
2,4-DICHLORO- PHENOXYACETIC ACID	2,4,5-TRICHLORO- PHENOXYACETIC ACID	25% COMPLETE	
BENZENE	4-CHLOROCATECHOL	COMPLETE	RATE SLIGHTLY LESS THAN BENZENE
	MONOCHLOROBENZENE	NIL (LESS THAN 5% COMPLETE)	
	TRICHLOROBENZENE	NIL	
NAPHTHALENE	1-CHLORONAPHTHALENE	15% COMPLETE	
	2-CHLORONAPHTHALENE	9% COMPLETE	

TABLE 8
SUBSTRATES EMPLOYED IN
STUDY OF DDT METABOLISM

COMPOUND	STRUCTURE	REMARKS
P, P'-TRICHLORO-1-(BIS-PARACHLORO-PHENYL) ETHANE (DDT)		NIL
4-METHYLBENZO-PHENONE		READILY METABOLIZED
4-CHLOROBENZO-PHENONE		PARTIALLY METABOLIZED 75% COMPLETE
4,4'-DICHLORO-BENZOPHENONE		NIL
DIPHENYLACETIC ACID		NIL
P, P'-DICHLORO-DIPHENYLACETIC ACID (DDA)		NIL
2-DICHLORO-1-(BIS-PARACHLORO-PHENYL) ETHYLENE (DDE)		NIL
2,2-BUTYLIDENE-4,4'-BIPHENOL		NIL

A. WARBURG STUDIES CARRIED OUT WITH CELLULAR MATERIAL
DERIVED FROM 4-METHYLBENZOPHENONE

TABLE 9

ORGANOPHOSPHORUS CROSS SUBSTRATE STUDY SUBSTANCES

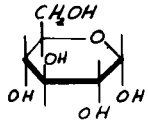
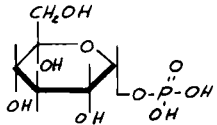
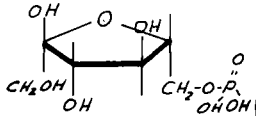
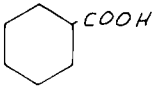
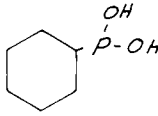
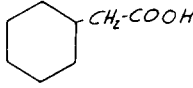
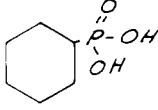
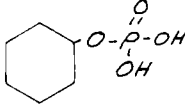
CULTURE SUBSTRATE		TEST SUBSTRATE		REMARKS
NAME	STRUCTURE	NAME	STRUCTURE	
DIETHYL CARBONATE	$\text{CH}_3\text{-CH}_2\text{-O}-\overset{\text{O}}{\parallel}\text{C}-\text{O}-\text{CH}_2\text{-CH}_3$	DIETHYL PHOSPHITE	$\text{CH}_3\text{-CH}_2\text{-O}-\overset{\text{OH}}{\underset{\cdot}{\text{P}}}\text{-O}-\text{CH}_2\text{-CH}_3$	NIL RESPONSE (HYDROLYSIS & METABOLISM OF HYDROLYSIS PRODUCTS)
4-OCTANOL	$\text{CH}_3\text{-CH}_2\text{-CH}_2\text{-}\overset{\text{OH}}{\underset{\cdot}{\text{CH}}}\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{-CH}_3$			
4-HEPTANOL	$\text{CH}_3\text{-CH}_2\text{-CH}_2\text{-}\overset{\text{OH}}{\underset{\cdot}{\text{CH}}}\text{-CH}_2\text{-CH}_2\text{-CH}_3$	DIMETHYL PHOSPHITE	$\text{CH}_3\text{-O}-\overset{\text{OH}}{\underset{\cdot}{\text{P}}}\text{-O}-\text{CH}_3$	
5-NONANONE	$\text{CH}_3\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{-}\overset{\text{O}}{\parallel}\text{C}-\text{CH}_2\text{-CH}_2\text{-CH}_2\text{-CH}_3$			NIL RESPONSE
4-HEPTANONE	$\text{CH}_3\text{-CH}_2\text{-CH}_2\text{-}\overset{\text{O}}{\parallel}\text{C}-\text{CH}_2\text{-CH}_2\text{-CH}_3$			
GLUCOSE		GLUCOSE 1-PHOSPHATE		NIL RESPONSE
		FRUCTOSE 6-PHOSPHATE		

TABLE 9 (CONTINUED)

NAME	CULTURE SUBSTRATE	NAME	TEST SUBSTRATE	REMARKS
	STRUCTURE		STRUCTURE	
BENZOIC ACID		PHENYL PHOS- PHONOUS ACID		NIL RESPONSE
PHENYL ACETIC ACID		PHENYL PHOS- PHONIC ACID		NIL RESPONSE
		PHENYL DIHY- DROGEN PHOS- PHATE		NIL RESPONSE (HYDROLYSIS & METABOLISM OF HYDROLYSIS PRODUCTS)

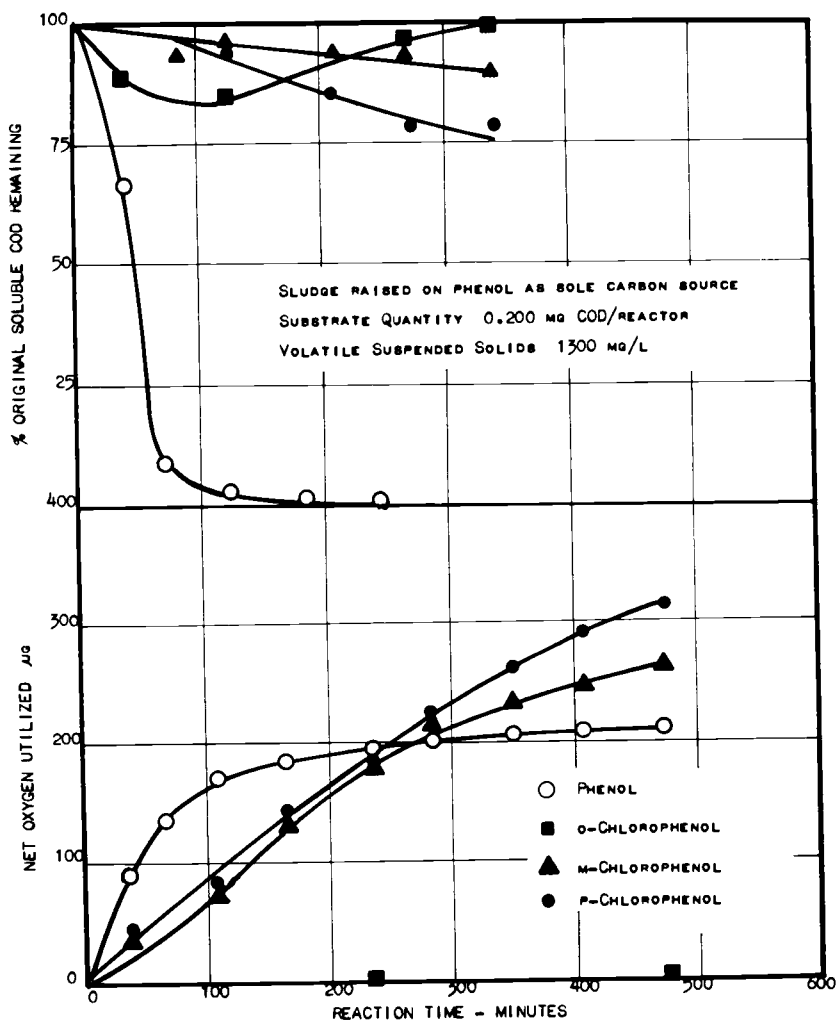
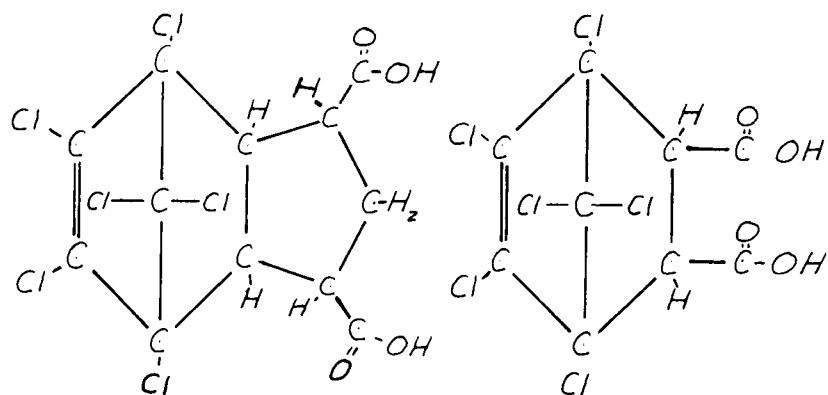


FIGURE 1 METABOLISM OF PHENOL AND MONOCHLOROPHENOLS



ALDRIN DIACID

HET ACID
(HEXACHLOROENDOMETHYLENE-
TETRAHYDROPHTHALIC ACID)

FIGURE 2 STRUCTURES OF ALDRIN DIACID AND HET ACID

PROPOSED SYSTEM FOR POLLUTION CONTROL IN THE COEUR D'ALENE RIVER VALLEY

LeVern M. Griffith

I wish to introduce this subject with a little historical background and a brief description of the geography in order that you may be correctly oriented and better understand the problems of pollution control in the area.

The South Fork of the Coeur d'Alene River flows west from the Montana line to its confluence with the Coeur d'Alene River 5 miles west of Kellogg, Idaho. The drainage is about 32 miles long. The valley is very narrow with steep mountains rising in a distance of 3 to 6 miles on each side to an elevation from 2,000 to 4,000 feet above the valley floor. Highway No. 10 from Spokane to Missoula goes up the valley before crossing the Montana line. The valley is also served by two railroads; branch lines of Union Pacific and Northern Pacific.

Water has never been a problem. It is clean and abundant. All of the domestic water needs of municipalities in the valley are served by gravity from nearby streams. The only wells are those used by industry for process water. For the most part the people living in this valley look on pollution control as a nuisance and an unnecessary cost. All sanitary wastes and most industrial wastes are dumped directly into the stream without treatment.

A Catholic priest, Father Ravelli, came into the area in 1847, and with Indian converts built the old Cataldo Mission, starting in 1848. Today, the original Mission church still stands and is the oldest building in Idaho. This church is on the Mission Flats, first slack water area of the Coeur d'Alene River drainage 12 miles west of Kellogg. I will be making reference to this area later. Captain John Mullan built the Pacific Northwest's second most important wagon road down the Coeur d'Alene River valley in 1859-1863 to provide a military road between the end of navigation on the Missouri River and the beginning of navigation on the Columbia, from Fort Benton in Missouri to Fort Walla Walla in Washington.

The South Fork of the Coeur d'Alene River is known in mining circles as the Coeur d'Alene Mining District, one of the eight richest mining districts in the world. The first gold rush into the area was on May 27, 1865. The second came in the

early spring of 1884. Gold prospectors fanning out over the area discovered lead-silver ore outcroppings of major importance in 1884. The Tiger Mine at Burke, the Polaris at Osburn, the Morning Mine at Mullan, and the Sunshine, 4 miles east of Kellogg, were staked out in 1884. The Bunker Hill, the largest, was discovered on September 10, 1885. Since that time there have been from 50 to 60 mines operating in the district. Today, only 7 mines are operating.

In 1917, the Bunker Hill built a lead smelter at Kellogg, Idaho; in 1928, an electrolytic zinc plant near Kellogg; in 1954, a sulphuric acid plant; and in 1960, a phosphoric acid plant. The only other industry in the area of any importance is lumbering, with a number of sawmills and wood treating plants in the valley. The industry supports a population of about 19,000 people, which represents over 90 percent of the total population of Shoshone County. The water pollutants consist primarily of the sanitary sewage from a population of approximately 17,000 people living next to the streams, and from the industrial wastes, very finely ground waste rock, from the concentrators treating the ores as they come from the mines, as well as the chemical wastes consisting of inorganic compounds and acids from the Bunker Hill's metallurgical plants. About two-thirds of the people live in Kellogg or to the west of Kellogg. The remainder of the people are in either the municipalities of Osburn, Wallace, Mullan, or scattered in small residential communities of 10 to 20 houses along the valley floor. With the exception of Smelterville and Osburn, none of the municipalities or residential communities has complete sewage collection systems. None of them has sewage treatment plants, and only Osburn has separate storm sewers. Pinehurst, 4 miles west of Kellogg, with a present population greater than Wallace, has no sewer system whatever.

In order to effect high recovery of the sulfide mineral values, the mined ore is finely ground to an average of about 40 percent-325 mesh for subsequent flotation of the values from the waste tailings.

Since 1949, more and more of the mines have resorted to sand filling, which is a system for returning all of the coarse fractions and a small part of the finer fractions of the tailings back into the mines to fill the voids created from the mining of the ore. About 55 percent of the total waste product from the concentration process, or 55 percent of the total tailings produced, are returned to the mines for sand filling. With the exception of the Bunker Hill Mine and the Page Mine, the

remaining 45 percent of fine tailings are dumped into the South Fork of the Coeur d'Alene River. The Bunker Hill and the Page both have tailings impounding areas which effectively remove all of the suspended solids. Tests have shown that the effluent from these impounding areas carry about 5 ppm of suspended solids. The tailings dumped into the river by the five mines east of Kellogg average better than 90 percent-325 mesh. The specific gravity of these tails varies from 2.6 to 3.5, with an average of 2.8. The mines are presently working five days a week, with the tailings being dumped into the stream today averaging 1,050 tons per working day. This amounts to 273,000 tons per year, or 116,000 cubic yards per year at a specific gravity of 2.8. The minimum flow of the South Fork of the Coeur d'Alene River averages in the order of 60 to 80 cubic feet per second. At this minimum flow the solids contributed by the mines to the stream are in the order of 6,000 ppm, or 0.6 percent. The North Fork of Coeur d'Alene River has a flow average about three times that of the South Fork, and at this point the dilution by the North Fork, an uncontaminated river, results in a silt load to the Coeur d'Alene River of approximately 0.15 percent or 1,500 ppm.

At Kellogg there are a number of sources of contaminated water. Drainage water from the mine averages about 1,400 gallons per minute with a pH of 3.4, 1,250 ppm of dissolved solids, and 213 ppm of undissolved solids, 370 ppm of sulfur as sulfate, 149 ppm of calcium oxide, and 55 ppm of iron. The effluent from the Bunker Hill tailings pond has a pH of 7.6. The pH of tailings water from other mines averages from 7.3 to 7.6. From the Bunker Hill smelter there is a flow of 4,500 gpm carrying 665 ppm of undissolved solids and 195 ppm of dissolved solids. There is 17 ppm of zinc, 0.2 ppm of lead, and the pH of this water is 7.1.

From the zinc plant we have a flow of 1,600 gpm with a pH of 2. This water carries 1,500 ppm of zinc.

From the phosphoric acid plant we have a flow of 660 gpm with a pH varying from 3.4 to 1.0 and carrying 250 ppm of F, 30 ppm of P_2O_5 , 470 ppm of CaO , 60 ppm of H_2SO_4 , and 3,101 of undissolved solids (gypsum silica, Al and Fe).

In 1929, the mine operators became concerned with the tailings load carried by the river and formed a Mine Operators Association for the purpose of installing and operating a dredge for the removal of mine tailings from the Coeur d'Alene River. This association purchased over 2,000 acres of land in the

vicinity of the old Mission below Cataldo. This is the area where the river first hits quiet water, approximately 12 miles west of Kellogg and 20 miles upstream from Coeur d'Alene Lake. The dredge was installed and began operations in mid-summer of 1932, impounding the dredged tailings behind dikes in the Mission Flats. Since then, many millions of cubic yards of materials have been impounded in this area. The installation and operating costs of this project have been close to \$2,000,000, with over 23 individual companies having voluntarily shared in this expense through the years. For the past two years the Idaho State Department of Highways has been using this material as fill material in the relocation of Interstate Highway No. 10 across the Mission Flats.

In the summer of 1961, the operating mining companies in the district organized a Pollution Control Advisory Committee for the purpose of studying pollution problems and recommending a solution to the mining companies and to the communities.

This Pollution Control Advisory Committee worked closely with the Idaho State Department of Health in analysis and feasibility studies in an effort to determine the best possible solution to pollution control for the entire district. In 1958, the City of Kellogg hired an engineering firm to make a complete study of an adequate sewage collection system and treatment facilities for the city. The estimated cost for this complete system was \$450,000 to \$500,000.

The mine's Pollution Control Advisory Committee first examined the success of the Anaconda Company in the transportation and treatment of their combined industrial and domestic wastes between Butte, Montana, and Anaconda, Montana, and from this the decision was reached to investigate a similar district-wide system for the South Fork of the Coeur d'Alene River. The first work in this direction involved the gathering of as complete as possible data on the nature, volume, and location of all pollutants in the district. From these data the Idaho Health Department conducted a series of tests to determine the interaction of all the pollutants and the problems of treatment to obtain an effluent satisfactory for return to public water.

The Idaho Health Department's tests indicate that the variety of pollutants in the district are synergetic in the respect that in combination they tend to neutralize each other chemically and sterilize biologically. The indications are that settling time and lagooning will provide most of the treatment required to reduce

solids and biochemical oxygen demand to satisfactory minimums, with a possibility of some further chemical treatment for flocculation and neutralization. Preliminary engineering studies indicated that the cost of a single pipeline large enough to carry all of the polluted waters by gravity through the valley to the Mission Flat area was in the realm of economic feasibility. The minimum velocity required for safe transportation of the mine tailings through this pipeline was considered the most critical problem affecting economic feasibility, and it was recognized that gravity head alone might be insufficient to carry the suspended solids load through the lower end of the valley. The economic studies for the collector systems and the engineering problems involved with the pipeline transportation of solids were too complex to be undertaken locally. The mining companies advanced funds to the county commissioners as trustees for the purpose of employing an engineering firm to conduct a feasibility study. The results of this feasibility study were received on August 6, 1962. This engineering report indicated that a district-wide pipeline collector system was physically feasible. However, the cost of installation of the pipeline and pumping facilities required was estimated at over \$3,000,000, with additional costs for feeders to the main pipeline and for the costs of impounding and lagooning facilities. A very preliminary estimate of cost for operation and maintenance of the system indicated these costs would be in the order of \$5,000 to \$10,000 a month. In addition to these costs, each of the communities will have some costs for completing their sanitary sewer collection system and the separation of storm sewers.

If a community-wide collection system is not put in, the alternate, then, is for each of the larger communities to put in individual sewage treatment plants. This involves at least seven sewage treatment plants caring for approximately 15,000 people and with no facilities for the scattered residential areas, which would probably account for another 1,000 to 1,500 people. In addition, each of the industrial plants would be required to put in some kind of pollution abatement system. At the upper end of the valley, because of the very steep, narrow canyons, safe impounding of tailings is almost an impossibility, and at the least, very expensive. It is estimated that the individual sewage treatment plants would cost somewhere in the order of \$1,200,000, and experience indicates that small sewage treatment plants are generally very poorly maintained and operated over a period of time.

Because of the narrow valley, there is no opportunity for the use of lagoon systems by more than one or two of the communities, and even for these very questionable because of a lack of isolation and danger from floods.

I mentioned before that the mining companies in the past 30 years have spent almost \$2,000,000 in their dredge operation. In addition, the Page Mine and the Bunker Hill Mine have each spent about 5¢ per ton of ore mined for the operation of their individual tailings impounding areas. This would come to about \$30,000 a year. The total cost for the past 30 years in tailings control efforts alone is probably well above \$3,000,000.

I would like to briefly review with you some of the physical features of the pipeline as we visualize it, if it followed the stream topography.

From Burke, the highest point in the pipeline system, to Mission Flats, the lowest point, is a difference in elevation of 1,706 feet. The length of the pipeline would be 156,400 feet, or 29.6 miles. From Burke to Wallace the grade is 34 feet per 1000; from Wallace to Osburn it is 8.3 feet per 1000; from Osburn to Kellogg it averages about 6 feet per 1000; from Kellogg to Enaville it averages about 3.3 feet per 1000; and from Enaville to Mission Flats it is only 1.1 feet per thousand. You can readily understand that from Kellogg on down we begin to get into velocity problems if we rely on gravity.

Rather than following the river drainage, an alternate route from Pine Creek west has been examined, following the highway right-of-way, which shortens the distance by 4 miles but involves going over two ridges, each of which is approximately 120 feet above the low point at Pine Creek. If pumping is necessary, however, and it undoubtedly is going to be to maintain the minimum velocities for the solids transportation, then the shorter pipeline has some definite advantages, and the elevation on the last ridge will just nicely be sufficient to carry the tailings on into the Mission Flat area by gravity.

Some consideration has been given to the separation of the tailings from the other industrial liquid wastes and sewage, transporting the tailings in a pressure pipeline, and transporting the sewage and other liquid industrial wastes in a separate pipeline by gravity. This particular solution needs considerable further study to determine the feasibility and exact

comparison of costs, as we haven't gone into enough detail to determine exactly the pumping costs with this system. The preliminary examination indicated that the installed cost would probably be higher, but that over a period of years the operating costs would be enough lower to possibly justify the separation of the tailings from the largely liquid type of pollutants. The pollutants should be well mixed before dumping into the impounding area at Mission Flats to derive the maximum of benefits from the combination of chemical pollutants and tailings mixed with the sewage.

Another neat little engineering problem in this district is arriving at a reasonable factor for future growth. I have already mentioned the very substantial loss in the numbers of operating mines and the changing technologies that today are resulting in better than 50 percent of the total tailings being returned to the mines for sand filling. What should an engineer design for in the way of future sizing for mine tailings? The population in the county now is just about what it was 30 years ago, and is 2,000 less than it was 10 years ago. We do know that there has been a gradual shift in the population from the eastern part of the county to the western area. How many and where 20 years from now? Over the years the Bunker Hill's metallurgical plants have grown both in the variety of products and volume of products. What do we design for the future? For sure, the metallurgical plants can make substantial reductions in the volume of polluted water with the following corrections:

1. Eliminate the mixing of clean water with polluted water.
2. Maximum reuse of contaminated water.
3. Recovery of contaminants within the limits of economic feasibility.

All of industry must place particular emphasis on the reduction to a minimum in the volumes of polluted waters to the pollution control system, keeping their concentration of contaminants high with dilution coming from the sanitary waste water. This will insure maximum effectiveness in interaction among pollutants, minimum pipe size, and lowest pumping costs.

In February of this year the County Commissioners of Shoshone County employed the engineering firm of Cornell, Howland, Hayes and Merryfield to make a complete engineering study for the design of a pollution control system and for the

forming of a pollution control district. Since there is no public money available for this kind of study, the first endeavor was to apply for a Housing and Home Financing Agency loan for this preliminary engineering study. The Idaho Code for setting up a pollution control district declares that the organization of a district shall be initiated by a petition signed by not less than 10 percent of the taxpayers of the district, and that the petition shall set forth the name of the proposed district, a general description of the improvement to be constructed or installed within the district, the estimated cost of the proposed improvements, a general description of the boundaries of the district with such certainty as to enable a property owner to determine whether or not his property is within the district, and a prayer for the organization of the district. Further on, the Code specifically states that no property owner of 5 acres or more may be compelled to be included within the district without his consent.

The Shoshone County Commissioners, with the endorsement of the Idaho Department of Health, petitioned HHFA for a loan to make the engineering study and establish a pollution control district. Early in April, the reply from HHFA was that the county commissioners in Idaho have not been delegated the authority for carrying on such a project, and the application for funds was denied. The county commissioners have deferred to the attorney general of the State of Idaho for a ruling on whether or not they do, in fact, have the authority to proceed with the engineering study required to legally set up the machinery for establishing a pollution control district. We have not been able to find any place in the Idaho Code that makes provision for use of public money for making the engineering determinations required before a pollution control district can be petitioned for. It was our belief that the money that was appropriated by Congress was for this specific purpose, recognizing that many states have this kind of problem in lack of funds for the preliminary work of establishing a pollution control district. Mr. Durkee, Northwest Director of HHFA, said, "We will be happy to assist any way we can when the sanitary district is formed." The question is not only when, but how?

We sometimes feel frustrated by the demands from one side and the restrictions from the other. For instance, the Highway Department has taken up all the available valley floor between Wallace and Mullan and say that we cannot build a pipeline on the right-of-way. It will be interesting to see what happens when the Public Health Service tangles with the Federal

Highway Administration and the Idaho Department of Health tells the Idaho Department of Highways what is going to be done.

After the district is formed I would anticipate that it is going to be a difficult selling job to get enough of the voters to recognize their responsibilities for pollution control to pass the necessary bond election. I anticipate that the problems we have had to date are only the beginning of those we will have in the future, and that a lot of polluted water will go down the river before we have finally solved our pollution control problems.

Mining operators and industrial plants are cognizant of their responsibility for pollution abatement. Much has already been done toward this control and many responsible citizens of our area realize the need of the proposed community pollution control.

LAND DISPOSAL OF INDUSTRIAL WASTES

Ralph H. Scott

INTRODUCTION

For purposes of this paper the writer has drawn on experience gained over the past 17 years as a stream pollution control and industrial waste engineer with the State of Wisconsin. Having been privileged to live in the Northwest less than a year, there has been neither time nor opportunity to become fully acquainted with the extent of land disposal methods as practiced in this region. It is appreciated, however, that a number of sizeable and satisfactory installations of this type are operating in the area. It is hoped that this supplemental information, based on Wisconsin experience, may stimulate more widespread use of land disposal methods.

The application of sewage and industrial wastes to land areas is certainly one of the oldest methods of disposal. In Europe such practice dates back to the 1860's. While many land disposal installations have been replaced by more sophisticated and modern facilities, a number of such sites in Europe and this country have continued to operate, providing satisfactory and dependable waste disposal at reasonable costs. Perhaps we should take a second look at these older facilities which over the years have filled the need for dependable disposal methods, at the same time adding and applying modern advances in equipment and knowledge to gain even more satisfactory operation. While we may be motivated to discard the old and embrace the new, in some respects the science of waste treatment has come full turn, and for necessary ultimate treatment we can look again at land disposal methods. The growing literature on the subject attests to this trend.

Officials at all levels of government, who are responsible for maintaining satisfactory surface water quality and faced with growing waste disposal requirements, are interested in facilities that are economical, dependable, and adequate to meet the most stringent requirements for stream pollution prevention. Suitable land disposal methods can satisfy these requisites.

The field engineer, sanitarian, or drainage basin engineer faced with giving advice concerning specific disposal methods to be used can safely recommend spray irrigation or

ridge and furrow irrigation in most instances. Such methods are particularly adaptable, although not restricted, to small facility waste disposal needs such as those of cheese factories, creameries, small slaughter establishments, and poultry dressing plants. This group represents the small industries which can best utilize land disposal. At the same time they are less able financially than other industries to meet the costs of conventional secondary treatment and are in less favorable position to maintain and satisfactorily operate complicated treatment devices.

Land disposal is also useful to satisfy seasonal waste loads as developed in the canning industry where design of combined treatment facilities for municipal sewage and industrial waste is seldom a reasonable approach, except in larger communities. Land disposal methods may also be employed to meet the lower stream loading requirements during seasons of low stream flow and high temperatures.

SPRAY IRRIGATION

The land disposal method most familiar to those in the waste treatment field is that of spray irrigation. This process is of fairly recent development, with only a few installations operating prior to 1950. This is unusual since spray application of irrigation water had long been used for growing crops. To the writer's knowledge, the first spray disposal system was operated in Minnesota by a cannery faced with a court injunction if it continued to discharge its wastes to the stream. While the canning industry was experimenting with conventional secondary treatment, chemical precipitation, and improved lagooning of wastes to gain satisfactory treatment, the spray irrigation possibilities went unnoticed.

Since 1950, however, this method of waste disposal has mushroomed to permit disposal of tremendous quantities of wastes that would otherwise reach receiving streams. Earlier use of the method was principally to handle seasonal canning wastes, but added knowledge and experience now permits year around disposal of a variety of organic wastes even in northern areas having severe winter conditions. The literature contains ample reference to specific operations of this type involving waste disposal by canning, milk, and pulp and paper industries. These have appeared in the Journal of the Water Pollution Control Federation, the Purdue Industrial Waste Conference Proceedings, as well as in publications of the State Water Pollution Control Board of California and the National Council for Stream Improvement.

Spray irrigation waste disposal is a fairly simple operation but highly effective in removing the total waste loading from the receiving stream course. Waste waters are sprayed onto the land, usually through use of revolving nozzles. Lightweight metal pipe is used to convey waste waters, under pressure, from a sump pump to the disposal site. The same equipment is used in standard crop spray irrigation. While such lightweight distribution systems permit easy movement of pipe sections to change spray areas, investment in sufficient distribution line to permit use of alternate disposal areas, merely by valve manipulation, provides even more dependable operation.

Adequate screening of waste waters is of prime importance to prevent clogging of spray nozzles. Basket screens, easily removed and cleaned, are employed at the entrance to the wet sump for small volume waste sources, while rotary or overhead vibratory screens are necessary for larger installations such as canning plants. The need for adequate land area for spray irrigation cannot be over-emphasized. Likewise, operators of such facilities must be impressed with the need for alternate use of land segments within the acreage set aside for disposal purposes. One unsatisfactory operation within a regional spray irrigation industrial waste disposal program can cause much damage. Fly breeding, odor nuisances, and runoff to adjacent water courses can result simply because available areas have not been fully utilized through proper movement of distribution lines.

Spray irrigation permits considerable latitude in selection of land areas for this purpose. No special preparation is required, although disposal rates are believed to increase considerably where underdrains are employed. Brushland, woodland, and pasture areas all lend themselves to spray irrigation disposal.

Out of a total of some 1,550 Wisconsin milk processing plants at the present time, 61 (mainly cheese factories) are employing spray irrigation for disposal of wastes. Of 107 vegetable and fruit canneries operating in the state, 32 use spray irrigation, 7 of them in combination with lagooning.

The majority of the milk waste spray disposal systems have been installed and placed in operation with the aid and advice of the regional water pollution control engineer. Such small installations are not attractive financially to qualified

consulting engineers. The larger installations represented in the canning industry likewise require minimal engineering services, considering that a sizeable body of information on spray irrigation of croplands already exists. One Wisconsin equipment supplier has found the canning industry waste disposal field sufficiently profitable to provide engineering services.

Standard design now involves use of a central collection sump for all wastes, with low lift pumping to overhead vibratory screens from which solids may be discharged to trucks hauling screenings for stock feed. Screened wastes are discharged to a holding tank of sufficient capacity to permit control of high volumetric flows during wash-up operations and to level out the operation of the float controlled high pressure pumping facilities discharging wastes to the pressure main leading to the irrigation site. The basic concepts for adaptation of spray irrigation methods for disposal of small waste volumes are detailed in Figures 1 and 2. These show wet sump construction to assure periodic discharge of very nearly all wastes from the sump and alternate use of spray areas so necessary for success of this method of soil disposal.

With the exception of beets, the usual canning operation in Wisconsin is concluded prior to freezing weather. Some milk waste disposal systems have been operated satisfactorily throughout the year by providing certain facilities which experience has proved feasible to this type of operation. At mid-winter zero temperatures the sprayed wastes form an ice cap of increasing thickness which may cover the nozzles. In some instances risers have been heightened to as much as 8 feet, with the surrounding ice layer approaching even this thickness. To prevent freezing damage to distribution lines, the foot valve is removed from the pump suction line and self-draining couplings used on the distribution system, or bleeder lines employed to empty the pressure main and risers. Instead of float controlled pump operation discharging wastes several times during the day, the pump is operated manually to pump down the wet sump purposely designed to contain the entire volume of one day's waste flow. There is thus only one period of waste discharge at the conclusion of the day's operation. Because grasses and vegetation are killed by ice formation, plants employing spray disposal in winter provide separate acreage for this purpose. One might suspect that considerable quantities of polluttional material would be released with spring thaws. The accumulated frozen waste, however, melts no faster than the surrounding thawing ground can absorb the waste. When completely melted

and the area dried, all that remains is a fine, grey, sludge-like material, formed no doubt by freeze-out of dissolved solids as the ice deposit was formed layer upon layer throughout the winter.

The land area requirements for disposal of waste waters by irrigation may vary considerably, depending on drainage characteristics, soil and waste temperatures, and evapotranspiration as influenced by temperature, humidity, available soil moisture, and nature of the cover crop. For Wisconsin conditions during the active growing season, it appears reasonable to employ a disposal rate of about 10,000 gpad on medium loam soils typical of the region. With heavy clay soils bordering Lake Michigan, this rate may drop to 4,000 gpad, or increase to 50,000 gpad on the sandy soils of the central state area which exhibit good drainage in depth.

Cropping the area employed for spray irrigation is possible because of the ease with which distribution lines may be dismantled and removed. On alfalfa plantings handling pea and corn canning wastes, it is usual practice to obtain at least one extra cutting per year. Where smaller volumes from milk plants are involved, pasture areas are usually cropped off by admitting cattle to the disposal site while alternate fenced off acreage is employed. Some canning plants also pasture beef stock on lands used for spray irrigation. The compaction of soil and cutting and destruction of turf cover by running stock over such areas makes this practice undesirable when soils are still saturated with moisture. A reasonable drainage and drying period should be allowed prior to pasturing stock on spray irrigation acreage.

Spray irrigation may be successfully employed for the disposal of waste waters at a reasonable investment in equipment for the small plant operation. Pump, motor, floats, switches, and distribution system for disposal of 5,000 gpad can be obtained for about \$600. Cost of the pumping pit and enclosure is additional. Needed land may be already owned by the industry and readily available. As the method requires little land preparation and can utilize moderate slopes with several types of vegetation, land costs are not usually an undue burden. For the example above, one acre of land would be more than sufficient.

For larger spray disposal systems, which may alternate 20-to 40-acre plots, purchase or lease of an entire farm may be

necessary. Most of the canning plants in Wisconsin have acquired necessary land by purchase, permitting considerably more latitude in land management and cropping practices.

RIDGE AND FURROW IRRIGATION

Prior to the 1900's, ridge and furrow irrigation for disposal of sewage effluents in Europe and this country utilized broad irrigation methods where wastes overflowed furrows to spread across flat adjacent areas for seepage into the ground. Present practice retains waste waters in the furrows at a level below the adjacent flat areas of vegetation and permitting evaporation, transpiration, and seepage into the soil to dispose of the volumetric loading applied.

As with spray irrigation, alternate-area rotation should be practiced to maintain satisfactory soil disposal rates and to prevent continuous flooding of root structures and killing of vegetation. With constantly wetted surfaces, slimes are eventually developed which act to bind the soil particles together and prevent seepage. Some types of waste promote considerable sludge accumulation along the bottom of the distribution furrows, reducing seepage and horizontal passage of water into the adjacent areas of vegetation for disposal through transpiration. Complete drying of such distribution ditches by switching to an alternate plot results in drying and cracking of the sludge, destroying slimes and aerating the adjacent soil and root areas. The lowered water table also renews the waste disposal capacity when the area is returned to use.

Basic concepts involved in construction and operation of ridge and furrow disposal systems are shown in Figures 3 and 4. While a pressure system is necessary to reach elevations above the point of waste origin, gravity flow is possible where acreage with sufficient natural or graded downslope between adjacent sections can be obtained. In such cases, considerable saving in original cost and maintenance may be realized and, other than changing stop-log elevations at control points once a month to operate an alternate section, little additional attention is required.

The main distribution ditch may be constructed down one side of the disposal plots or bisecting the disposal areas, with suitable control gate elevations to permit selective and alternate use of separate areas. While the main ditch profile

must change to lead flows to downgrade disposal areas, all lateral ditches within any section are cut at the same level throughout their individual length, and in relation to each other. Wastes discharged to any single system of laterals thus reaches the same operating level in relation to the ridge areas throughout the section. A positive slope to lateral ditches results in pooling of wastes and flooding of ridges at the ends of disposal areas.

While the suggested installation is favored by nearly level or slightly sloping land, minimizing the amount of machine work and grading necessary to obtain level areas for ditch construction, main header ditches may also be pitched down a slope with lateral ditches cut on the contour. In this condition laterals spaced 15 to 20 feet apart and kept reasonably level with variation less than ditch depth may be extended along the contour to considerable lengths and yet function for waste disposal purposes. In such installations a separate diversion box is required at each junction point where laterals cross the main distribution ditch. By proper adjustment of diversion gates, successive laterals can be fully flooded prior to overflow of wastes downgrade via the main distribution ditch to the next diversion structure. Likewise, any lateral may be retired from use by permitting free discharge of wastes downgrade to lower diversion boxes. Experience indicates that ridge and furrow facilities constructed in this manner, on land having a 5-10 percent grade, function just as dependably as completely flat disposal areas. The cost of setting proper ditch levels and constructing diversion structures is small and no more expensive than bringing slightly rolling terrain to exact levels through cut and fill operations.

The first ridge and furrow installation for waste disposal in Wisconsin was placed in operation in 1954 for disposal of creamery wastes. The installation was substantially as shown in Figure 3, embracing about 3 acres of land. Total cost, including \$2,000 for land, amounted to about \$8,000. With average milk intake of about 50,000 pounds per day, the waste, including cooling water, averaged about 30,000 gpd, with a BOD of about 300 mg/l. The industry has never used more than half of the available area. Loadings per acre per day are about 23,000 gallons, containing 58 pounds of BOD. This field was underdrained by two lines of drain tile. Drainage occurs only during the winter months. Flow is less than 5 gpm with an average BOD of about 25 mg/l. Efficiency of treatment and disposal has been in excess of 95 percent at all times surveyed.

From this beginning, carefully engineered and constructed as a demonstration project, Wisconsin now has 32 milk plants employing ridge and furrow disposal methods effecting near total elimination of wastes from receiving water courses. In addition, one canning plant packing peas and corn discharges seasonal loadings to an 11-acre ridge and furrow area in sandy loam. This acreage regularly disposes of primary-treated municipal sewage effluent from a tributary population of about 5,000 persons, plus all polluttional wastes from a milk plant handling 400,000 pounds of milk per day. Costs of ridge and furrow installation have ranged from \$300 to \$30,000. Application rates range from less than 2,500 gpad to 45,000 gpad with BOD loadings of 10 to 1,000 pounds per acre. While volumetric and BOD loading rates show a considerable spread, this is in part due to over-design of some facilities and variation in waste strength dependent on the type of milk processing operation concerned.

In addition to the 32 milk processing and the two vegetable canning plants, three poultry dressing plants now employ ridge and furrow irrigation waste disposal, and a fourth industry will soon start construction for similar disposal. The method appears to operate very satisfactorily on poultry wastes with a surprising lack of odors. Poor house-keeping and inadequate blood collection caused heavier loadings than normal at one periodically-observed poultry waste disposal installation located on sandy loam. Even here, objectionable odors were lacking except in close proximity to the disposal fields. Construction included four courses of under-drain tile laid on about 80-foot centers. The four field disposal sections were bisected by a drainage ditch formerly in place, which also served to lower the water table. The plant processes and freezes a maximum of 12,000 chickens per day. At this kill-rate wastes amount to about 80,000 gpd with a BOD content of 300 mg/l. The BOD of drain tile grab samples over the past four years has varied from 5 to 39 mg/l, with the higher results found during the winter. Loading rates are about 40,000 gpad and 100 pounds BOD per day per acre.

Contrary to the simplicity of installing spray irrigation disposal facilities, proper design and planning of larger ridge and furrow installations involves adequate engineering services. This type of installation has thus gained considerable more attention from the professional standpoint. While original costs are higher than those of spray irrigation, operation is dependable

and results in either total disposal or a continued high treatment efficiency where underdrain systems are employed. Operation parallels that of a slow sand filter, and it is not surprising that high quality effluents are developed from installations of this type. Further advantages are realized because of continued operation through the zero temperature periods of Wisconsin winters. Grasses growing luxuriantly on the ridges and edges of the furrows fold over the furrows to support a snow layer, thus insulating the furrow from serious freezing. For this reason ridge and furrow disposal has gained greater prominence for year-long disposal of wastes in Wisconsin climate.

Land requirements are much the same as for spray irrigation, varying from the 10,000 gpad, depending on tighter or sandy soils utilized. Objectionable features involve mainly the likelihood of odor problems during periods of hot weather. Milk waste disposal systems of this type should be located at least 500 feet from private property and public roads, as control of odors from milk decomposition presents considerable difficulty. Several milk plants use spray irrigation during the summer months and ridge and furrow during the remainder of the year.

Cropping of the land is difficult, except by hand labor. Growth of water and freezing-tolerant grasses, such as Reed's canary, provides a poor forage crop and is mainly usable as bedding. Consequently, with adequate moisture, some fertilization from wastes, and no cutting of grasses and volunteer weeds, ridge and furrow areas become so choked with vegetation as to obscure the outlines of lateral ditches. A common control for this condition is to burn off dead grasses each spring. The only additional maintenance might involve deep raking of the dry furrows every second year to remove accumulated dried sludge deposits formed by some types of waste, such as those from chicken packing plants or slaughterhouses.

LAND DISPOSAL OF STRONG ORGANIC WASTES

Discharge of high organic content wastes to land areas has been practiced in Wisconsin. The September 1962, WPCF Journal covered these projects in some detail, but a brief resume may be informative.

Sewage Sludge Disposal

There is a definite trend in Wisconsin toward the land disposal of liquid digested sewage sludge as opposed to use of conventional drying beds with attendant difficulties in drying, cleaning, and odor nuisances. Of the nearly 400 sewage treatment plants in the state, at least 45 practice the spreading of liquid sludge on land. Some plants provide tank truck facilities for hauling, whereas other municipalities contract for hauling of liquid sludge in specified amounts at stated costs. Where forage crops are grown, liquid sludge may be spread in the early spring and late fall months prior to early plowing and after the last hay cutting. In some cases land in the soil bank has been used for disposal purposes. Figure 5 shows the equipment owned and operated by the City of Juneau, Wisconsin, for disposal of liquid sludge on a 30-acre plot of land in the soil bank. Total cost of the rig was about \$1,200, employing a used 4-wheel drive truck chassis and a used 1,200-gallon oil storage tank. Turn around time amounts to about 40 minutes per load. Plant records show that an average of 85 loads have been hauled each year, representing about 100,000 gallons of liquid sludge. Most of the hauling is concentrated in the spring and fall months and may be fitted to the plant operator's schedule of other operation and maintenance activities.

With sufficient land area this disposal program functions without odor nuisances or runoff and provides a satisfactory outlet for sewage sludge at reasonable cost while avoiding the maintenance, cleaning, and ultimate disposal problems associated with use of sludge drying beds. It should be added that the plant operator does pour sludge over a small drying bed at the plant to provide dried sludge for local citizens wishing to use the material for mulching of flowers and lawn dressing.

Whey Disposal

Wisconsin produces about 45 percent of the cheese manufactured in the United States from the processing of 6.47 billion pounds of the total 17.7 billion pounds of milk produced. About 10 pounds of cheese and 90 pounds of whey are produced for every 100 pounds of milk processed. Thus, approximately 5.8 billion pounds of whey are produced per year which, at 6 percent total solids, represents 350 million pounds of milk solids remaining in this by-product of the cheese industry.

Several large whey drying and processing industries are located in Wisconsin. They handle the majority of whey entering such use channels and market about 33 percent of the dried whey solids produced in the United States. Whey originates from cheese factories handling 5,000 to 10,000 pounds of milk per day up to large modern plants processing 250,000 to 300,000 pounds of milk per day. Unless diverted to drying or processing channels, or used for stock feed, whey becomes a waste product of significant pollutional importance considering the great number of production points involved, the volume to be disposed of during the period of high milk production in the spring, and the pollutional loading contained in whey, the BOD of such material averaging around 35,000 mg/l.

The usual cheese factory disposes of whey as stock feed to patrons, or by sale to whey processors. These are satisfactory outlets over most of the year. However, during the spring flush, milk production increases considerably. Both factories and whey processors are hard-pressed to dispose of the excess. This is also the period of lowest consumption as pig feed supplement. Consequently, both factories and whey processors have developed the practice of land disposal of excess whey during these periods of oversupply.

The practice involves merely a disposal of volume without development of runoff or generation of odor and fly nuisances. Whey is usually spread over pasture or crop land by use of tank truck equipment, employing a spreading bar or splash plates. Some cheese factories use soil bank land for disposal. Whey application to most soils improves the soil characteristics and provides a per ton equivalent of \$1.00 worth of commercial fertilizer. The Agricultural Department at the University of Wisconsin has found that 50 tons of whey per acre per year may be used without adversely influencing soil structure and to provide considerable fertilizer value. If light, even applications are used, the material is decomposed without odor nuisances. The improvements in soil structure and the added fertilizer values are appreciated by many informed farmers. As a consequence there is usually little difficulty in obtaining adequate land area for whey disposal.

Sulfite Liquor

Wisconsin has 14 sulfite pulp mills, most of them considerably smaller than the usual sulfite mill found in the

Northwest. All sulfite pulp waste sources in the state employ regularly, or on a seasonal basis, some degree of treatment or control for wastes discharged in an attempt to reduce the effects of this pollutional load on the receiving waters. As the spent liquor has a BOD of 30,000-34,000 mg/l and an oxygen demand of 600 to 700 pounds per ton of production, treatment or control is indicated. Such measures include installation of yeast fermentation plants and evaporation plants to utilize certain elements of the spent liquor for development of commercial products, use of spent liquor for roadbinder, and the development of holding lagoons for controlled discharge in relation to available seasonal stream flow. There are also several land disposal programs which function principally over the period of low stream flow and higher water temperatures; late June through September. A brief coverage of land disposal methods may be of some interest.

Badger Paper Mills at Peshtigo, Wisconsin, presently owns 800 acres of relatively cheap waste land in an area bounded on the north by the Peshtigo River, and on the east by Green Bay, with shallow ground water drainage in these directions. A portion of the area has been developed into shallow lagoons to obtain seepage of SSL into the soil and to obtain some degree of stabilization by passage through lagoons in series prior to overflow into marsh and swamp areas bordering the river.

During the summer months SSL is hauled to such disposal areas for lagooning and broad irrigation, and also employed as roadbinder on secondary roads. The industry has installed a 100,000-gallon woodstave tank for storage of digester strength liquor at the mill. Two mill-owned trailer trucks are available for hauling to the disposal site or for use as roadbinder. The land disposal program has handled from 15-20 million gallons of liquor for the past several years, in addition to the 3.0-3.5 million gallons disposed of as roadbinder. Costs of storage tanks, pump, and used trailer trucks are figured at about \$15,000. Land costs were \$8,000. Operating costs for 1960 were figured at \$21,840.

Kimberly-Clark Corporation operates a sulfite pulp mill at Niagara, Wisconsin, on the Menomonee River. Seasonal low flows in the stream reduce waste assimilation capacity, with the result that the industry has developed standby land disposal methods for use if needed.

This program was developed with considerable advance planning and development. The area used is across the river in the State of Michigan. Wastes are collected as digester strength liquor at the mill, pumped across the river to elevated storage and truck loading facilities, and trucked to the land disposal area. Each truck hauls a high-pressure spraying unit attached to the trailer. Liquor is drawn from the trailer to the spray unit via a hose connection and discharged at controlled spreading rates along the 45-foot right-of-way of the road grid developed in the disposal area. Figure 6 shows the spray of SSL by such equipment during application. About 4 miles of roadway exists for this purpose. While earlier studies by the Sulfite Research League, using lysimeters, indicated an application rate of 1 pound of liquor solids/day/square yard could be employed with satisfactory soil microorganism stabilization of the waste, this rate has never been approached during periods of use.

Cost of development was about \$110,000 for construction of facilities and building the industry-owned spray equipment. Three trucks operating over 24 hours are leased at a cost of \$500/day. Maintenance of roads and equipment have also added to the cost. Operating costs are calculated by the industry as adding \$1.39/ton to the yearly sulfite production or \$5.56/ton to pulp produced during the period the spraying program is operated.

The Kansas City Star Company, Flambeau Paper Division, Park Falls, Wisconsin, has for many years followed an aggressive program aimed at stream pollution control, based on diversion of digester strength liquor to roadbinder use, or disposal through combined lagooning and soil seepage areas.

The soil disposal area, as it existed in 1961, is shown in Figure 7. Located adjacent to the Flambeau River, it encompasses about 110 of the 200 acres owned by the industry, has a 3 to 8 percent grade toward the river, and is underlaid with bedrock which outcrops along the stream bank. Controlled discharge lagoons at the higher elevations will permit storage of about 10,000,000 gallons of spent liquor, and the optimum rate of release from the lagoons to the ditched soil disposal areas. Slow percolation through the soil occurs and soil organisms ferment the wood sugars contained in the liquor. There are five separate drainage systems fed by separate lagoon storage and release at the crest of the ridge, with the exception of the ditched area in the upper section of Figure 7. This is a ridge

and furrow area with fixed level overflows between the furrows to feed waste to ditches in series. This small area disposes of large volumes of wastes. The disposal rate for the entire area has varied between 7,000,000 and 20,000,000 gallons per summer season.

The industry also operates a roadbinder program for disposal of spent sulfite liquor. Figure 8 shows one company truck spreading hot liquor on a secondary road in the vicinity of Park Falls. In addition to four trucks operated by the mill for hauling to land disposal and spreading of roadbinder, two counties in Wisconsin and one county in Michigan haul spent liquor from the mill for secondary road conditioning.

The cost of spent liquor collection and disposal is charged partly to land disposal and the remainder to the roadbinder program. A 110,000-gallon strong liquor tank and pumping unit loads all trucks at the mill. Mill-owned trucks haul from 3,000 to 4,250 gallons per load, and during critical stream flow conditions operate on the 24-hour basis. The land disposal acreage cost \$6,500 and yearly machine work and development costs are charged to the project as improvements to increase the disposal capacity of the area. Operating costs were \$10,816 for 1960. This cost fluctuates with the amount of liquor trucked to the disposal site each season.

SUMMARY

Some brief information concerning land disposal of industrial wastes and sewage sludges has been presented, based on Wisconsin experience. While much detail is omitted, these projects may offer ideas to supplement already existing land disposal methods operating in the Northwest area, or perhaps stimulate wider use of such methods where they may apply. Much remains to be learned in this field, but the operational aspects and accomplishments appear to be fairly well defined.

HOLDING RESERVOIR FOR SPRAY IRRIGATION DISPOSAL SYSTEM

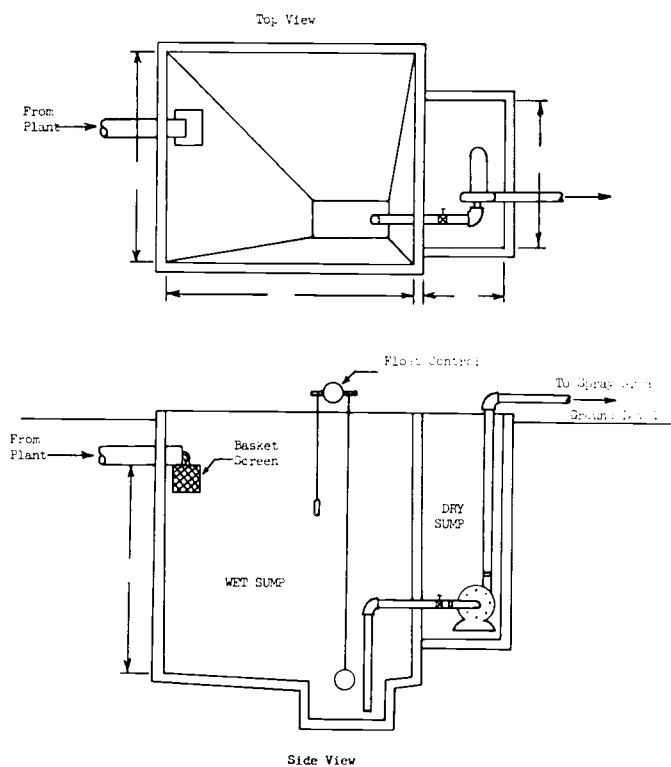


Figure 1.

SPRAY IRRIGATION
DISPOSAL SYSTEM

General Layout

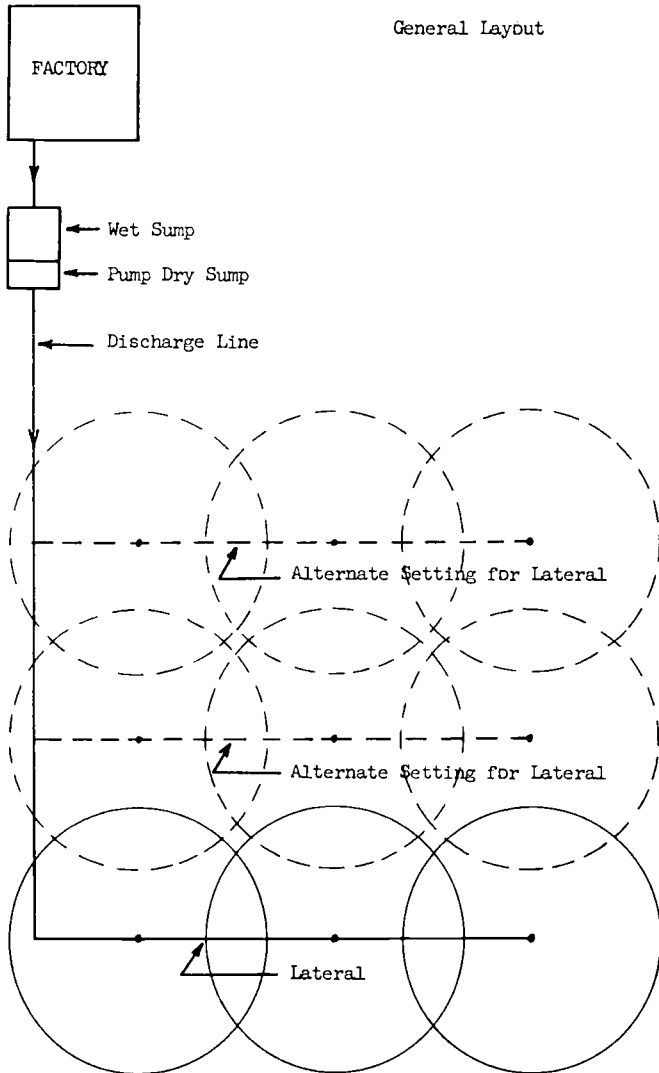


Figure 2.

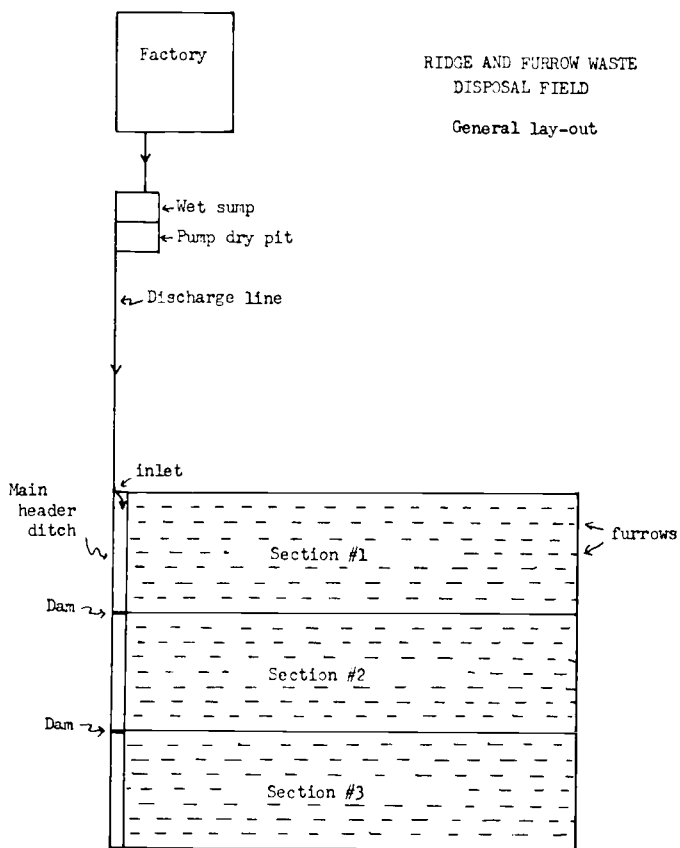


Figure 3.

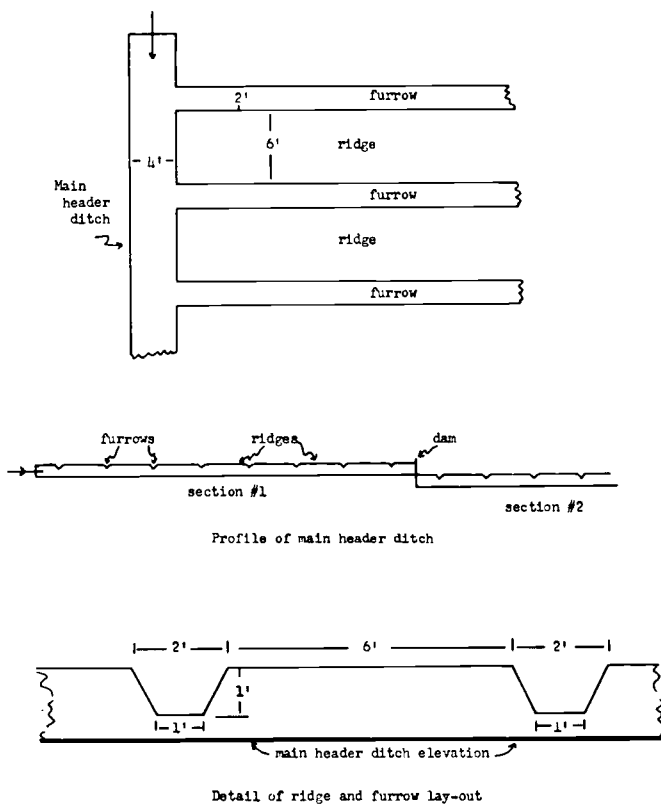


Figure 4.



Figure 5.



Figure 6.

THE KANSAS CITY STAR CO.
 TAMBORN MAPS CO.
 SURFACE MAPS
 SEC. 35 T. 40N R. 10W 40N 40E
 7-31-61 SCALE 1/4" = 1 MI.

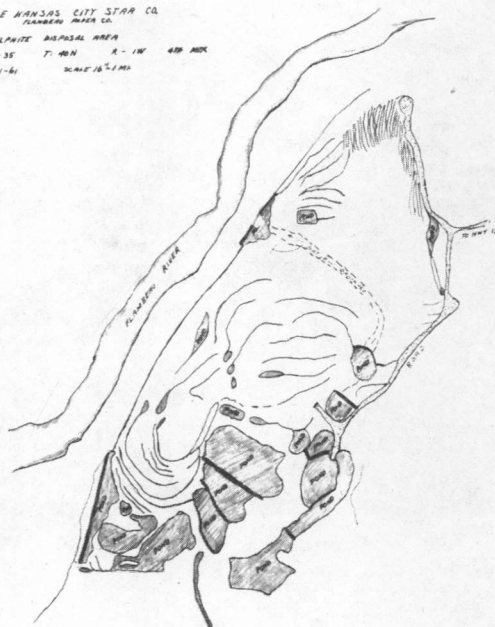


Figure 7.



Figure 8.

PRE-PLANT LOCATION BACKGROUND STUDIES

Robert O. Sylvester

INTRODUCTION

Traditionally, industrial plants have been located in consideration of the availability of raw materials, transportation, markets for the product, a labor force, and an adequate supply of processing and cooling water. In recent years they have added a sixth location criterion, the possible impact of their operation on the water and air environment. This sixth criterion has been added because of an increased use of our water and air environment by all parties concerned, an increased awareness by the public towards water and air quality, and because the industries are desirous of living in harmony within their respective communities. A pre-plant location background study is therefore one that endeavors to tailor a plant's future emissions with the requirements of its environment, and it further documents the condition of the water and air environment both before and after plant operation.

Related to industrial plant background studies are the many basic data collection programs now underway on our nation's waters and air masses. These seek to document air and water quality and the biological response over an indefinite period of time so that there is some point or points of reference for evaluating their present condition and changes that may occur. Examples of these recent basic data programs are the cooperative water quality studies of the lower Columbia River by five pulp and paper mills, the Washington Pollution Control Commission, and the Oregon Sanitary Authority; the national water quality networks of the U.S. Public Health Service and the U.S. Geological Survey; the basic data program of the Washington Pollution Control Commission; the sewer outfall location studies made by many municipalities; the air sampling programs of the Oregon and Washington State Health Departments; and the pre-impoundment and pre-irrigation water quality studies made for the U.S. Fish and Wildlife Service and the Corps of Engineers. The principal criticism to be made of these studies is that they were not started many years ago when the number of variables involved were comparatively few in number.

Nearly all of our lakes undergo a natural process of maturing over the years wherein they change from oligotrophic (low enrichment) to an eutrophic (high enrichment with nuisance

algal blooms) state. This process may be greatly accelerated by man's domestic and industrial activity. Background studies will indicate the approach of eutrophication and its probable cause or causes in time for corrective measures to be taken.

USE OF BACKGROUND STUDIES

Since the conference is concerned primarily with industrial wastes and water quality, this paper will be so limited. Pre-plant location background studies have the following practical uses:

1. They provide a documentation of the physical, chemical, and biological properties of the water environment prior to plant operation. A basis is thus provided for evaluating future allegations concerning the condition that existed prior to plant operation. This pre-plant operation condition cannot be ascertained once a plant is in operation.

2. They provide information on the most suitable area in which to situate a plant (if a choice is available) and the best or most practicable location for discharge of waste waters to be in harmony with requirements of the environment, both present and foreseeable in the future.

3. They provide the background information necessary to determine the extent of industrial waste treatment or waste prevention required, if any.

4. They provide an investment for the future with a relatively minor down payment whose sum is small as compared to litigation costs, the cost of belated pollution control measures, and the damage caused by adverse water quality.

SCOPE OF BACKGROUND STUDIES

The scope of a background study will vary somewhat with the plant location, the physical nature of the receiving water, the characteristics of the plant effluent, and the variety of competing water uses (considering waste water dispersion and assimilation to be a water use). The protection of these competing water uses is, of course, the primary purpose of a background study.

Information to be obtained might include a part of or all of the following⁽¹⁾:

1. Present and predicted future water uses and their seasonal occurrence, considering a full development of the local water resources.

2. Suitability of the water for the present uses.

3. The intrinsic and dollar value of present and future predicted water uses.

4. Sources and characteristics of other waste water discharges involved in the same water regimen.

5. Water quality criteria required by the local competing water users.

6. Critical time or season of the year for water quality to be of prime concern.

7. Climatological, stream flow, or tidal data as applicable.

8. Physical characteristics of the water body.

9. Water current patterns with depth under varying tidal, wind, and/or stream flow conditions.

10. Water quality under various flow and seasonal conditions.

11. Biological: flora and fauna, their types, seasonal distribution, numbers, and their condition.

12. Bottom deposit characteristics of the area subject to discharge influence.

13. Subsequent background data needed after plant operation commences and the preferred time of data collection.

The scope of the background study must be adequate to provide all the necessary information, otherwise it is subject to challenge and a lack of belief or confidence. A few random observations and water samples are not adequate as they may be misleading and are of little value to all parties concerned.

Observations on stream water quality must be made under all flow conditions, with particular emphasis during low flow periods. If the background study is being conducted on salt water, observations should be made on all tidal conditions at times when the various prevailing winds are at different intensities and when the fresh water runoff is at its minimum, maximum, and average stages. Essential water quality determinations are dependent

upon the nature of the waste effluent to be discharged, nature of other waste effluents in the area, and in the anticipated water uses to be protected. In general, the regulatory agencies and an industry, before going into an area, should have a fairly complete record of all significant water quality items, whether or not they appear to be important at the time. Normal natural waters may have seasonal deteriorations in quality; i. e., dissolved oxygen deficiencies, high turbidity, color, pH, temperature, presence of hydrogen sulfide, or the occasion of very low salinities in sea water.

Biological background data should include not only occurrence of various fishes in the water, but also abundance of plankton, flora and fauna of the shorelines, and the benthos organisms. Samples for benthos, or bottom organisms, should also be examined for the type of bottom, presence of hydrogen sulfide, amount of organic matter and debris, and presence of dead animal life.

BACKGROUND STUDY EXAMPLES

The following examples of data from background studies will illustrate the type of data obtained and its significance in regard to future water quality control.

Several years ago it was proposed that a pulp mill be built along the Willapa River estuary in southwest Washington. The Washington Pollution Control Commission made a study⁽²⁾ of the estuary to determine, among other things, existing conditions and the impact waste water discharge would have on the estuary if it were discharged at one of several optional locations. Figure 1 illustrates the dissolved oxygen data obtained by measurement and by calculation during the period of low flow in the Willapa River. Existing dissolved oxygen saturation deficiencies caused by local discharges of untreated sewage and from sawmill operations were surprising. Theoretical calculations made in consideration of the existing oxygen depletion, oxygen demand of the proposed kraft mill wastes, and detention time of the waste waters in various segments of the estuary, indicated that the proposed mill effluent would have to be discharged from 7 to 10 miles further down the estuary than originally contemplated if satisfactory dissolved oxygen values were to be maintained in the estuary.

A pre-plant location background study in Silver Bay

near Sitka, Alaska⁽³⁾, produced some interesting information in regard to the location of the mill sewer outfall. Salt water outfalls are usually located in as deep water as is practicable to permit a maximum of dilution and dispersal. Studies of the currents with depth at the entrance to Silver Bay (see Figure 4) under low and high freshwater runoff conditions indicated a net outflow in the upper 10-16 feet, while the deeper water had a net inflow velocity. These flow velocities are illustrated in Figure 2. Therefore, to keep the effluent from being carried southeastward into Silver Bay where it would tend to become concentrated under usual wind and current conditions, the better solution was to discharge the effluent near the surface where it would be swept out of the bay for subsequent dilution in Sitka Sound. Figure 4 further shows that the effluent from a mill at the mouth of Sawmill Creek should be discharged on the northwest shoreline to insure its normal discharge from the bay. Similar currents were observed with low stream discharge (less than 100 cfs), and on an ebbing tide the entire entrance surface current is seaward. Another item of interest on the pre-plant study was the finding of hydrogen sulfide containing sediments over most of the bottom in Silver Bay (Figure 3). This type of bottom would not support any significant marine life, and is a condition that might well have been later attributed to mill operations.

During the summer and autumn following the decline of surface runoff, deep oxygen-deficient ocean water moves into the Puget Sound area and is dispersed into the upper water layers by vertical mixing that takes place due to upwelling and channel configurations. This will frequently result in low dissolved oxygen values that have no relationship to industrial operations. Low oxygen values may also be found just before daybreak in shallow water areas supporting heavy blooms of plant life. It is highly desirable that these be found and documented prior to an industry's commencement of operations. Table 1 illustrates water quality values found over an oyster bed during a pre-plant operation study⁽⁴⁾ for an oil refinery on Puget Sound. The waters of this area were presently being used for effluent dispersion and assimilation by another oil refinery and by a pulp mill. Items of particular interest in Table 1 are the variations in dissolved oxygen, pH, and turbidity, most of which can be attributed to activities of the phytoplankton. Determinations were made for copper, chromium, phenols, sulfides, and oil because they may be found in refinery effluents as a by-product of crude oil

refining or as corrosion products. Iron was determined because of its widespread occurrence in local ground water and because of its toxicity in higher concentrations to some of the biota. The remaining water quality values were obtained as they described seawater variations due to local runoff, or because they are constituents of other local waste discharges.

Figure 5 shows typical current studies made from the point of proposed effluent discharge from under a refinery pier. These current studies⁽⁴⁾ indicated that for maximum effluent dispersion, and dispersion away from oyster beds, the effluent should be lagooned and released during a period extending from one hour before slack water following the flood tide to about two hours before the onset of the next flood tide.

The shellfish industry has long been concerned with the effects of water quality on the growing of oysters. In the area that might conceivably be related to the effect of an industrial discharge, it is most important that any oyster beds therein be carefully examined as to the extent of oyster plantings, the condition of the oysters, and the effect of any conditions adverse to the oyster, such as silting or the presence of parasites. These examinations should be made jointly by biologists representing the oyster grower, the industry, and the state, and they should concur in their findings before the inspections are terminated. Figure 6 shows the condition of oysters observed during a background study⁽⁵⁾ for an oil refinery on Georgia Strait. These oysters were in poor condition because of silting and the parasitic oyster drill.

Figure 8 shows the variety of bottom animals from a single dredging taken in the vicinity of the Georgia Strait refinery location. The large number of empty shells in the upper picture are natural occurrences and are not from pollution. Dredgings in the vicinity of the proposed point of effluent discharge produced black odorous mud containing essentially no bottom life. This type of pre-plant information is of interest and value to all parties concerned. Figure 7 illustrates the algal mat in an intertidal area along Georgia Strait where pre-plant current studies indicated the dispersed refinery effluent would be carried shorewards. The red algae are particularly sensitive to unfavorable environmental conditions. This refinery has had six intertidal surveys made since production commenced in 1954 to ascertain the presence and condition of the intertidal flora and fauna over eight miles of adjacent shoreline.

CONCLUSIONS

Our water resources can be maintained in a useful state only by foresight on the part of those planning and designing structures which in some manner affect the receiving water quality. In the absence of a background study, there can be only supposition.

Many environmental conditions, other than those imposed by man, affect the quantity, condition, and presence of aquatic life in a given area. An evaluation of water quality and aquatic life can be made only after the entire environment has been carefully scrutinized over a period of time. Studies of the nature discussed herein may be useful in proving or disproving allegations of fanciful or real pollution damage.

It is hoped that someday our knowledge and management of our water resources will be sufficiently developed so that a piecemeal approach of the nature herein described will no longer be necessary.

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3. Eldridge, E. F. , and R. O. Sylvester, "Silver Bay Water Pollution Control Studies Near Sitka, Alaska," Report No. 10, Alaska Water Pollution Control Board, June 1957.
4. Sylvester, R. O. , and F. L. Clogston, "A Study of the Pre-operational Marine Environment in the Vicinity of the Texas Company Refinery, Puget Sound Works, Anacortes, Washington," The Texas Company, October 1958.
5. Kincaid, T. , M. P. Wennekens, and R. O. Sylvester, "A Study of the Oceanographical and Biological Characteristics of Southeast Georgia Strait Prior to Operation of the General Petroleum Corporation Refinery at Ferndale, Washington," General Petroleum Corp. report of December 1954 with supplement of September 1955.

Table 1 - Summary of Water Quality Data Collected Over an Oyster Bed
(From Reference 4)

<u>Constituent</u>	<u>Concentrations Observed</u>			<u>Tidal Condition</u> ¹
	<u>Minimum</u>	<u>Median</u>	<u>Maximum</u>	
Temperature, °C	10.2	19.2	21.7	Flood
Dissolved Oxygen, mg/l	3.4 ²	10.1	12.2	"
% Diss. Oxygen Satur.	46	124	158	"
pH units	7.8	8.15	8.8	"
Chlorinity, p.p.t.	13.1	14.7	15.8	Ebb
Color units	3	6	17	"
Alkalinity, mg/l CaCO ₃	89	102	108	"
Turbidity units	3	9	13	F & E
B.O.D. in mg/l	0.2	1.4	3.6	Flood
Total Oil, mg/l	0	Tr	3	Ebb
Phenols, mg/l	0	0	0.01	Flood
Sulfides, mg/l	0	0.03	0.06	F & E
Phosphate, mg/l	0.07	0.12	0.17	Ebb
Copper, mg/l	0.05 ³	0.05-	0.08	"
Chromium, mg/l		0		
Total Iron, mg/l	0.05-	0.10	0.36	Flood
Spent Sulfite Liquor	0	6	15	Ebb

¹ Tidal condition when high values were observed.

² Pre-dawn value near end of an ebbing tide.

³ Minus sign means less than.

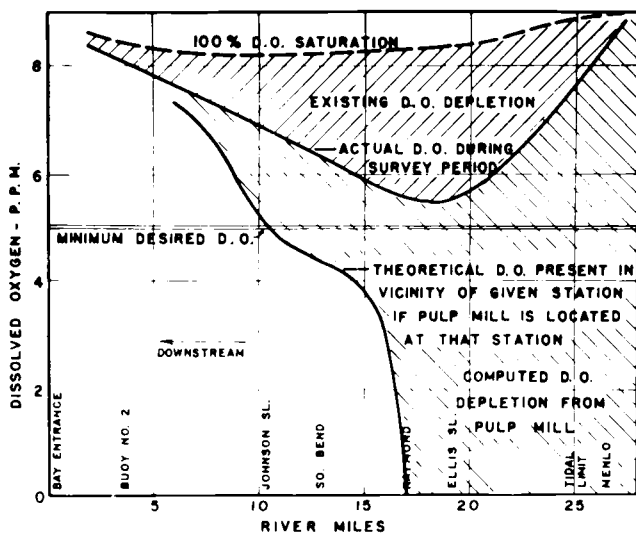


Figure 1. Existing and Theroetical Dissolved Oxygen Values on the Willapa River Estuary

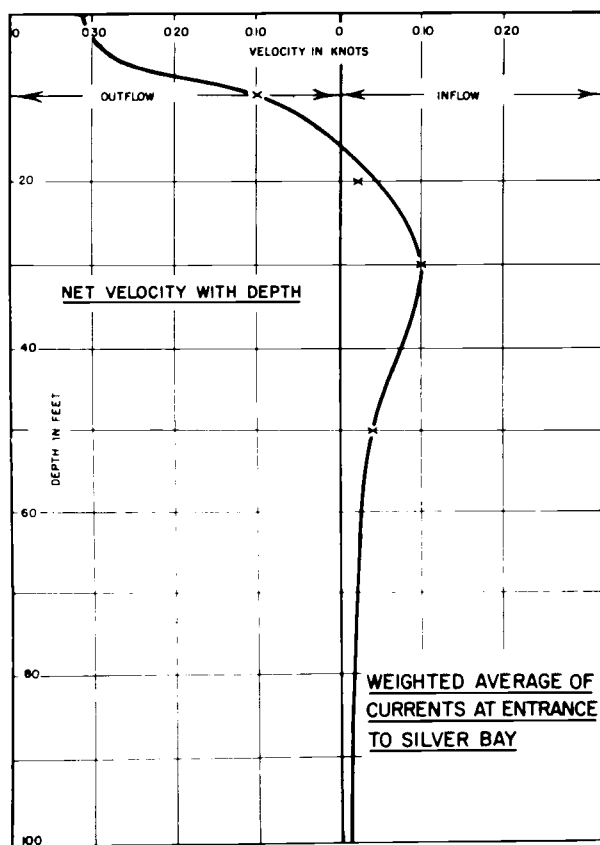


Figure 2.

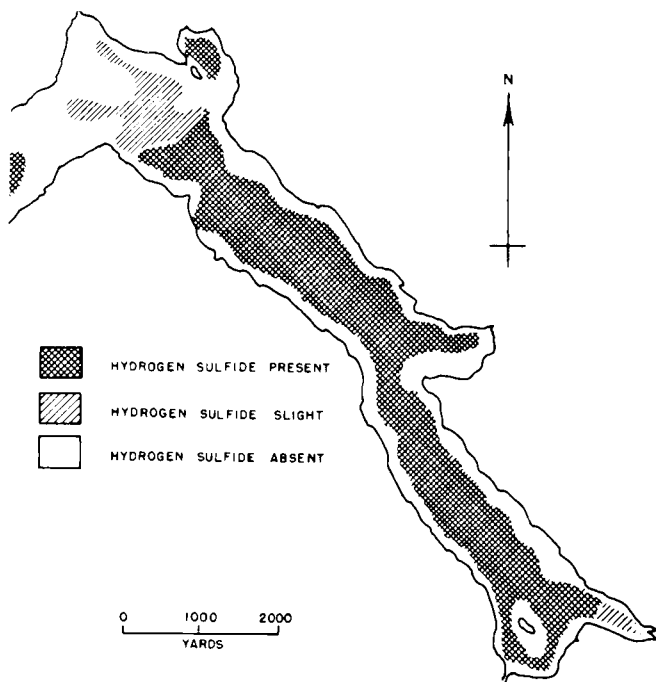


Figure 3. Distribution of Hydrogen Sulfide in Silver Bay, July 1956

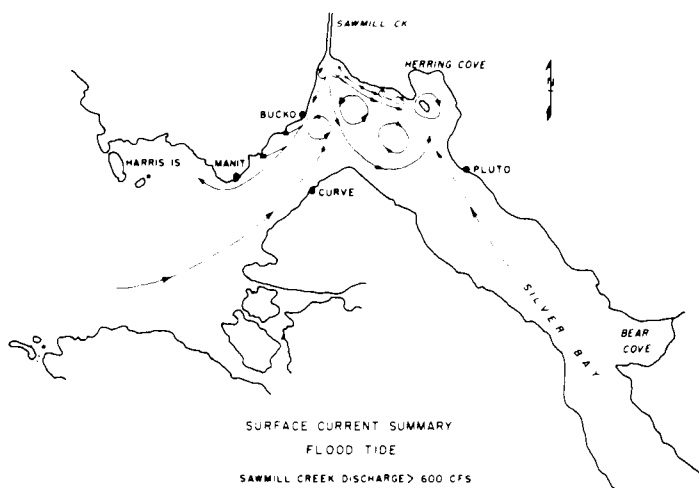


Figure 4. Silver Bay Currents

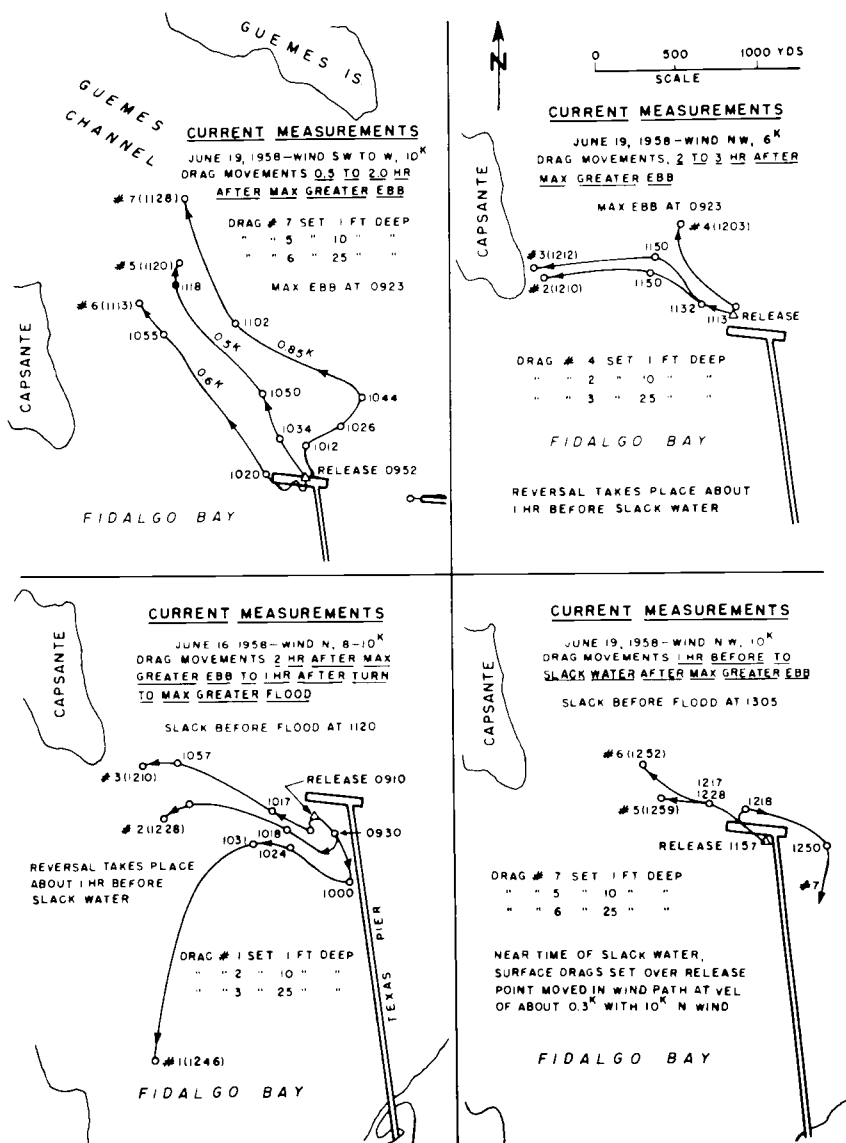


Figure 5. Tidal Current Dispersion from Point of Expected Oil Refinery Discharge



Figure 6. Oyster Bed with Mostly Empty Shells
Due to Silting and Parasites



Figure 7. Intertidal Zone
Heavy Brown and Red Algal Matting

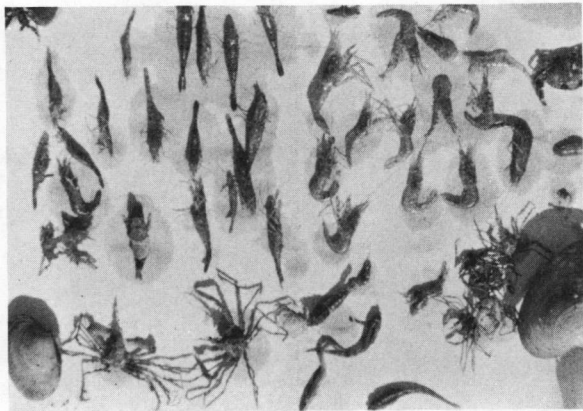


Figure 8. Sample Dredged from Bottom Showing Empty Shells and Bottom Life as Documentary Record

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