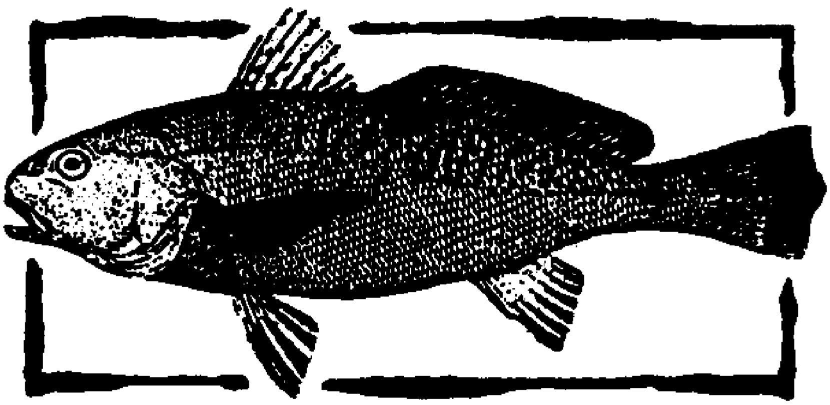

The 1991 Seafood Environmental Summit
PROCEEDINGS

Edited by

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UNC Sea Grant College Program

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Introduction

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The 1990s are being touted as the "decade of the environment" in the United States. This environmental focus is occurring in government, in industry and among concerned citizens. The domestic seafood processing industry is no exception. Faced with declining natural stocks, increased market competition from imported products, consumer questions on seafood safety and stricter enforcement of environmental regulations, the industry is facing tough challenges ahead.

The Seafood Environmental Summit focuses on environmental quality, pollution prevention and waste reduction in processing aquatic fishery products. It represents a broad and diverse view of subjects that impact domestic fisheries and the seafood processing industry in the United States.

It is hoped that the presentations and discussions resulting from this summit will encourage a better understanding of the complexity of issues facing our seafood industry today. With this understanding, we may embark on a path that would strategically plan for the future of the seafood processing industry in the United States.

We gratefully acknowledge the following:

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Tropical and Subtropical Fisheries Technological Society

Protecting Environmental Quality Today

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Without a healthy environment, there will be little or no seafood. In North Carolina, the commercial harvest of fish and shellfish is 95 percent estuarine dependent. The environment these commercially important species depend on has two parts: habitat and water. Habitat encompasses specific areas utilized by various stages and species of fish and shellfish. These include spawning and nursery areas, feeding areas and migratory areas. Water quality for fisheries is the ability of water and its chemical constituents to support healthy populations of fisheries resources. Combined state and federal controls are sufficient at present to protect the environment from most existing threats.

Until the last 20 to 25 years, wetlands were considered wastelands to be converted to better uses, waters were considered dumping grounds, and resources were considered inexhaustible. Rules controlling dredging and filling, pollution and harvest limits were minimal or non-existent.

State and federal laws enacted from the late 1960s to the present have halted large-scale habitat destruction and reduced pollution discharges. But the results of past habitat loss and pollution persist. Thousands of acres of marsh have been converted to finger canals and developments. Additional thousands of acres of coastal wetlands have been drained for mosquito control, which works poorly at best. Tens of thousands of acres of non-coastal wetlands were drained for agriculture and silviculture - activities that affect runoff and nutrient input to estuaries. Tens of thousands of acres of productive shellfish bottom have been closed to harvest because of poorly sited, malfunctioning septic systems, failing package treatment plants and municipal sewage treatment plants. Additional closures occur periodically following heavy rains and the accompanying runoff. Fish consumption advisories have been issued for some areas because of long-term dioxin contamination. The Chowan River is still eutropic from nitrogen discharges in 1960s and 1970s, which resulted in massive blue-green algae blooms.

Although major new losses of habitat are no longer occurring, continued coastal development results in small incremental losses that add up. Habitat lost previously is not being replaced. And mitigation, especially habitat creation, has not been shown to be very reliable. Sometimes mitigation works, but it can take many years to equal the lost ecological function. Fish kills and oyster, crab and fish diseases are increasing. Noxious algae blooms and episodes of hypoxia/anoxia still occur.

Coastal waters are at the "end of pipe." Upstream problems are transported downstream to the estuaries. These include industrial and municipal discharges and runoff. Inland development fails to consider how it affects the coastal area. North Carolina's total coastal habitat and water quality program is among the nation's best, and it's improving. Coordination among state agencies, N.C. Division of Environmental Management, N.C. Division of Coastal Management, N.C. Division of Marine Fisheries, N.C. Division of Shellfish Sanitation Branch and federal agencies is good and getting better. But programs are understaffed and cannot meet increasing needs as coastal development grows. And enforcement and penalties are insufficient.

Unless critical policy and political decisions are made at state and local levels, coastal development will probably continue to gradually degrade habitat and water quality. As sea level rises, coastal areas will be inundated. Coastal wetlands will be lost. In bulkheaded areas, the estuary will not be able to retreat inland to create new marsh, thus losing estuarine productivity. If decisions are made to pay the necessary costs (monetary and other), coastal productivity can be restored and maintained, continuing to contribute economically.

Sea Grant and Fisheries Environment

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Awareness of the coastal environment and its current status has been growing in the hearts and minds of the public. Hardly anyone has not read or heard of environmental issues in the newspaper, on radio or on television. Indeed, the talk at social gatherings and on the street corner will include something about the environment. There is ample evidence that there is a growing desire to do something about environmental quality and its decline. For example, 12,500 volunteer recently attended "Big Sweep" activities in our state and gathered up hundreds of cubic yards of trash from the beaches and waterways. Surveys of public opinion reveal that a majority are willing to pay "extra" for a cleaner and safer environment. Discriminating consumers are changing their buying habits to improve their diet and avoid contamination of food and drink. Thousands subscribe to magazines and use video-taped educational materials to become better informed.

Seafood and the environment are intricately intertwined. A recent analysis by a National Academy of Science panel concluded that the quality of seafood is more related to the quality of the environment from which it is taken than to what happens to it during processing and handling. These findings underscore, more than ever, the need for improved environmental quality if we are to maintain the availability of wholesome and safe seafood for the future. That is what this "summit" is all about.

Sea Grant Colleges, as institutions, are dedicated to a priority of assisting the nation to ensure high quality, safe and abundant seafood. Sea Grant combines the research, extension and education expertise of most of the nation's universities to focus on identified problems and solutions affecting coastal economies. One of the most prominent issues includes seafood and its environment. Sea Grant offers several unique qualities to address the issue:

1. Networking: Sea Grant is a network of institutions in each of the coastal and Great Lakes states. This closely knit network enables the efficient and timely exchange of ideas and rapid combination of solutions to address an issue.

2. Multidisciplinary Approach: Sea Grant has the unique ability to combine disciplines to address an issue. By combining legal, technical, engineering and social sciences, problems can be addressed at their base, and multidisciplinary solutions can be developed. Effective research, extension, education and communications are applied simultaneously to bring new and vital information to the workplace and the public's attention.

3. Interagency Coordination: By working will all agencies, interest groups and commerce, Sea Grant efforts often get to the heart of an issue. By working together, solutions have a better chance of being effective and finding their way into the workings of those who can make a difference.

4. Outreach: Sea Grant supports an outreach program called Marine Advisory Service. These dedicated individuals, located in coastal areas, work directly with resource users to apply the latest information to identified problems. In turn, the agents bring relevant problems to researchers for the development of new solutions. This interaction enables the transfer of new information to take place in a timely fashion.

SOME IMPORTANT ISSUES

I will suggest some issues that seem to be most important as we enter the 1990s. Of necessity, those issues that face the seafood industry are very similar to those that face other coastal resource interests.

1. Resource Allocation: As the number of people using coastal resources increase and the total amount of resources available remain the same or decline, we are faced with the increasingly important question of "who gets what." This is mainly a socio-economic issue but requires a fundamental knowledge of biological productivity and optimal yields. The issue of catching large numbers of unintended species while harvesting targeted species (i.e. bycatch) has become extremely controversial. Overfishing of many species is now problematic. I believe that these problems are solvable, but the solution will require sophisticated, multidisciplinary research and careful application of the results in a well-educated industry and public.

2. Water Quality: As we have already heard, seafood quality is inextricably intertwined with water quality. Until we are able to reverse the trend of water quality decline, we will continue to have problems with quality of our catch. News of water quality problems affect the sales of product, regardless of whether contamination has actually occurred. There is some good news — the inflow of many contaminants to the nation's coastal zone has declined. But, considerably more progress is required if we are to regain the optimum productivity needed to supply the increasing demand for good seafood.

3. Product Quality and Waste Disposal: With new standards of quality and safety, the seafood industry will need new information and techniques to remain competitive. Disposal of wastes is becoming more of a problem, and we need to develop alternative ways of using the waste instead of disposing of it into the increasingly stressed environment. This will require multidisciplinary research and application to realize recovery, treatment, recycling and reduction. All of these have economic and social ramifications as well as technical problems.

4. Habitat: We must maintain crucial habitats if we are to maintain and even enhance seafood production and quality. With the mood for mitigation and habitat restoration, there are many opportunities to test new techniques and ideas on how habitats work and how they are related to the magnitude of production, often in ecosystems far removed from the original.

The bottom line is that we all have a RESPONSIBILITY to tackle these issues with purpose and our best ideas.

Overview of the Albemarle-Pamlico Estuarine Study

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The Albemarle-Pamlico Estuarine Study (APES) was the first National Estuary Program to be designated under the 1987 amendments to the Clean Water Act. It represents a cooperative effort between the Environmental Protection Agency and the state of North Carolina. It was designed as a five-year program. It combines scientific research, evaluation of potential management alternatives and public involvement and education to protect the long-term productivity of our estuarine waters. The study area covers 30,000 square miles of the watershed for the Albemarle and Pamlico sounds. APES has published a document compiling current knowledge about the status and trends of the system's environmental quality. This document, along with results from continuing research, will serve as the foundation for the development of a final Comprehensive Conservation Management Plan (CCMP) due in November 1992. The CCMP will make recommendations for coordinating various state, federal and local programs with responsibility for specific aspects of the estuarine environment and its watershed in an effort to protect these valuable resources.

One of the major contributions of APES has been the creation of a geographically referenced database of the region. This database, which includes more than 50 data layers, contains information on land use and land cover, roadways, soils and hydrology to name a few. The database is housed and maintained by the N.C. Center for Geographic Information and Analysis and is available for agency and public use.

The public involvement portion of APES disseminates information and facilitates involvement of concerned citizens in APES and the CCMP development process. To do so, APES funds public involvement projects. One such project identified and quantified the level of environmental protection desired by citizens and the high level of public support for environmental management. The Citizens Water Quality Monitoring Program has resulted in almost four years of valuable water quality data and involved many local residents.

The technical acquisition portion of APES, through the compilation of existing studies and funding of new studies, has addressed four broad areas of concern: the human environment, critical areas, water quality and fisheries. The status and trends of each area as well as highlights of recent research efforts are discussed below.

In 1990, the permanent human population of the Albemarle-Pamlico counties was roughly 2,670,000 and is expected to reach 3 million by the year 2000. This relatively rapid growth of the permanent population and a concomitant growth of the seasonal population increases demands on and conflicts over the limited and fragile resource base. To address issues of resource allocation, one APES-funded study developed a sample water-use plan for Carteret County by analyzing the county's growth indicators, water-use indicators and policies regarding the use of public trust waters, and by developing a classification scheme for water use.

APES has and will continue to study the impacts of man's activities on the critical areas within the estuarine system. These critical areas include submerged aquatic vegetation (SAV), wetlands, nursery areas and fishery habitats, and barrier islands.

SAV occurs in shallow waters along the eastern shores of the Albemarle and Pamlico sounds and in much of Core, Back, and Bogue sounds. SAV habitat supports populations of bay scallops and other species of shellfish, fish and birds. SAV habitats in the eastern portions of the Albemarle and Pamlico sounds are stable, but have been almost obliterated in the Pamlico River and Back Bay. Decline of SAV may be caused by decreasing light penetration due to increased turbidity and encrustation by algae. In certain areas, the decline is due to physical destruction or disturbance by dredges, boat propellers and illegal fishing practices. If these conditions and practices continue, SAV will likely continue to decline.

Wetlands occur throughout the study area. Tidal salt marshes and fringe swamps are now protected by regulations and are stable in areal extent. But there is evidence of extensive localized reduction of ecologically important riparian wetlands and isolated inland wetlands. It is estimated that 25 to 50 percent of the wetlands that line tributaries or lie inland have been lost or altered so significantly that their functioning has been severely impaired. Roughly 66 percent of inland pocosins have been converted to different land uses. A study conducted by the N.C. Natural Heritage Program identified, described, mapped and prioritized exceptional wetlands and other special natural areas in counties adjacent to Albemarle Sound. This data is available to other agencies for resource assessments.

Fisheries nursery areas may be influenced by freshwater runoff, bottom disturbing practices or hypoxic and anoxic conditions. A program designates and protects nursery areas from harmful fishing practices, and analysis indicates that most of the designated areas are currently functioning satisfactorily. However, records of water quality indicate deteriorating conditions within some nursery areas.

Human impacts on the barrier islands have reduced the original coverage of maritime forest, shrub, herbaceous dune growth and soundside high marsh to remnant quantities. On private lands, losses of habitat continue at a substantial rate from urbanization and related development. Acreage in the public trust is increasing the protection of some of these habitats. Fortunately, about two-thirds of the Outer Banks is now in public ownership.

APES continues to study water quality within the region by specifically addressing nutrients and eutrophication, metals and toxicants, freshwater discharge and flow regimes, and anoxia and hypoxia.

The waters of the estuarine system are phosphorous-rich and relatively nitrogen-limited. These nutrients, along with the right climatic conditions, can cause blooms of algae, associated hypoxic or anoxic events, changes in the food chain and even toxic conditions. Algal blooms are a common occurrence during the summer and fall warm, low-flow months. An APES-funded study indicated that to reduce these events, inputs of nitrogen and phosphorous must be controlled. APES is currently funding a study to develop a nutrient budget for the region as a first step towards developing nutrient reduction goals.

Despite reported increases in loadings in the estuarine system, concentrations of nitrogen and phosphorous in the water column have, in general, declined in the recent past. However, increased concentrations of chlorophyll a (an indicator of algal abundance) may account for the declining concentration of nutrients.

APES-funded studies of the concentrations of toxic pollutants within the water column describe safe and reasonable levels, but studies of the sediments of Pamlico Sound and the Neuse River indicate that areas of localized but significant enrichment of metals exist, most often associated with known point source dischargers. APES is funding an inventory of toxicants in the region to identify potential problem areas.

Alteration of the natural flow regimes of the tributaries to Albemarle and Pamlico Sounds can have significant effects upon the water quality and the health and distribution of flora and fauna in the receiving waters. This alteration is often a result of drainage ditches, overdraught of coastal aquifers, dams, construction and development. Due to the complex hydrology of the estuarine system, precise trends of changing salinity remain unknown, but the pace of that change appears to be decreasing.

Anoxia or hypoxia can stress or kill affected biota, however, such events are usually not widespread and are usually short-lived. Anoxic and hypoxic events are often caused by natural conditions of concurrent warm temperatures and stratification of the estuarine waters. These events may, however, be exacerbated by algal blooms caused by cultural eutrophication.

APES continues to study issues of fisheries dynamics within the region, specifically shellfish bed closures, diseases, commercial fisheries and recreational fisheries.

Currently, about 36,000 acres within the study area are closed to the harvest of shellfish, and additional areas may be closed for a few days or weeks following a heavy rainfall. Bacterial contamination from point sources and urban and agricultural runoff can cause the closure of shellfish beds. Current regulations require immediate closure of shellfish beds in a given proximity to marinas.

Prevalence of fish diseases has increased dramatically in some areas since 1984. Several new or epidemic diseases have been documented recently among the fish and shellfish of the region. Causes of fish and shellfish diseases seem to be multiple and interrelated. Outbreaks of diseases have been linked to general water quality degradation, elevated levels of toxicants, phytoplankton-produced toxins, increased salinity during periods of drought and decreased salinity.

In 1989, within the study area, commercial fishermen landed a total of 59.1 million pounds of fish, and North Carolina fishermen, as a whole, landed 85.4 million pounds of estuarine-dependent fish (excluding menhoden). The total commercial catch-per-unit-effort has decreased despite improvements in fishing gear and methods. Since 1988, total commercial landings have declined 14 percent to 151.5 million pounds. Specific causes of the declining landings are unknown, but several factors have been associated with the declines, including alteration of riverine flow regimes, declining water quality, increased "effective effort" (the ability to inflict mortality), increased size and power of fishing vessels and improved electronics, fishing gear and techniques. These improvements, in turn, can lead to overharvesting.

Recreational anglers compete for many of the same species as commercial fishermen and can account for a significant proportion of the total catch. For some species of fish, recreational harvest probably exceeds commercial harvest. The total recreational catch-per-unit-effort has also decreased, despite increasing effective effort due to improvements in gear and techniques.

The action plan/demonstration project portion of APES was developed to target funds at identified problems and to support measures that could be employed on a wide scale to address those problems. A study conducted in the Merchants Millpond/Upper Bennett's Creek Watershed investigated the use of best management practices in animal operations to achieve appropriate nutrient reductions in nutrient-sensitive waters.

Coordination of all facets of this program will result in a final consensus document — the Comprehensive Conservation Management Plan — to protect and preserve our estuarine system.

National Marine Fisheries Service Environmental Research in the Southeastern United States

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The National Marine Fisheries Service is mandated to conserve and protect living marine resources. This is directly related to the quality and quantity of fishery habitat. In 1991, NMFS published a strategic plan for fisheries and Goal 6 of the plan is: "Protect Living Marine Resource Habitat" and the objectives are:

1. Use the authority of the Fish and Wildlife Coordination Act, Magnuson Act, Marine Mammal Protection Act, Endangered Species Act, Oil Pollution Act, Superfund and other legislation to implement a cohesive strategy to protect and restore habitat of living marine resources.

2. Quantify the effects of habitat modifications and contaminants on populations of living marine resources.

3. Determine if artificial or restored habitat fulfills essential habitat needs of LMRs. Artificial habitats, such as reefs, or habitat restoration may be used to mitigate development.

4. Restore depleted stocks that have been adversely impacted by habitat modification.

This goal and these objectives provide the basis for the research programs that are addressing how environmental quality impacts seafood production.

The environmental research effort in the Southeast is a multidisciplinary, generic program concerned with estuarine-coastal habitats that addresses the above mentioned goal and objectives. The program is a mixture of field, satellite and laboratory research with the common goals of: (l) determining the key processes that regulate fishery production and (2) developing the capability to predict and assess the effects of habitat alterations and contaminant additions on fishery organisms/production. The NMFS facilities that are primarily involved in this research effort are located at Beaufort, Galveston, Miami and Mississippi. The environmental issues being investigated in a generic and specific manner in the Southeast are: (l) coastal habitat modification; (2) effects of water diversion; (3) the value of mitigated habitat; (4) contaminant loading; and (5) cumulative/additive effects of habitat loss and contaminant additions on fishery populations. In addition, coastal nutrient loading is a concern but is not being addressed by existing research in our region.

The estuarine research efforts in the Southeast are determining the relative values of nursery areas, including marshes, seagrasses and non-vegetated habitats for fishery species. Impacts of physical changes to fishery habitat as well as the value of measures used to mitigate these changes are being evaluated. The primary concern of these investigations is to determine the processes that control the productivity of submergent and emergent vegetated habitats together with associated unvegetated areas in the coastal areas and how perturbations of these areas may affect important fishery organisms. These studies are using the recruitment of larval and juvenile fish and shrimp into estuaries as well as their abundance as a measure of the value of natural wetlands.

With accelerated coastal development, the process of mitigation has become an important topic. It is important, therefore, to determine whether the created wetlands have the same or similar habitat value as the original acreage that was destroyed. These types of investigations utilize the methodologies developed for investigating natural wetlands, and the studies of experimental mitigation sites are being conducted in North Carolina, Florida and Texas.

Another environmental modification that has been studied extensively is the effect of freshwater diversions on environmental quality in Texas and southwest Florida. In both cases, the investigations are addressing the problem of freshwater inflow, but the two problems are different. In Florida, the problem is salinity reduction due to increased freshwater inflow. In Texas, the situation is reversed due to reduced freshwater input. Both changes in the flow patterns of fresh water have significantly altered habitat productivity and quality and species composition. As a linkage between the open Gulf of Mexico and the estuarine areas, satellite measurements of surface seawater temperatures are being used to predict the levels of primary production in nearshore waters and how they interact with other estuarine processes.

Other environmental concerns are the increased contaminant loading and increased incidences of disease among fishery organisms, both of which may be the result of accelerated coastal development. In the Southeast, selected estuaries and organisms are being monitored as part of NOAA's National Status and Trends Benthic Surveillance Program. This ongoing program is determining the concentrations of both organic and inorganic contaminants in fish and sediments in 19 estuaries in the Southeast, 14 of them on the Gulf of Mexico. In addition to monitoring efforts, studies are also conducted on the processes that control the effects of trace metals on marine organisms. These studies are not confined to the Southeast because metal contamination is much greater in the estuaries in the Northeast. The data derived from these studies and others on the metabolism of metals by fishery organisms are useful in assessing the potential impacts of metal contaminants on estuarine processes. Increased incidences of disease in fish and shellfish have been reported from different locations in the Southeast. The fish disease, ulcerative mycosis, has been identified in fish collected from the Pamlico River in North Carolina and the St. Johns River in Florida. Blue crabs, with an extremely aggressive form of shell disease, have been collected in the Pamlico River in North Carolina and in Biscayne Bay in Florida. An investigation to describe the etiology of this disease among the blue crab population is currently underway in North Carolina.

Efforts also are being made to examine the cumulative and additive effects of multiple environmental perturbations on important fishery organisms. Although it is attractive to draw direct correlations between decreased fishery yields or disease outbreaks and loss of wetlands or industrial or domestic contaminant inputs, such correlations are generally to simplistic and will probably be misleading. For example, the etiology of most disease processes are complex and require more than one factor before the disease can be expressed. Another difficulty in predicting how or why populations of organisms vary is that the sources of variability have not been adequately described. Also, our understanding of such things as larval survival and recruitment is not complete enough to predict how normal, unstressed populations should behave. In other words, the prediction or assessment of cumulative/integrated effects of compromised environmental quality may be first-order questions, but extensive knowledge of processes that control natural populations is required before such effects can be successfully described.

EPA: Pollution Prevention Strategy and Related Legislative Acts

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The Waste Reduction Resource Center's function is to serve as an information clearinghouse and to provide technical assistance in waste reduction efforts to clients in Region IV, EPA. Our primary role is to provide backup technical assistance to Region IV state technical assistance programs.

To understand the Environmental Protection Agency's (EPA) Pollution Prevention Program as it exists today, it helps to look at what preceded its creation. EPA was an outgrowth of the massive public demonstrations which occurred on Earth Day, April 1970. Congress was forced to take action to initiate legislation to correct past mistakes and to protect the environment. The Environmental Protection Agency was created by the National Environmental Policy Act of 1970.

Legislation continued to be passed, ranging from regulations designed to protect individual media such as air, water and solid waste to legislation governing multi-media wastes such as toxic and hazardous wastes. Comprehensive environmental recovery acts such as CERCLA came into being too. Regulations were often difficult to understand or were not acceptable to industry resulting in protracted litigations.

Regulations often were not only confusing but were too stringent requiring repeated amendments or new acts. In the 1980s, new concepts were introduced such as cradle-to-grave tracking and responsibility under RCRA. The first requirement to begin waste reduction planning originated with the Hazardous and Solid Waste Act (HSWA) Amendments of 1985.

In 1986, EPA changed its emphasis from end-of-pipe treatment to the prevention of waste generation. States had led this initiative by developing direct, free non-regulatory technical assistance to industry to eliminate waste by stopping its generation at the source. The following summarizes EPA's Pollution Prevention Program initiation and new direction as reported in its annual report to Congress in 1986.

- To provide technical assistance programs on waste minimization to waste generators and the states.
- To assist states in developing technical assistance programs.
- To develop a waste minimization information system to disseminate information to producers and the states.
- To implement waste reduction throughout EPA across all media programs.

To implement EPA's proposed redirection as stated above, Region IV's Hazardous Waste Roundtable, including heads of the region's state programs, representatives of the Tennessee Valley Authority, the Department of Energy, and the Southern States Energy Board, decided on a two-pronged effort to meet EPA's stated objectives.

The states were to start technical assistance programs in waste reduction for industries, local government and the general public. A central clearinghouse of waste reduction information, staffed with experts who could assist states in getting started, was needed. This gave rise to the Waste Reduction Resource Center funded and staffed principally by EPA, Region IV but with assistance by TVA.

The center was located with the N.C. Pollution Prevention Pays Program to take advantage of the state's extensive waste reduction library and the expertise of its engineers. The center opened its door for business on April 1, 1989.

EPA's Pollution Prevention Office and Program was initiated in 1988, four to five years after many states started similar programs and after Region IV sponsored a program for the entire region.

Between its establishment in October 1988 and passage of the Pollution Prevention Acts of 1990, the EPA's Pollution Prevention efforts were largely outreach. These included funding research, putting on training courses, funding 25 state technical assistance programs and planning the integration of pollution prevention in all EPA programs.

Last year, many new acts were introduced that will have a lasting impact on the way waste problems are addressed in the future. The new Clean Air Act, The Pollution Prevention Act of 1990, The National Environmental Policy Act Amendments, the pending Federal Facility Compliance Act and updates to CERCLA and RCRA all place new requirements on all waste streams.

The Pollution Prevention Act of 1990 establishes pollution prevention as a national objective. The act establishes a hierarchy of environmental protection priorities as follows:

- source reduction,
- recycling on-site/off-site,
- treatment, and
- disposal.

Pollution Prevention, particularly source reduction will become an integral part of all EPA programs, regulatory and non-regulatory.

Other new initiatives include the voluntary 33/50 Toxics Reduction Initiative; 1991 Small Business Grants for pollution prevention projects; and a new $8 million state grant program that funds 16 new state programs (50 percent state match for initial grants now reduced to 10 percent match). Form R reporting becomes a regulatory part of The Pollution Prevention Act of 1990. A Municipal Pretreatment Program grant will attempt to demonstrate that pretreatment regulators and non-regulatory technical assistance programs working locally can reduce waste at the source sufficiently to keep POTW'S in compliance with discharge limits.

In addition to EPA, states have independently initiated legislation to require waste reduction plans and the establishment of specific waste reduction goals in constrained time frames for specific waste streams. Wise generators are initiating waste reduction plans and goals for all waste streams.

Waste reduction makes sense economically, environmentally and socially. To get started or address difficult waste reduction problems, contact the Waste Reduction Resource Center at 1-800-476-8686.

New England Seafood Processors and the Environment

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This talk was prepared on short notice, and my initial thought was that the waste disposal situation in New England could be summed up in one sentence; to wit: The harsh effects of the fish meal plant closings and the skyrocketing tipping fees for landfills have been mitigated by the diminution of the fish stocks and the lower catches that have resulted. This being said, I will try to sketch in a few details of what is happening in New England.

I recently visited a New Bedford processor who is paying $90 per ton for landfilling dogfish wastes and $120 per ton for landfilling giant tuna heads. He is putting about $120,000 per year into tipping fees. His situation is not unique.

Shellfish processors are also having a hard time disposing of shells. Disposal fees are going up, and some processors claim not to know where their wastes are taken and prefer not to know in case they are disposed of illegally. One relatively small crab processor pays about $50,000 per year in disposal fees and is doing his best to reduce this by finding alternative markets for as much of the crab as he can. For example, he has been exporting back shells to Europe where crab meat is often presented in the shell, and he is also selling brown meat abroad.

In Massachusetts, most standard finfish wastes are collected, ground, frozen and sold for pet food or to mink farmers. This is a breakeven situation for the processors. In season, a tremendous amount of finfish waste is also sold for lobster bait, although this market is limited to those species landed and processed in the round. Thus, our problem species are those that are undesirable as bait and for grinding and freezing; i.e., shellfish, dogfish, skates and squid, with the latter two constituting a relatively small proportion of the region's waste.

When the dollar weakened, making exports more attractive, and the stocks of more traditional species diminished, more fishing vessels and more processors moved into the dogfish and skate fisheries, especially into dogfish for which a larger market exists. New Bedford processors are landfilling their dogfish wastes, but most processors north of Boston are grinding and dumping at sea. The EPA official who permits for dumping at sea has stated that, in his opinion, only about one in six of the dumping operations is conducted according to EPA guidelines, but he is reluctant to come down hard on offenders until alternatives are identified.

A Phase I Department of Commerce Small Business Innovation Research grant has been awarded in Massachusetts to pursue the development of equipment for processing dogfish and skates at sea and to stabilize the processing wastes onboard. The grant was awarded to a joint venture composed of several Gloucester-based vessels, Alphatron Corporation, an engineering and manufacturing firm owned and managed by two ex-fishermen, and our company. The fishing vessels are very interested in the concept of onboard waste stabilization since this constitutes a second product, which they hope will increase their profits.

North Atlantic Products of Rockland, Maine, the largest dogfish processor in New England, purchased, permitted and prepared land for composting. They started to do turned, windrow composting and stopped before the end of their first year of full operation because of neighbors' complaints. Bill Jackson, the president of the company, has stated that he felt that the complaints were justified; there really was odor. The company has since purchased a boat and is now dumping at sea.

Salmon aquaculture is growing in New England, and there are no firm policies yet on what to do with the viscera and morts. Since the morts must be collected by divers, in icy, murky waters, they are not collected often and are not usable in pet food or livestock feed. The viscera are in excellent shape, but the quantities are I small. The aquaculturists are afraid to incorporate them into feed because of the dangers of recycling disease and no one has set up full-scale composting, which is probably their main option. One company is said to have two to three years worth of viscera frozen and is still trying to decide on a path of action.

Two fish processors have set up two separate Gloucester-based hydrolysing operations and are selling most of their product to the Massachusetts cranberry bogs. The price is coming down but is still higher than what is realistic in the long run. On a per nitrogen basis, compared to chemical fertilizers, the price is extremely high. However, the cranberry growers feel that this is justified for use in bogs with particularly porous soils because this organic fertilizer does not leach out into water supplies the way that a chemical fertilizer would. The buyer of the hydrolysate, who stores and re-sells to the farmers, is not happy with the problems of storing, stirring and pumping all of this water (the fertilizer is unconcentrated) and would prefer a dry product. On the other hand, he sees the handwriting on the wall for fertilizers that do not leach out into the water table, on farms close to drinking water supplies. So he is committed to an organic fertilizer for the sandy bogs.

The Stinson Canning Company, of Bath, Maine, which had the first hydrolysis plant in the Northeast and carried out the first commercial fermentation of hydrolysed fish, has been purchased, and the new owners have closed down the waste utilization operation.

The Portland, Maine, Fish Auction has received a permit to hydrolyse fish wastes and is currently carrying out hydrolysis on a small-scale. They have received Saltonstall-Kennedy funds to test their product on selected Maine crops this summer.

At least one company is collecting clam processing cooking waters, boiling them down, spray drying them and selling the resulting powdered product as a flavor base for soups and chowders.

To close with a general observation on water use, even though water and sewerage costs are going up, almost all New England processing plants still require boots for a visit and still flume their offal so that they have high BODs and low quality offal.

A Report on an Incident That Impacts the Gulf and South Atlantic Seafood Processors and the Environment

Robert Jones
Southeastern Fisheries Association

It is impossible for me to cover eight different states and all processing sectors in 20 minutes. I would have trouble doing it in 20 hours. So I have decided to present a paper to show what could happen to all seafood processing and packing houses in the Gulf of Mexico and South Atlantic regions.

I'm going to report on an incident I was personally involved with on behalf of the industry. I'm going to call this incident, **The Raffield story, part II**

Raffield Fisheries Inc. is located in Port St. Joe, Fla., about 25 miles east of Panama City and 15 miles west of Apalachicola. Raffield Fisheries, like many other processing and packing plants in the Southeast, catch fish, ice them down, bring them to the dock, unload them into a vat on the dock to wash the ice off, send the fish into the processing room by conveyor and then empty the water into a flowing canal, river or bay.

In Raffield's case, he empties into the same canal used by a chemical plant, a coal unloading facility and one of the largest paper mills in the state of Florida. There is swift movement in this canal on the rising and falling tide. The canal connects the Intercoastal Waterway on the north to the Gulf of Mexico on the south, a distance of less than 7 miles.

Raffield Fisheries is a well maintained professional fishing operation. It is the third largest employer in Gulf County. It has had as many as 350 people on the payroll during the height of its production and processing.

About five years ago, Gene Raffield was issued a federal permit to catch redfish in federal waters off Louisiana. At least 12 other vessels were also issued permits, including several from Florida. Raffield's boat harvested 40,000 pounds of redfish in the federally exclusive economic zone. His fishermen loaded them in trucks to ship them back to his plant in Port St. Joe, Fla. When the trucks carrying the legally harvested redfish crossed the Florida line, they were immediately followed by undercover agents. When the trucks arrived at the Port St. Joe plant, 20 marine patrol agents arrested one truck driver, a female plant employee and Gene Raffield for possessing food fish taken with a purse seine.

The Florida statute said that a Florida citizen cannot possess food fish taken with a purse seine from anywhere in the world. And this statute was upheld by the Florida Supreme Court in June 1991 after four years.

Raffield had a federal permit and a federal observer on board. He caught the fish in federal waters under federal rules. Four other Florida boats caught redfish with a purse seine and were never approached. Raffield's arrest and the subsequent litigation has been festering for almost six years. He and I felt that he had been unjustly selected for special enforcement treatment by those people bent on destroying the commercial fishing industry in Florida.

On August 2, 1991, a federal judge in Washington, D.C., declared that the law used to arrest Gene Raffield was unconstitutional. On August 6, 1991, a Miami federal judge ruled in Southeastern Fisheries Association v. Martinez that: "A state can no longer discriminate against its own citizens and that such action violated equal protection, interstate commerce and is compensable under the civil rights guaranteed to everyone."

Now you're wondering why I'm telling you this at a meeting about seafood processing and the environment. Now I will tie it all together and make my point. Earlier in this presentation, I described the unloading operations at Raffields. Now I want to show what can happen to a citizen when he becomes a "target" of "selected law enforcement" by government.

Raffield's company immediately started to come under close scrutiny from several state agencies. One of them was the state department of environmental regulation. An official for the department told Raffield he could no longer put the vat water in the canal because it contained oil. Raffield said it was fish oil. The state person said, "Oil is oil whether it is crankcase oil or fish oil, and you can't put it in the water."

Now I would like to show you the result of this declaration of "oil is oil."

Raffields has installed an accumulation tank that receives all wastewater from the plant, including rainwater if it lands on the unloading docks. In the filtration tanks, solids are removed. Water comes out of accumulation tanks where solids are removed by 1/8-inch diameter screens. In concrete tank top, one-third of the water is removed. The bottom two-thirds makes up a customized aerobic process.

The sand filtration system further removes solids. The main holding tank is 10 feet deep, 40 feet long and 12 feet wide. The bottom third is still utilizing an aerobic process that reduces odor and solids. The water is then sprinkled on the grass of the land surrounding the plant. One more problem has developed in that the water is so rich it has a tendency to kill the grass.

The Southeastern Fisheries Association has applied for a copyright on the system used by Raffield. It costs about $145,000. The system is effective and efficient. Any processing or packing plant that has interest in installing this system can contact the Southeastern Fisheries Association for more information.

The only recommendations Southeastern Fisheries Association makes to the government regulators is to be fair, be consistent and be compassionate as you work your way through the very diverse and highly complex professional fishing industry.

North Pacific Seafood Processors and the Environment

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University of Alaska at Fairbanks

When David Green invited me to speak at this conference, I called him to ask what he wanted covered in my presentation. He mentioned two things. The first was a discussion of concerns that seafood processors have about how environmental factors affect or will affect their operations. The second was a review of the information presented at the International Conference on Fish Byproducts held in Anchorage, Alaska, in April 1990. So I have divided my talk into two parts.

To determine what seafood processors in the Alaska fishing industry feel are important environmental concerns, I asked University of Alaska Sea Grant advisory agents to question processors in their communities. This survey included large and small processing operations, and it included ones that have access to a fish meal plant and ones that do not. The information is from plants in Alaska only.

Very early in our discussions, we found that the concerns were in two areas: seafood processing plant operation and the supply of fish and shellfish.

ENVIRONMENTAL CONCERNS AFFECTING PROCESSING OPERATIONS

Table 1 lists the environmental considerations that affect or may affect in the future operation of a seafood processing plant. The concerns are listed in order of priority with the one listed first being of greatest concern. This order was established by giving higher ranking to topics mentioned most frequently and to topics that seemed more important based on ensuing discussions.

Environmental Protection Agency regulations for disposal of seafood processing waste are of great concern to Alaska seafood processors. This is not surprising since EPA has fined 12 seafood processors in Alaska during the last four years. They are concerned about whether changes will occur in the regulations and about variations in strictness of enforcement of existing regulations. Compliance with existing regulations is not difficult as the rules are few and easy to understand. Some Alaska seafood processors are covered by the General Permit. But if they operate in areas where there are large numbers of processors or large amounts of fish processed, they are issued an individual permit. The General Permit is issued every five years, and the current one was issued in 1989. The permit requires seafood processors to grind their waste to less than one half inch and to discharge in water below the surface. The waste cannot be discharged into shallow waters, lakes, areas with poor flushing, areas closer than one mile from drinking water sources or areas such as critical habitat areas that are of special environmental concern.

Production of byproducts from processing waste is the best solution for the environment. But byproduct production incurs power costs for production and freight costs for shipping to market.

The use of plastic and styrofoam materials in packing and packaging for shipping and marketing of seafood ranked high in the concerns of seafood processors. These materials are inexpensive and are helpful in maintaining product quality. However, there are environmental problems in their disposal.

A good supply of potable water is not a problem at most processing plants in Alaska. It can, however, be a problem at some remote locations.

Environmental concerns about the use of fluorocarbon refrigerants was a low priority. Processors seem to feel that it is a problem for the refrigeration industry to solve.

ENVIRONMENTAL CONCERNS AFFECTING RAW MATERIAL SUPPLY

Table 2 lists the environmental considerations that relate to a continued supply of fish and shellfish. As can be seen from Tables 1 and 2, there is much more concern over the availability of raw material for processing than there is about how processing can adversely affect the environment.

Bycatch is of highest concern to seafood processors now. Use of bycatch quotas results in closure of commercial fishing for the target species when a bycatch quota for another species is reached. The fishery may be shut down long before the catch quota for the target species is reached. Processors are also concerned about discarding prohibited species. These fish are supposed to be returned whole to the sea with the expectation that some will survive. However, a very high percentage probably do not live. This is a loss of the resource, and the discards may in the future be included in EPA regulations on waste disposal.

Processors are equally concerned about marine mammal protection regulations. The entire fishery for some species could be closed to stop or to slow down the decline in population of a particular marine mammal. The commercial fishing industry may face problems similar to those faced by the timber industry due to protection of spotted owl habitat.

Competition from the sports fishery and, to a lesser extent, from the subsistence fishery for access to the resource is increasingly a problem for Alaska's commercial fishermen. Competition for the resource between land-based fish processing plants and offshore fish processing vessels creates some very complicated fisheries management issues.

Harvesting finfish for roe may have adverse affect on the stocks of that species. It is also a waste of the resource if the carcass is discarded. Concern has arisen recently about waste of the Alaska pollock by fishing operations that strip the roe and discard the carcass. Decrease in stocks of some species due to overharvesting has in the past been a problem. Processors are also worried about the effect of global climatic changes on productivity in marine waters.

Pollution of the marine environment has long been an important concern of the commercial fishing industry. Public health concerns about industrial pollutants like PCBs, DDT and mercury as well as microbial pathogens in fisheries products is more of a problem with fish from lakes and rivers than with those from marine waters, especially those caught in offshore waters. Adverse effects on fish habitat from timber harvesting, mining and hydroelectric power development is of importance to those involved in a fishery for an anadromous species such as salmon. Transportation of oil in tankers will always be a worry to the fishing industry in Alaska due to the grounding of the Exxon Valdez in Prince William Sound and the subsequent loss of nearly 11 million gallons of crude oil. This spill spread over 800 miles. It killed thousands of birds and marine mammals and contaminated finfish and shellfish.

There is a lot of disagreement as to whether there are serious adverse effects on genetics and health of wild stocks of fish due to fish hatchery operations and pen rearing of finfish. Alaska has a large number of salmon hatcheries that release juvenile fish into the natural environment for harvest in common property fisheries (ocean ranching). Rearing of finfish in a totally captive environment (ocean farming) is not permitted now in Alaska.

Some cost is involved for fishing vessels, fish tenders and floating processors to comply with the Marine Plastic Pollution Research and Control Act. This law implements Annex V of the International Convention for Prevention of Pollution from Ships (MARPOL). The cost is not so great as to make this a very high priority.

FISHERIES BYPRODUCTS

In April 1990, the Alaska Sea Grant College Program and the Alaska Fisheries Development Foundation sponsored a conference on fish byproducts. Most of the papers presented at this conference were about production of and markets for byproducts. Table 3 gives a list of the byproducts discussed at the conference.

Fish meal was the byproduct that received the most attention at the conference. There were two main areas of interest. One was the demand or market, both current and future, for fish meal. The other was a review of fish meal quality or specifications needed for the different uses. Markets for fish oil and bone meal were also discussed. These two byproducts are usually produced along with fish meal.

A report on fish silage described the Icelandic experience in production methods. In another report, a composting method was described for producing a low-cost soil amendment. There was also a paper presented that gave a review of the uses of marine byproducts in agricultural crop production.

Two papers were given by researchers from Japan on use of an enzymic method to produce fish flour or fish protein. The fish flour is intended for use in animal feed and the fish protein is intended as an additive for human food. A discussion of the size of the pet food market in the United States and the potential for using marine byproducts in pet foods indicated this could be a good way to use processing wastes. However, it was pointed out that cats and dogs are sensitive to "off" flavors so poor quality waste is not suitable.

Other byproducts that were the subject of reports given at the conference are fish leather, chitin-chitosan, astaxanthin and seafood flavor extracts.

A copy of the proceeding of this conference is available from the University of Alaska Fairbanks, Alaska Sea Grant College Program, 138 Irving II, Fairbanks, Alaska, 99775-5040. The cost is $10.

Table 1. Environmental Concerns of the Alaska Seafood Industry: Concerns About Operation of Seafood Processing Plants.

Subject	Concern
1. Waste disposal regulations	Changes in regulations
2. Waste disposal regulations	Variations in strictness of enforcement
3. Plastic and foam packing and packaging	Environmental concerns caused by use of these materials
4. Byproducts	Freight costs to ship to market
5. Waste disposal regulations	Compliance with existing regulations
6. Byproducts	Power costs for production
7. Processing water	Supply of potable water
8. Refrigeration	Environmental concerns over use of fluorocarbon refrigerants

Table 2. Environmental Concerns of the Alaska Seafood Industry: Concerns About Supply of Raw Fish and Shellfish.

Subject	Concern
1. Bycatch quota use in fisheries management	Commercial fishing closures when bycatch quota is reached
2. Marine mammals	Effect of conservation regulations on commercial fisheries
3. Offshore fish processing vessels	Competition for the resource
4. Sports fishery	Competition for the resource
5. Finfish roe fisheries	Adverse effects on stocks
6. Industrial pollution	Public health concerns about PCBs, DDT, mercury, etc. in food supply
7. Microbial pollution	Public health concerns about microbial pathogens in food supply
8. Habitat degradation	Adverse effects on fish habitat due to timber harvesting, mining, oil resource development and hydroelectric power development
9. Oil spills	Disruption of fish harvesting operations and contamination of fish stocks
10. Chronic oil pollution	Deterioration of water quality caused by deballasting, recreational boats, small spills, etc.
11. Overharvesting	Decrease in fish stocks from increased fishing effort and/or sloppy management
12. Discarded bycatch	Waste of fisheries resource
13. Fish hatchery operations	Adverse effects on genetics, health and food supply of wild stock
14. Subsistence fishery	Competition for the resource
15. Pen rearing of finfish	Adverse effects on genetics and health of wild stock
16. Global climatic changes	Effect on productivity in marine waters
17. Marine debris	Higher cost of fish due to cost of bringing back debris and disposing of it

Table 3. Reports on Production of Byproducts from Seafood Wastes Presented at the International Conference on Fish Byproducts, Anchorage, Alaska, April 25-27, 1990.

Byproduct	Author	Topic
1. Fish meal	B. Crowder	U.S. demand for fish meal
	T.J. Starkey	U.S. markets for fish meal, fish oil and fish solubles
	M.J. Meehan, F.M. Husby, C. Rosier and R.L. King	Alaskan production of fish byproducts
	B. Marki	Fish meal quality
	R. Hardy and T. Masumoto	Fish meal specifications for aquaculture use
	N.C. Jensen	Fish meal specifications for use in feeds
	E.V. Bertullo, J.F. Bingaman and D.G. Snyder	Biological fish meal
	J.S. Kilpatrick	Future production and utilization of fish meal
2. Fish oil	B. Hjaltason	Markets for fish oil
3. Bone meal	J. Cowger	Markets for bone meal
4. Fish silage	S. Arason, G. Thoroddsson and G. Valdimarsson	Production of fish silage in Iceland
5. Composted fish waste	W.F. Brinton	Composting of seafood processing waste
6. Fish fertilizer	B. Wyatt and G. McGourty	Fish fertilizer for use on agricultural crops
7. Pet food	T. Willard	Use of marine byproducts in pet foods
8. Fish flour	Y. Uchida, H. Hukuhara, Y. Shirakawa and Y. Shoji	Production of fish flour using an enzyme process
9. Fish protein	Y. Shoji	Production of creamy fish protein using an enzyme process
10. Fish skin leather	R.V. Lewis	Opportunities for aquatic leather manufacture
11. Chitin and chitosan	O. Skaugrud and G. Sargent	Uses and markets for chitin and chitosan
	S.P. Meyers, H.M. Chen H.K. No and K.S. Lee	Preparation of chitin and chitosan from crawfish waste
12. Astaxanthin	S.P. Meyers, H.M. Chen H.K. No and K.S. Lee	Extraction of astaxanthin from crawfish waste
13. Seafood flavors	T. In	Production of seafood flavoring materials by enzymic hydrolysis

Nutrient Management With Land Application Systems

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All living things contain nutrients. Nutrients occur in bone, cells, fluids, enzymes and most other parts of organisms. A natural and biologically driven process of decomposition begins when death occurs. Microorganisms drive the process breaking complex molecules into simpler ones and with time eventually releasing nutrients to the environment. A simplified example of this process is the decomposition of complex proteins into simpler amino acids and eventually the release of nitrogen in the forms of ammonia and ammonium.

Land application of large concentrations of organic or inorganic nutrients (uncontrolled disposal) are subject to surface runoff and leaching that may contaminate ground or surface waters. The potential for contamination is site specific. For example, sites with flat topography, coarse textured sandy surface soils and permeable subsoils are more susceptible to ground water contamination than sites with sloping topography having fine textured clays and silt that are less permeable. Where ground water contamination is a concern, depth to ground water, location of wells and well-head protection are important factors to consider in developing a land application program. In areas where surface water contamination is a concern, key factors to know include degree of slope, distance from surface waters, use and classification of surface waters, and rate of water percolation into the soil profile. Although most site evaluation criteria are technical, there is an additional sociological factor that is becoming more important: distance from neighbors for potential nuisance and odor complaints.

The quantity of nutrients within organic materials varies considerably between different materials and within the same material if processed or handled differently. Because of this diversity, it is extremely important that all organic materials be analyzed for nutrient content before being land applied. In addition to a standard nutrient analysis, it is also important to know the quantity of heavy metals, oil and grease, and sodium that may be present in the material and the chemical oxygen demand (COD) required to decompose it. Each of these factors must be considered in a land application program.

The nitrogen and phosphorus present in organic materials are common water pollutants. These nutrients contaminate surface water, but nitrogen is the predominant groundwater pollutant. Contamination of surface waters is primarily from soil erosion. Attached nutrients, pesticides and organic matter in eroded soil disperse throughout the aquatic system. Algae present in the water thrive on the addition of nitrogen and phosphorus and rapidly increase in numbers. Microorganisms use oxygen in the water to decompose the dead algae. The low water oxygen level from algae decomposition results in fish kills. Management to prevent surface water contamination begins with soil conservation. Best management practices include conservation tillage, contour farming, strip cropping and grassed waterways and field borders.

Ground water is less vulnerable to nutrient contamination than surface waters because of direct competition by plants and soil organisms. Contamination can occur, however, when concentrations applied to the soil exceed plant nutrient needs. The primary nutrient of concern with groundwater contamination is nitrogen. Nitrogen is a very dynamic element. It can be present in several molecular forms and in a solid, liquid or gaseous state. Most forms of nitrogen are of little concern to human health. The air we breathe is 78 percent nitrogen gas. The first inorganic forms released from organic materials applied to soil are ammonia, a gas, and ammonium. Ammonia, if not incorporated can be lost through volatilization. Ammonium NH_4^+, on the other hand, is a molecule with a positive charge. Clay particles and humus in soil contain negative charges. The weak magnetic forces of molecules with positive charges, like ammonium, are less likely to leach to ground water. While this "magnetism" is an excellent mechanism to retain nutrients in the soil, microorganisms use the ammonium and convert it into a negatively charged molecule called nitrate. Since nitrate is negative and soils have a negative charge, nitrate is susceptible to leaching and is the primary source of nitrogen found in ground water. Nitrate is also the one form of nitrate that can be a concern for human or animal health.

The maximum drinking water standard for nitrate is 10 ppm for humans. At concentrations above this level, an increased health risk exists for infants less than six months of age. The digestive system of a human infant has a higher pH and different microorganisms than that of adults. When nitrate enters their digestive system, it converts rapidly to a form called nitrite that is extremely reactive and combines with oxygen-carrying hemoglobin in the baby's blood steam and forms a compound called methemoglobin. This compound eventually decreases the oxygen available to the baby's system, and the baby begins to suffocate from lack of oxygen. The disease is methemoglobinemia or blue baby syndrome. Death occurs when 70 percent of the body's hemoglobin converts to methemoglobin. Although cases of blue baby syndrome are rare, it is still important to prevent nitrate buildup in drinking water. To prevent an over application of nitrate or other nutrients, it is important to know the concentration and availability of all nutrients present in organic materials and the nutrient requirements of the plant being grown. A waste characterization analysis performed by a certified laboratory should report the concentration of all plant nutrients. When looking at the concentration of nutrients, it is important to know that all the nutrients are not readily available to plants. Only about 50 percent of the organic nitrogen is available to plants during the first year of land application, while most inorganic nitrogen is readily available. A waste analysis helps a land application program by balancing the available nutrients present in the organic material with the nutrient needs of the plant system. This balance is the best way to prevent the entry of nutrients from water sources.

Other management decisions also need to be considered in a land application programs. These include proper timing of land application to coincide with the nutrient needs of the plant system being grown, uniform application of the organic materials to prevent over and under fertilization, and the presence of constituents in the organic material other than nutrients that would alter application rates, such as sodium, oils, grease or substances like heavy metals that would limit the length of time that the site could be used.

Land application systems can be valuable tools for recycling the nutrients present in organic materials that now go to landfills or to ocean dumping. Land application requires a well-planned program to balance the nutrients present in the materials with a cropping system capable of using the same nutrients. A balance between the application rate and plant use has a minimal impact on the environment.

ADDITIONAL REFERENCE MATERIALS

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Anaerobic Treatment of Clam Processing Wastewater

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A clam processor in the southeastern United States was required to install secondary treatment for its waste effluent. A consultant was engaged, and several alternative treatment technologies were investigated (viz., SBR, high-rate UASB, powdered activated carbon and a low-rate anaerobic reactor).

The consultant concluded that the low-rate anaerobic system was best in this application, based on its lowest ten-year present worth and projected effluent quality. An important factor in the economic analysis was the low projected sludge generation and resulting low sludge disposal costs.

Based on the recommendation of the consultant, ADI was engaged to undertake an eighteen-week pilot study using its patented low-rate BVF™ reactor technology.

This paper presents the results of the pilot study and highlights some of the operating details that led to the installation of a 1.7 MG ADI-BVF® reactor. Details of the full-scale BVF system are also provided.

PILOT STUDY OBJECTIVES

The primary objectives of the pilot study were to:

- Verify anaerobic treatability of the raw clam processing wastewater.
- Verify proposed design criteria for the full-scale system.
- Evaluate the system performance at 25 C in terms of COD, BOD, SS and FOG removals and at different loadings.
- Project the net sludge production rate for the full-scale reactor.
- Determine the chemical requirements for nutrient supplementation and pH control.
- Determine the range of biogas quality.
- Assess reactor stability under shock organic loadings without equalization and with the high sodium concentrations characteristic of this type of waste effluent.

Apparatus

The pilot reactor consisted of the following basic equipment (see Figure 1):

1. Day tank, sample pump and timer (for collection of 24-hour composite sample for next day's pilot feed stock).
2. Feed tank, mixer and timer-controlled variable-speed pump (to feed reactor and recirculate reactor sludge).
3. A 50-litre ADI-BVF reactor with heating tape and insulation for temperature control and biogas sampling/venting system.

Operations

The 50-litre reactor was seeded with 14 litres of anaerobic sludge collected from a nearby municipal digester; this sludge was approximately 2 percent SS and 1.3 percent VSS.

The HRT was set at approximately six days and, based on the initial seed charge and average wastewater characteristics, the F/M was approximately 0.16 day^{-1}. A sludge recycle rate of 1:1 and operating temperature of 25 C were used throughout the study.

The reactor was fed on a semicontinuous basis, with new feed being prepared daily. No macro- or micro-nutrients were added to the feed as ample quantities were available in the raw waste. Sodium bicarbonate was added to the feed at start-up to ensure sufficient alkalinity for a stable and satisfactory pH.

The study included two phases of operation. Phase One, weeks 1 through 8, represents the start-up period where the reactor loading was gradually increased by increasing feed wastewater strength. Phase Two, weeks 9 through 18, represents the period at full loading and 100 percent wastewater strength. During the second phase, the pilot reactor was subjected to shock loadings and the bicarb addition was reduced and finally eliminated.

SAMPLING AND TESTING

The frequency of sampling and testing and routine analyses performed on the reactor are outlined in Table 1.

Figure 1: Pilot Reactor System

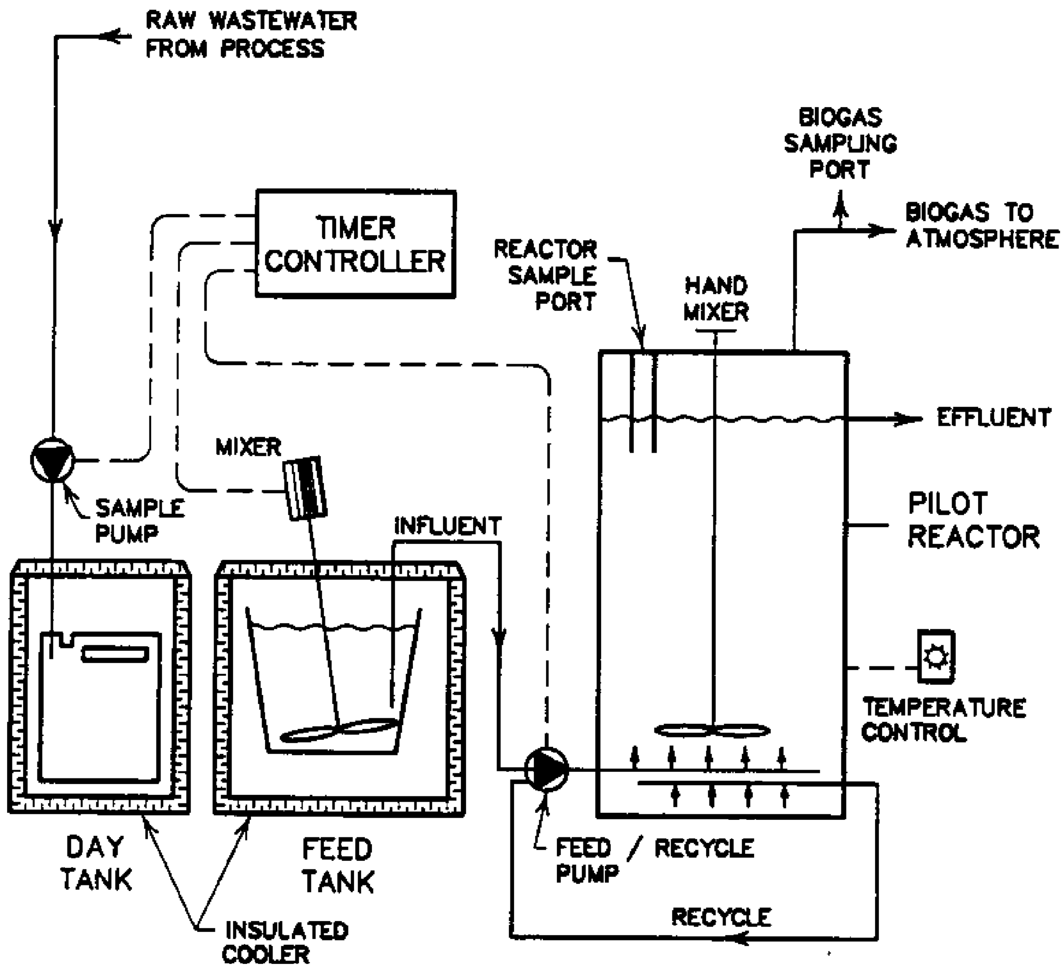


Table 1. Sampling and Testing Schedule

Parameter	Reactor@ Influent	Reactor Effluent	Raw@ Wastewater
COD	TW	TW	TW
BOD	TW	TW	TW
SS	TW	TW	TW
VSS	TW	TW	TW
pH	D	D	D
Temperature	D	D	D
Volatile Acids	TW*	TW*	-
Alkalinity	TW*	TW*	TW*
TKN and Ammonia	M**	M**	M
Total Phosphorous	M**	M**	M
FOG	M**	M**	M

Biogas analysis for CH_4, CO_2, H_2S — weekly, after reaching full strength, using Draeger gas analysis kit.

*Notes

Samples are composites unless noted otherwise.

@	=	one or the other, not normally both (after 100 percent, these are the same streams)
D	=	daily
TW	=	twice weekly
M	=	monthly
*	=	on grab sample
**	=	after full-strength wastewater was being fed to reactor.

All COD test results were total COD, and all BOD results were total five-day BOD. Biogas was analyzed for CO_2 and H_2S; CH_4 was determined by difference.

RAW WASTEWATER DATA

A typical set of wastewater characteristics for the raw clam processing effluent are listed in Table 2 below.

PILOT REACTOR PERFORMANCE/ RESULTS

The COD, BOD and SS removals are given below in Tables 3 and 4. Table 3 summarizes the overall performance for weeks 9 through 18; Table 4 is a summary of performance data for weeks 13 through 18 when feed strengths were deliberately increased with a high-strength inplant stream to simulate shock loadings and increase reactor stress.

The temporal variations in the influent and effluent COD, BOD, SS, COD and BOD loadings, removals, alkalinity (ALK), volatile acids (VA) and pH are given in Figures 2 through 8, respectively.

Table 2. Wastewater Characteristics

	Filtered Sample	Unfiltered Sample
pH	6.04	6.03
BOD	2,100.0 mg/L	2,200.0 mg/L
COD	2,656.0 mg/L	2,479.88 mg/L
Total Kjeldahl Nitrogen	300.0 mg/L	175.0 mg/L
Ammonia	137.76 mg/L	149.52 mg/L
Total Phosphorus	49.50 mg/L	48.50 mg/L
Filtered Iron	4.60 mg/L	4.30 mg/L
Filtered Cobalt	<0.05 mg/L	<0.05 mg/L
Filtered Nickel	0.24 mg/L	0.26 mg/L
Filtered Copper	0.08 mg/L	0.06 mg/L
Filtered Molybdenum	5.4 mg/L	4.8 mg/L
Filtered Manganese	0.10 mg/L	0.10 mg/L
Filtered Zinc	0.348 mg/L	0.298 mg/L
Sodium	8,005.0 mg/L	7,928.0 mg/L
Chlorides	11,579.74 mg/L	11,579.74 mg/L
Sulfates	52.0 mg/L	65.2 mg/L

Table 3. Overall Reactor Performance at Full Strength (Weeks 9-18)

Parameter	Influent (mg/L)	Effluent (mg/L)	Loading (lb/1000 ft^3.d)	Removal (%)
COD	3813	594	36.6	84.4
BOD	1895	337	18.2	82.2
SS	856	130	8.2	84.8

Table 4. Overall Reactor Performance at Full Strength Weeks 13-18

Parameter	Influent (mg/L)	Effluent (mg/L)	Loading (lb/1000 ft^3.d)	Removal (%)
COD	5854	733	54.1	87.5
BOD	2342	395	21.6	83.1
SS	976	148	9.0	84.8

Figure 2: Influent and Effluent COD

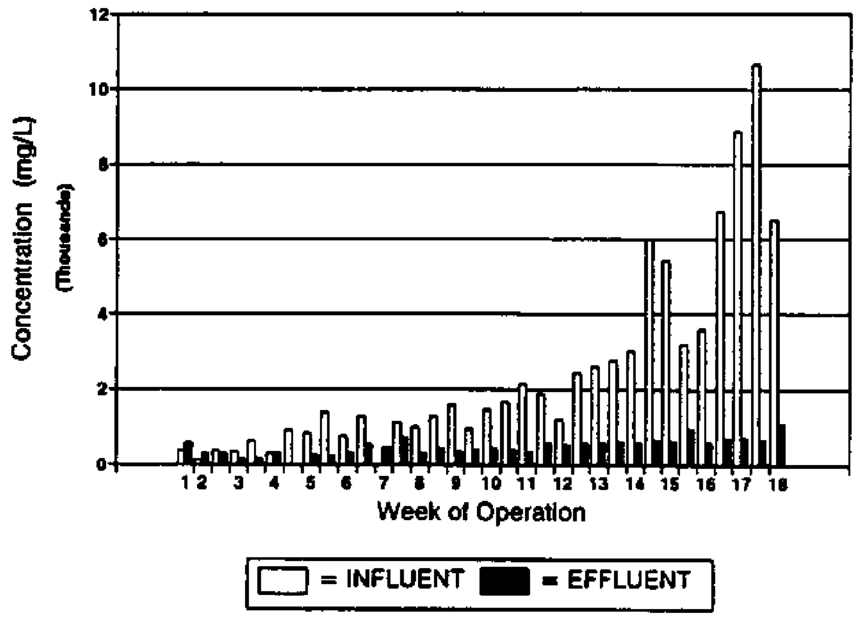


Figure 3: Influent and Effluent BOD

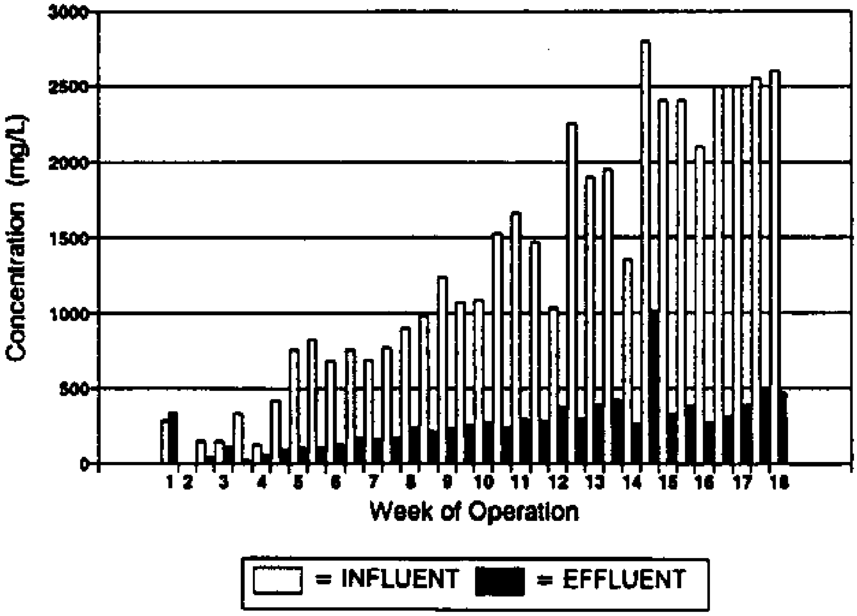


Figure 4: Influent and Effluent SS

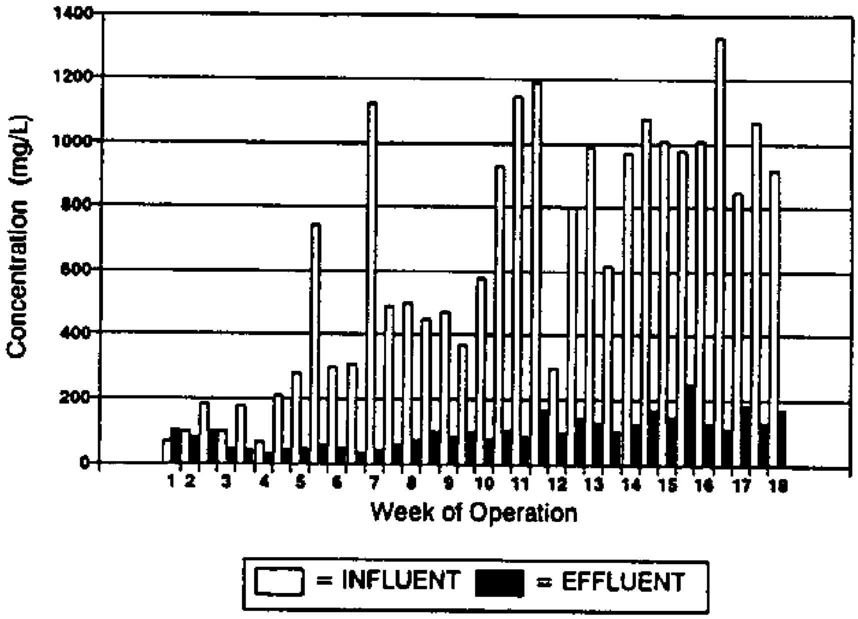


Figure 5: COD, BOD and SS Removal

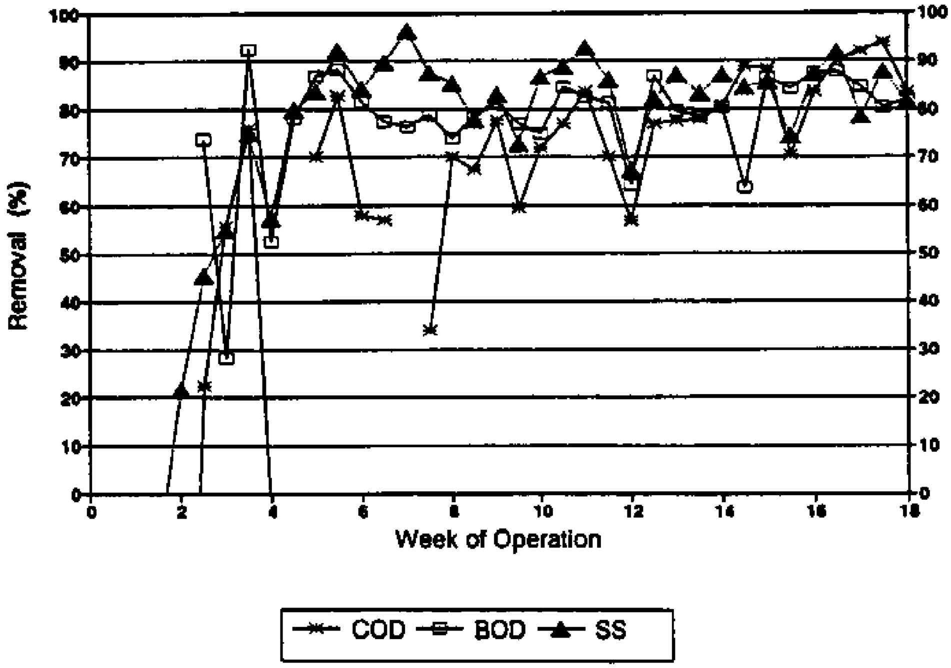


Figure 6: COD, BOD and SS Loading

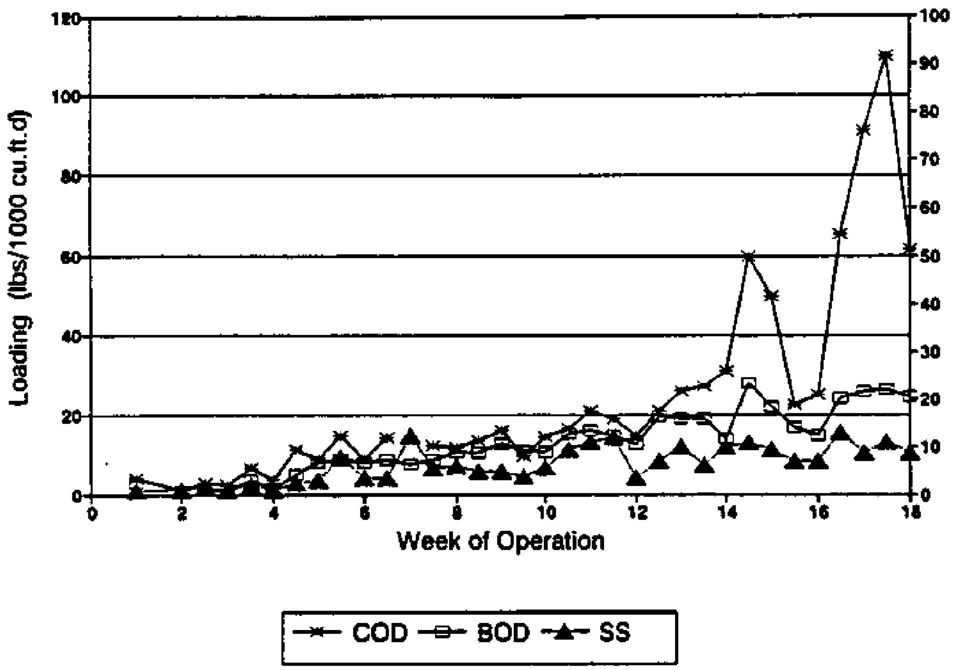


Figure 7: Influent and Effluent pH

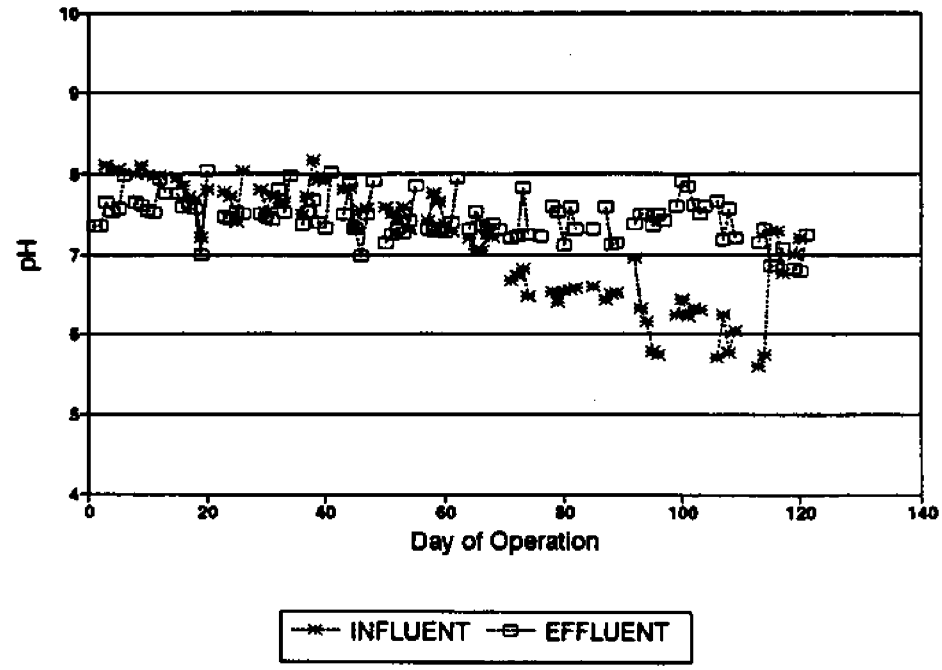
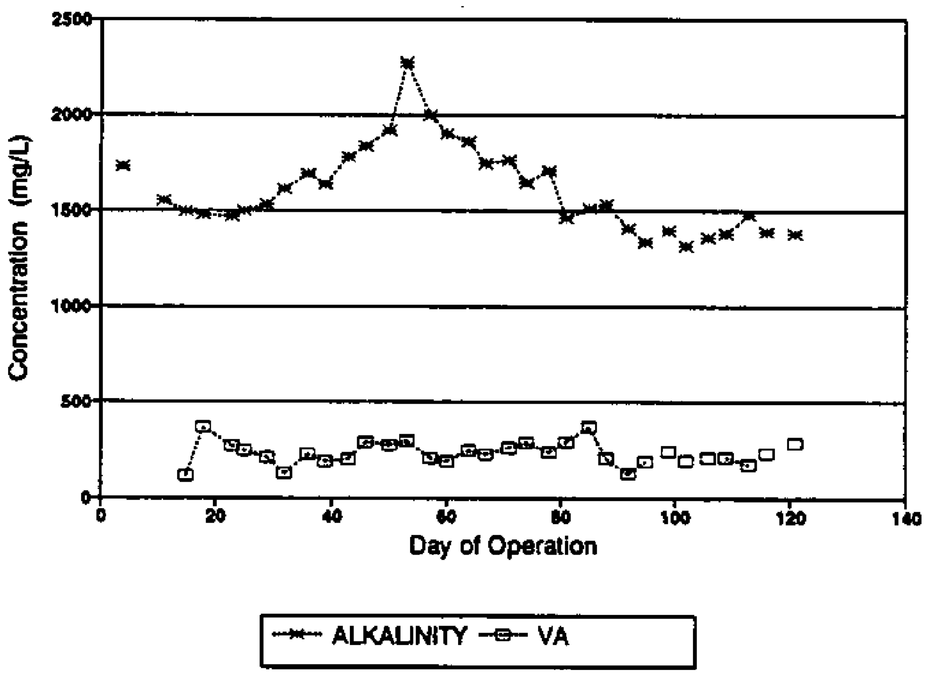


Figure 8: Effluent VA and Alkalinity



The biogas was of relatively high quality, and its composition varied slightly over the course of the study. The methane and hydrogen sulfide concentration averaged approximately 76 and 1.4 percent, respectively.

At the end of the study, the reactor contents were analyzed for sodium concentration. It was found to be approximately 7,000 mg/L.

The rate of sludge buildup during the study was minimal. The mass balance analysis revealed the following:

258 g SS added as seed sludge
383 g SS captured in reactor (from influent SS)
22 g SS generated from COD destruction
331 g SS remaining in reactor at end of study

The above numbers reveal that, over the course of the study, there was an increase of approximately 73 g of SS in the reactor (i.e., 331-258) and, over that same time period, 383 g of SS were added. These figures indicate that 81 percent of the SS added to the reactor were digested.

DISCUSSION

The overall results indicate that the low-rate BVF reactor is well suited for pretreatment of this clam processing wastewater. Furthermore, the results reveal that BOD, COD and SS removals of 80 to 85 percent can be expected in full scale at an operating temperature of approximately 25 C and the range of loadings investigated here.

The influent and reactor (effluent) pH were generally near neutral throughout the study. This was also the case even after bicarbonate additions were terminated on day 92 (week 14). The influent (raw wastewater) pH, throughout the time (weeks 14 to 18) of no bicarbonate addition, ranged from approximately 5.6 to 7.3; it had an arithmetic average of 6.3 and was, thus, only slightly acidic in nature. The reactor pH during the same time frame ranged from 6.8 to 7.9; it had an arithmetic average of 7.3. This suggests that a full-scale BVF system should be able to operate without any pH control after the reactor has reached maturity.

The volatile acid (VA) levels while at full strength ranged from approximately 100 to 400 mg/L, with an arithmetic average of approximately 230 mg/L. This range of VA is considered acceptable provided there is sufficient alkalinity (ALK) present to keep the reactor pH at or above 6.5.

FOG (scum) accumulations were found to be almost nonexistent during inspections of the BVF reactor, midway through and at the end of the study. Lab tests on three occasions showed values of FOG present in the influent and effluent at less than 5 mg/L. It is therefore believed that scum buildup in the full-scale reactor will not be significant or pose any problems.

The sludge mass balance figures reveal very little solids buildup during the study. Furthermore, it should be pointed out that these mass balance figures ignore any bios yield and, if taken into account, the actual percent digestion of net SS is approximately 87 percent.

ADI's experience in full scale with food processing wastes has shown that a 90 percent SS digestion figure, including biomass yield, is a realistic value; during the course of the study an 81 percent figure was obtained. This number agrees very well with the above statement when one realizes that 74 percent of the net SS addition to the reactor took place in weeks 9 to 18. This translates into a solids retention time (SRT) of approximately 6 weeks for SS digestion to occur. In a full-scale system, the SRT would be much longer, and an overall 90 percent digestion figure is believed to be realistic.

Regarding the need for micro- and macro-nutrient supplements, none were added during the course of the study and the high level of performance (>80% BOD removal) suggests that none will be needed in full scale.

The biogas quality throughout the study averaged 76 percent methane and 1.4 percent hydrogen sulfide, which is typical of many industrial wastes.

CONCLUSIONS

The following conclusions summarize the major findings of this study.

1. This clam wastewater proved to be well-suited for anaerobic treatment.

2. For the wastewater conditions studied, a full-scale, 1.7 MG ADI-BVF® system (design HRT of approximately 6 days at 25 C or loading less than or equal to 60 lb COD/1000 ft^3.d) should result in BOD and SS removals in the 80 to 85 percent range.

3. Macro- and micro-nutrient addition should not be necessary as this wastewater appears to have adequate levels of both.

4. Chemicals for pH control should not be necessary in a full-scale system once the reactor has matured (in 12 to 18 months).

5. Sludge accumulation in the full-scale reactor should not be significant, and it will probably be several years before sludge wasting must begin.

6. The biogas produced was of high quality and should pose no technical problems in a boiler for the production of steam or hot water if so desired.

7. FOG accumulation in the full-scale reactor should be minimal and not problematic.

8. The BVF reactor demonstrated its ability to handle shock loadings without equalization and/or any special operational modifications.

9. The high sodium concentration found in this wastewater did not appear to inhibit reactor performance to any significant degree. If sodium was eliminated from the wastewater, marginally better reactor performance would be anticipated.

FULL-SCALE SYSTEM

As the result of a successful pilot study and tender for the supply and installation of a complete anaerobic pretreatment system, ADI was awarded a contract to build a full-scale BVF system.

The shell of the reactor is an insulated, above-ground steel tank; it has a special floating geomembrane cover system to provide positive odor control, prevent heat loss and allow collection of all the biogas generated. The reactive volume is approximately 1.7 MG, and the tank dimensions are 77 feet in diameter by 50 feet high.

The reactor and its ancillaries are in a severe marine environment, and special tank coatings (inside and out), an internal cathodic protection system and special materials of construction were used. The tank itself has a design life of thirty years, as specified by the Owner.

The processing plant site was very congested and presented severe reactor siting problems. In the end, it was decided that the reactor would be located over the water on a cap-and-friction piling system; the piles are 110 feet long.

The low-rate BVF reactor, because of its physical size, requires no equalization; furthermore, it requires no primary treatment other than coarse screening (10 mesh) and grit removal to protect pumps and reactor internals.

The reactor will provide removal of dissolved organic and suspended solids (small pieces of clam) from the processing effluent and convert the majority of these substances into biogas. For the present, the biogas will be flared.

A duplex pumping station delivers the degritted and screened wastewater to the reactor for treatment. The wastewater is stabilized within the reactor and then discharged to the receiving water. The reactor contains a number of internal proprietary features that assist in the stabilization of wastes. These are:

1. A special influent header and lateral system that creates and distributes the influent in the sludge bed where much of the stabilization takes place.

2. A recycle system that helps promote better bios-substrate contact, provides attenuation of shock loadings and recycles alkalinity to provide better pH control.

3. A system of gas-liquid-solids-separators that serve to minimize the concentration of effluent suspended solids and thus retain bios in the reactor.

4. A system of sludge withdrawal pipes for removal of waste sludge in the future.

Construction of the full-scale system began early in 1991 and was completed in September 1991. The system is presently going through start-up mode and should reach full load in early December 1991.

Bioremediation: Theory and Applications to Seafood Industry Wastes

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The presence of anthropogenic chemicals, eutrophicants (nutrients) and pathogens in the environment is an issue of increasing concern in the United States and elsewhere. In general, these materials are introduced into the environment through releases from industrial and transportation activities as well as runoff from non-point sources such as city streets and agricultural lands (16). In many cases, the presence of these pollutants is known to pose significant human and ecological health risks (4, 11).

Public demand for pollution abatement and environmental restoration has escalated in recent years (13 - 15). Although substantial progress has been made in waste recycling, process optimization and waste volume reduction, it has been estimated that up to 90 percent of hazardous wastes, eutrophicants, infectious wastes and solids have been managed in environmentally unsound ways (4, 7, 15). The cost of remediating these wastes and restoring impacted ecosystems is estimated to be one trillion U.S. dollars, not including hidden or undiscovered problems, and those being generated currently (4). Clearly there is a need to develop remediation technologies that are economical, efficient in removing different target wastes, "clean" in generation of secondary contaminants, and deployable in a wide range of settings (4, 5, 9). In this regard, there is widespread interest in the potential applications of bioremediation in site cleanup/recovery, wastewater purification and polishing, and toxicity abatement in soils, groundwater and surface water bodies (9). In what follows, the background and basic theory of bioremediation will be discussed with emphasis on applications of these techniques in the treatment of domestic and industrial wastewaters. The potential significance of these approaches to wastes of concern to the seafood industry will be discussed.

MICROBIAL ASSEMBLAGES AND ENVIRONMENTAL CONTAMINANTS

Microbes in Extreme Environments

The presence of microbial consortia (fungi, protoctists and particularly bacteria) in extreme and inhospitable environments has been known for many decades (1, 5, 6). The enormous range of metabolic and adaptational strategies employed by microorganisms in these environments has been well established and is an area of continuing inquiry (1). In general, microorganisms exhibit short cell cycles (20 to 500 minutes), high rates of genetic mutation, gene amplification, high biomass and metabolism, and ease of genetic exchange (plasmids, conjugation, phage viruses and abiotic transfection), even between disparate species (1). These traits, in addition to small size, a range of resting or protective life stages and broadly specific detoxifying and cometabolic biochemical strategies, allow for microbes and microbial ecosystems to exist in environments that are refractory to higher plants and animals (e.g, hot acidic sulfur springs, Antarctic permafrosts, hypersaline anaerobic ponds, deep ocean hydrothermal vents, oil field brines). Microbial assemblages also are found in association with environmental pollutant mixtures including oil spills (12), chlorinated hydrocarbon mixtures (8) and toxic/carcinogenic tar mixtures (3). For example, one study demonstrated the presence of viable bacteria and, to a lesser extent, fungi and protozoa in sediments contaminated with extremely high levels (100 to 30,000 parts per million) of polycyclic aromatic hydrocarbons, nitrogen-containing aromatic compounds and trace metals including arsenic and copper (Table 1) (3).

Significantly, some of the bacteria and fungi found in these PAH-contaminated sediments were utilizing chemical constituents of the pollutant mixture as substrate (i.e., "food" source) (5). This means that several species of naturally occurring bacteria existed and multiplied in the presence of high levels of toxic and carcinogenic hydrocarbons that completely exterminated other sediment flora and fauna, such as benthic meiofauna (small invertebrates including nematodes and rotifers) (Table 1, Sites 3 and 4). The growth of bacteria on chemical constituents of the pollutant mixture transform and degrade these compounds to simpler and usually less toxic end products.

Table 1. Abundance Estimates for Bacteria, Fungi and Protoctists in Sediments Contaminated with Polycyclic Aromatic Hydrocarbons (PAHs) and Trace Metals

	Site 1	Site 2	Site 3	Site 4
PAHs**	Trace	3141	33820	49207
Bact. (ATP)*	22619	9117	5501	95
Bact. (CFU)+	5000	3500	1100	700
Fungi (ATP)*	6983	327	136	10
Fungi (CFU)+	58	40	39	0.25
Protoctist (ATP)*	19911	5857	4951	78
Meiofauna++	133	38	0	

**Polycyclic aromatic hydrocarbon concentration in parts per million on a sediment dry weight basis.
*Mean total adenosine triphosphate in relative light units.
+Mean total colony forming units (CFU), 96 h aerobic plate counts on selective agars at 37 °C.
++Total meiofauna per 10 cm^2, direct counts.
From: references 3 and 5.

Microbial Metabolism of Biogenic Compounds

In general, compounds of biological origin are more labile than pyrogenic or synthetic organic chemicals found in pollutant mixtures and are cycled more rapidly through environmental systems. Diverse assemblages of aquatic and sedimentary microbes have evolved biochemical mechanisms to assimilate, transform and transfer the basic elements of the living state — principally carbon, nitrogen, oxygen, hydrogen, phosphorous, sulfur and a suite of micronutrients (1,2). These microbial transformation and cycling processes are at the base of regional and global ecological processes including maintenance of estuarine and coastal food chains and biogeochemical cycles influencing global water and atmospheric chemistry (2).

In natural systems, a wide range of biogenic materials including toxins (such as plant and insect-derived poisons), metabolic wastes (feces, urine), cellular exudates (amino acids, sugars), lipids and structural elements (lignin, cellulose, chitin, bone) are decomposed readily by aquatic and sedimentary microbes under ambient conditions. Otherwise, the planet soon would become covered with dead plant and insect material such as chitin, pollen and other litter. Some biogenic materials, such as lignin, may accumulate in sediments under conditions of anoxia, rapid sedimentation, nutrient limitation and/or toxicity from materials such as polyphenols or dissolved sulfides. However, microbes associated with aerobic sediment-water systems specialize in the rapid and efficient degradation of a spectrum of complex organic compounds to simple and non-toxic end products (e.g., carbon dioxide, water, nitrate, ammonium, short chain hydrocarbons and metabolic acids).

Bioremediation

"Bioremediation" is a rubric for any procedure that exploits natural, enhanced or genetically engineered biological processes to alleviate a pollution problem (5). Its lineage and techniques derive principally from fermentation, food production, composting and sewage treatment technologies, which use adapted and engineered organisms under optimized conditions to achieve desired end points (6). In a strict sense, bioremediation refers to the use of any organism(s) in the treatment of pollutants. Hence, the use of oxidized rhizosphere processes in the salt marsh cordgrass *Spartina alterniflora* to air strip (volatilize) pollutants from sediments is considered a form of bioremediation. For the purposes of this discussion, however, "bioremediation" will denote the use of naturally occurring microbial consortia in the removal and degradation of contaminants from waste streams and water bodies.

The essence of bioremediation is simply to optimize the natural contaminant-degrading capacity of specific microorganisms by supplying essential growth factors (e.g., inorganic nutrients, carbon, particles or other surfaces, oxygen) and minimizing biotic and abiotic stress (e.g., grazing by predators, competition by unwanted organisms, accumulation of toxic or inhibitory products). The idea is to promote and enhance the desired metabolic activity by increasing the biomass of the appropriate microorganism(s) and then maintaining it at high levels by minimizing growth limiting factors. In many cases, this can be a matter of simple engineering: once the appropriate physicochemical conditions are identified and receiving systems constructed, maintenance of a biotreatment system can be as simple as fertilizing and regularly tilling a field, aerating a treatment lagoon or turning compost piles at regular intervals. Monitoring strategies for degradation rates and efficiencies can also be implemented in straightforward ways.

Bacterial metabolism of contaminants typically occurs through 1) assimilation of dissolved or particle-adsorbed compounds and nutrients (nitrate, ammonium), 2) direct dissimilatory reactions (aromatic ring opening, oxidation of fatty acids), 3) secretion of exoenzymes followed by assimilation, and 4) cometabolism, which involves the breakdown of primary carbon sources in conjunction with fortuitous transformation of the pollutant. Frequently, the degradation of organic compounds and mixtures requires a series of concerted metabolic events involving several species of bacteria or coupled interactions between bacteria and fungi. In these situations, an ideal bioremediation system would optimize, as far as possible, the conditions necessary for the individual metabolic steps to occur at maximum rates and efficiencies. If bioreactors are required in situations where concerted microbial activity is exploited, the maintenance of optimum physicochemical conditions can be daunting from an engineering perspective. But, for many applications, particularly industrial and municipal wastewater treatment in coastal, pond or lagoon systems, canals and natural or constructed wetlands offer more simple alternatives.

Compartments within the treatment system are tailored to particular reactions, and wastewaters or sludges are applied (loaded) at predetermined rates depending on various known parameters (ambient temperature, insolation). As solids and dissolved materials proceed through the system at optimized rates, different communities of specialized degrading organisms are encountered. Hence, sequential degradation and purification reactions occur in different areas of the treatment system. This approach currently is in use for domestic sewage treatment, industrial wastewater polishing and removal of some agricultural and food industry byproducts from wastewaters (17).

As suggested above, natural systems have the capacity to accommodate many wastes of concern to the food industry without extensive microbiological manipulation, particularly in warm coastal areas such as the Gulf of Mexico. For example, a 25-hectare swamp in south Louisiana was shown to assimilate and transform large quantities of sugar refinery water wastes (8). This swamp received 10 to 30 million liters a day of 200 mg/L BOD waters (170 mg C/L, or 5100 kg C/d) that proceeded through channels and flood zones before entering a waterway leading to a large river three kilometers away. Complete mineralization of excess BOD was observed by the time the effluent waters had reached the large river. It is likely that the BOD removal efficiency in this natural system could have been increased and optimized with physical modifications such as the establishment of aeration and settling ponds, a larger grid of controlled-flow channels and diversions, and the introduction of specific marsh and aquatic vegetation in terminal areas of the outfall. As it stands, the ability of the system to process large volumes of elevated BOD water is formidable.

Startup and Engineering Considerations

As suggested above, bioremediation technologies can span a range of approaches of widely differing sophistication. These can be as simple as passive composting or as complicated as computer-controlled sequences of bioreactors containing networks of beds on which microbes and enzymes have been immobilized. In all cases, the treatment system configuration should be adequate to accommodate the wastes of interest and should allow for waste-loading rates and physicochemical parameters to be controlled or manipulated in realistic ways so that system efficiency can be maintained at or near optimum. Over-engineering of the system should be avoided (enough is enough), but consideration of factors such as changes in waste type or volume and potential for future facility expansion should be included in the initial cost-benefit analyses.

Table 2 contains a summary of the general kinds of wastes that are of concern to the seafood industry (17). Although this list is admittedly not exhaustive, it is apparent that the wastes of concern are biogenic, with

Table 2. Major Wastes of Concern to the Seafood Industry

Solids:	Hulls, heads, skeletal remains, scales, picking scrap, shells.
Aqueous:	Press, stick, and cleaning waters, cooling waters, process liquids of high BOD/COD, TSS, and eutrophicants, water of high or low pH, and water containing dissolved or emulsified oil and grease.
Microbes:	bacteria, viruses, and other infectious agents.
Chemical:	Lubricants, pump oils, grease, and metals from processes or machinery. Depuration water may also contain unacceptably high levels of some contaminants.

biological fluids, proteins, lipids, cooking waters and structural materials (shells, bones, picking wastes) being most common. As discussed above, many of these materials can be readily degraded by naturally occurring microbial assemblages. They should sequentially bioremediate in lagoon systems, digesters and/or constructed wetlands after physical treatment of solids and separation of lipids and water soluble materials from waste mixtures.

To decide whether bioremediation is appropriate for a particular seafood industry waste, simple treatability approaches such as aeration/mixing, fertilizing and land spreading/composting with organic materials (peat, leaf and wood chips, agricultural byproducts) can be evaluated in the laboratory at minimal expense (5). Virtually any university microbiology, agronomy or food science department should have the equipment and expertise needed to provide lab demonstrations and pilot feasibility studies for removal of BOD/COD, proteins, lipids and solids from waste streams. Direct contact between the industry and the university laboratory is preferable to the use of intermediaries, such as consulting firms, especially in the preliminary stages of evaluating potential treatment options.

After treatability of the waste has been established (rates, efficiency), the isolation and deployment of "tailored" microorganisms can be considered. Experience with hazardous and stubborn organic chemical mixtures has shown that bioremediation of land and wastewater frequently is economical, effective and easily managed. In many cases, the degradation of target compounds proceeds as efficiently with naturally occurring microbes as with commercial "custom" inocula (5). For the food industry in general, and the seafood industry in particular, bioremediation should be seriously evaluated when considering disposal options, particularly when new facilities are sited.

CONCLUSIONS

The basic theory of bioremediation promotes the constitutive degrading and assimilative activities of naturally occurring microbes from water and sediments. This is done by increasing the biomass of specific degrading populations in the treatment system by providing micronutrients and other growth-limiting factors and minimizing sources of biotic or abiotic stress. The practice of bioremediation in numerous physical settings should apply well to a variety of seafood industry wastes and byproducts. Development and deployment of bioremediation for particular wastes is cost-effective, especially when compared with the rising costs of commercial waste disposal options off site. Because many bioremediation approaches are "low tech," the principles of operation and maintenance of many systems can be implemented with a minimum of training and overhead. Waste treatment options provided by bioremediation should be evaluated seriously by industries confronting increasing costs for traditional forms of waste disposal and stringent environmental regulations regarding water quality and land usage.

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Process Water Filtration and Treatment for Reuse

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The objective of this presentation is to provide the audience an overview of process water filtration and treatment research findings that may be applicable to seafood processors. I would like to preface this discussion by stating that many of the examples that I will refer to involve studies conducted using poultry process waters. A considerable amount of research dealing with water reuse and conservation has been cited in the literature. Due to the similarities between poultry and seafood processing water effluent characteristics, many of the research findings involving the poultry industry are directly applicable to seafood processors.

A number of factors have contributed to the food industry's adoption of water reuse, recycling and conservation programs. Some of these factors include water availability questions, increasing domestic and industrial water demands, water quality issues and escalating costs. It has been estimated that 25 percent of the nation's groundwater resources are being depleted at a faster rate than they are being replenished. This same trend is also true for some of our nation's surface water supplies. Furthermore, drought conditions, such as those experienced on the West Coast and in the Southeast over the last decade, and regional water shortages have also contributed to the need for development of water conservation and reuse programs. Recently, questions have been raised across the country about whether priority should be given to domestic users versus industry. This issue could seriously impact the food industry if a water allocation system were to be introduced across the country.

The lack of sufficient water supplies across the United States is further compounded by the fact that costs associated with water procurement and wastewater treatment are increasing at an alarming rate. These costs include water procurement costs, wastewater treatment costs, surcharges levied by POTWs for non-compliance of wastewater discharge permits and fines for discharge violations. An example of how water costs have escalated over the last 30 years is seen by comparing water and sewer costs for Gainesville, Ga. Their water and sewer costs increased over a 1,000 percent from 1960 to 1991 ($0.28 to >$3.00 per thousand gallons). Unfortunately for the food industry, food prices have not kept pace with water and sewer costs over that same time period. It has been estimated that by the year 1995 to 2000 that water and sewer costs may be as high as $15 per thousand gallons in some localities. Presently, several communities on the West Coast are already charging $10 per thousand gallons. Furthermore, the incidence and severity of fines for wastewater discharge violations are also on the rise. Not only are corporate executives facing these environmental fines, but some corporate CEOs and top management officials are also facing prison sentences due to discharge violations. Ultimately, these legal actions stemming from pollution violations result in corporate image problems in the community and a loss of public confidence.

If we look specifically at seafood processors, there is a tremendous range of water usage and associated cost variation among processors as indicated in Table 1. Water flow rates range from 7,000 gpd for blue crab processors to 3,600,000 gpd for some tuna processors. Estimated daily water and sewer costs for these two industries range from $49,000 to $2,700,000, respectively.

Finally, water quality issues have also surfaced that raise important questions about the safety of foods processed with contaminated waters. Numerous examples of water

Table 1. Estimated annual water and wastewater treatment costs of selected seafood processing industries

Category	Flow (GPD)	Costs ($3.00/1000 gal)[a]
Catfish	21-45,000	$16,000-34,000
Blue Crab	7,000	$5,250
Southern Shrimp	180-240,000	$135,000-180,000
Tuna	65,000-3.6 million	$49,000-2.7 million
Finfish	6,000-400,000	$4,500-300,000
Oysters	14,000-115,000	$10,500-86,000

[a]Costs do not include surcharges or pretreatment costs if discharging overboard.

pollution have been cited in the literature over the last decade. For example, there are an estimated 400,000 toxic dump sites in the United States and between 100,000 to 400,000 leaking underground storage tanks. In many cases, each of these have the potential for contaminating groundwater and surface water resources. In addition, groundwater and surface water contamination is also occurring from pesticide and fertilizer runoff from farmland and landfill waste.

These four factors aptly justify why it is necessary for food processors, and specifically seafood processors who are often located near sensitive coastal waters, to develop water conservation, water recycling, and water reuse programs. Although this presentation primarily involves water recycling activities, all three of these necessary activities are related and therefore specific programs should be developed for each.

When the terms water reuse or recycling are used, they imply the reuse or recycling of water for either edible food product contact or not for edible food product contact such as conveying of food waste materials via a water flume. A number of issues should be considered when reusing or recycling water for food product contact. They include consumer health protection from chemical residues and microbial pathogens, product wholesomeness, product adulteration; the regulatory requirement for potable water in food processing, sufficiency of potability standards and testing methods to detect chemical modifications and buildup during recycle, and aesthetic concerns generated from adverse public perception (i.e. questions on closing the process water loop).

Several regulatory agencies, regulations, and recommendations govern water reuse and recycling activities in the food industry (i.e., USDA, FDA, EPA, National Academy of Sciences). For example, federal poultry inspection regulations call for a water supply used in processing poultry that is ample, clean and potable. To prevent product adulteration, water that is to be used in direct contact with carcasses and equipment must originate from a potable supply. Potable water criteria, as defined in the National Primary Interim Drinking Water Regulations, include limits for coliform bacteria, heavy metals, nitrates and turbidity. Historically, the only approved reuse of overflow water from poultry chilling units for direct contact with product was in the scalder. Other approved non-product contact uses include flowing away heavy solids in eviscerating troughs, washing down feather flow-aways and picker aprons, and washing picker room floors.

The USDA Food Safety and Inspection Service (FSIS) enforces a number of regulations to address the sanitation level of poultry products, and these measures rely on the use of significant volumes of water. To help reduce the water-use burden on the poultry industry, the USDA adopted regulations permitting the recycling of reconditioned overflow chiller water in poultry chillers (12, Table 1). This regulation specifies that the identified treatment must reduce microorganism concentrations by at least 60 percent, including coliforms, Escherichia coli, Salmonella, and the total microorganism count. The regulations also call for the treated water to have a light transmission of at least 60 percent as measured at 500 nm. As the quality of reconditioned water improves, less of the reconditioned water is required to replace a gallon of fresh water in the chiller. At the maximum recycle ratio, 1.75 gallons of recycled chiller water is required to replace 1 gallon of fresh water. As the quality of the reconditioned water improves, this ratio decreases, making it possible to use as little as 1.1 gallons of reconditioned water to replace a gallon of fresh water. To recycle chiller water, a petition must be submitted to FSIS with equipment specifications and research data that demonstrate compliance with the recycling criteria.

Table 2. USDA criteria for recycling chiller water

Minimum % reduction of microorganisms in	Minimum % light transmission in treated water (500nm)	Gallons of reconditioned water to replace 1 gal. of fresh water
60	60	1.75
70	70	1.50
80	80	1.35
90	80	1.25
98	80	1.10

[1]Total microorganisms, coliforms, E. coli, Salmonella.

In the remaining time, I would like to summarize some of the water recycling research that has been conducted using poultry and selected food process waters. These studies have either examined various uses of recycled overflow poultry chiller water or have identified and tested water treatment systems for reconditioning poultry chiller or other food process waters.

One early study to examine the reuse potential of overflow broiler chiller water was an EPA-funded project conducted by Carawan et al. (1). In this study, the feasibility of using the combined process waters from the final bird washer and whole carcass chiller for selected uses in gizzard splitters was evaluated. Specific objectives determined the physical, chemical and biological characteristics of the combined process waters and evaluated the changes in product quality when these waters were substituted for fresh water in the gizzard splitters.

The effluents from a final bird washer and the carcass chiller were collected, settled and screened prior to pumping to the gizzard splitter rinse sprayers. Their studies demonstrated that the combined use of chiller water and final bird wash water for flushing in gizzard splitting machines had no detrimental effects on the wholesomeness of the gizzards. Biological oxygen demand (BOD) and suspended solids (SS) content of the gizzard splitter reel washer rinse water were similar when using either potable or combined chiller and final bird wash water (Table 3). Furthermore, no statistically

Table 3. Quality characteristics of reel washer rinse water and gizzards using different sources of water in the gizzard splitter (Carawan et al., 1)

Characteristics	Source of water Potable (mg/L of water)	Chiller & Final Bird Wash (mg/L of water)
BOD[1]	28 (13-19)	32 (21-49)
COD	80 (20-300)	45 (20-180)
Total solids	149 (31-302)	213 (127-315)
Suspended solids	25 (12-110)	23 (4-54)
Grease	38 (1-297)	53 (6-180)
	(colony forming units, $\log_{10}$/gm or ml)	
Gizzards, total count	3.67 (2.91-4.58)	3.96 (2.86-4.83)
Gizzards, coliforms	3.00 (0.79-3.78)	3.04 (0.76-3.95)
Reel washer water total count	2.88 (0-3.52)	3.20 (0.32-3.89)
Reel washer water coliforms	0.30 (0-1.32)	0.08 (0-1.0)

[1]Means (range) were calculated from 12 samples (three per day) taken over a fifteen day period.

significant differences in the total bacterial or coliform counts were detected between gizzards processed in splitters using potable water or recycled chiller and final bird rinse waters.

A second major EPA-sponsored study which examined the recycling potential of poultry chiller water was conducted by C.J. Rogers in 1978 (10) at the Stanford Research Institute. In this study several combinations of treatment processes were evaluated for reconditioning overflow chiller water. The treatments included cyclonic desludgers, vibrating screens, flotation cells, centrifugal waste concentration, filtration with diatomaceous earth (DE) filter aid and activated carbon treatment. All treatments were followed by a UV irradiation treatment to control the microbial population.

Of the systems tested, the use of a DE pressure leaf filter having an equivalent DE pore size of .7 microns (Hyflo Super Cel) was the most economic option that maintained bacterial levels below that in a chiller without recycled water. The DE filter removed all suspended solids, greatly reduced the BOD and removed a significant portion of the oil and grease (Table 4). Use of the filter elevated the transmission of UV light from 1 percent to 16 percent. In a companion study, a grade of DE having an equivalent pore size smaller than Hyflo Super Cel (celite 512) was used to filter chiller water. DE filtration without chlorination was capable of removing in excess of 99 percent of all bacteria present. Rogers concluded that the reconditioning of chiller water through DE filters and subsequent reuse could reduce potable water requirements in the chiller from 0.5 gallons to 0.2 gallons per bird without deterioration in the bacterial quality of the water in the chiller. He speculated that had such a recycling system been in use in 1970, approximately 1.5 to 2 billion gallons of water could have been saved and 4 million and 5 to 6 million pounds of suspended solids and BOD, respectively, would not have been released in wastewater stream effluents.

Since Rogers (1978) study, several other researchers have also examined the use of DE filtration to recondition poultry chiller overflow water. Lillard (7,8,9) conducted a series of studies that evaluated the efficacy of DE filtration for reconditioning broiler chiller water. In her studies (8), Lillard evaluated two grades of DE in a vertical tank

Table 4. Characteristics of prechiller water after treatment with a diatomaceous earth filter (Rogers, 10)[1]

Water Quality	Prechiller Water	Filtered Prechiller Water
	(mg/L of water)	
BOD	623	198
Total solids	1184	773
Suspended solids	315	0
Filterable residue	869	773
Oil and grease	165	37
Light transmission (254 nm)	<1%	16%

[1] Pressure leaf filter, 0.1 lb of Hyflo Super Cel (Johns-Manville) precoat per square foot of filter area, 0.05 percent DE (w/v) body feed, 1 gallon per square foot of filter flow rate.

pressure leaf filter that was followed by chlorination. With both grades of DE, significant reductions were obtained in suspended solids, dissolved matter, grease, COD, BOD and total Kjeldahl nitrogen which allowed for an effective disinfection with only 26 to 28 ppm chlorine gas (Table 5). Total aerobic counts, fecal coliforms and salmonellae were not detectable in the water following filtration and chlorination. DE filtration alone yielded a 96 percent reduction in the aerobic plate counts. In follow-up studies, Lillard (7,9) demonstrated that fecal coliform levels and salmonellae incidence on necks flumed in either potable water or DE-filtered chiller water were similar. Furthermore, fluming necks with chiller water would result in significant water savings for the poultry industry. The quality of the reconditioned chiller water also satisfies the current USDA recycling criteria for reuse in the chiller.

More recent studies (2,3,4,5,11) have also tested the quality characteristics of overflow chiller water filtered through DE-coated pressure leaf filters. Sheldon and Carawan (11) successfully reconditioned broiler prechiller water using a combination of screening and DE filtration through a 1.0 square foot pressure leaf filter. Significant reductions of 60.6 percent for COD, 95.8 percent for aerobic plate count, 98.4 percent for coliforms, and 90.5 percent for E. coli were achieved with the filter (Table 6). Light transmission (500 nm) averaged 95.6 percent following filtration. The reconditioned water would qualify for recycling back to the chiller at a rate of 1.25 gallons of reconditioned water in replacement of one gallon of fresh water. The addition of a final UV irradiation disinfection step resulted in further reductions in the total microflora in excess of 99.9 percent. No culturable microorganisms were recovered from the filtered and UV irradiated water (>3.9 log reduction). Under the operating parameters of this study, a projected filter run cycle time of 5.6 hours to reach the 60 psig pressure leaf filter maximum was predicted.

Table 5. Characteristics of broiler chiller water after treatment with a DE filter (Lillard, 8)[1]

Water Quality[2]	Chiller Water	Filtered Chiller Water
	(mg/L of water)	
BOD	407 (226-770)	207 (179-328)
COD	623 (544-752)	259 (79-451)
Suspended solids	160 (125-189)	9 (2-15)
Dissolved matter	414 (198-526)	324 (102-413)
Total grease	137 (73-243)	16 (2-43)
% Light transmission (540 nm)	56 (44-66)	96 (91-100)
	Mean $\log_{10}$/mL	
Aerobic count	5.12	3.72
Fecal coliforms	3.13	<0
Salmonellae	0	0

[1]Vertical tank pressure leaf filter, 0.26 lb of Dicalite 4200/Speedflow (1:1 w/w) precoat (Johns-Manville) per square foot of filter area, 0.05 percent DE (w/v) body feed, 14.7 gallon per minute flow rate.
[2]Means (range), n = 12 to 18.

The potential economic impact of introducing this water reconditioning treatment into a 200,000 bird per day broiler processing plant were summarized by Sheldon and Carawan (11). They predicted a plant of this capacity could annually save 21.2 million gallons of chiller water valued at approximately $41,000 (250 days, $1.90/1000 gallons). The plant's effluent discharge could be reduced by approximately 179,000 pounds of COD and 81,000 pounds of total solids per year. These reductions in waste loads were projected to save the processor almost $25,000 per year on BOD and SS surcharges levied by POTWs. Furthermore, the recovered solids could be sold to renderers for an annual savings of $1,800. Finally, significant energy savings in refrigeration costs of approximately $25,000 per year might be realized through these recycling efforts. Thus, a total annual savings of about $93,000, less operating costs and capital investments, were projected. Based on the projected filter run cycle times reported in their studies, a filter cost of $50,000 to 100,000 was predicted that would result in an equipment payback of about one year.

In a separate study, Chang and Sheldon (3) examined the effect of chilling broiler carcasses in reconditioned overflow prechiller water on carcass quality and shelf life. Prechiller overflow water was reconditioned using a Perflex DE filter (Hayward Pool Products Inc.) coated with Celatom DE (Eagle Picher Industries). Following filtration, the water was ozonated for 15 minutes in a countercurrent flow sparge tower. Broiler carcasses were chilled in reconditioned chiller water and ice, and the results were compared to carcasses chilled in potable water and ice. No significant treatment differences between measures of carcass quality including skin color, cooked flavor or shelf life were detected. Furthermore, no significant differences between whole carcass rinse aerobic plate counts, or coliform and Salmonella counts were found for carcasses chilled with potable or reconditioned chiller water. They concluded that poultry chiller water could be conserved through recycling practices without adversely affecting the wholesomeness of the carcass.

In addition to DE filtration of chiller water, other filtration methods have been tested to recondition poultry process waters (6). In their studies, poultry scalder and chiller water and frankfurter chiller brine were filtered through a Ceraflow microfiltration module (Norton Co., Worchester, MA) consisting of filter bundles of porous (0.2 or 0.45 micron) ceramic tubes. Prior to filtration, the process waters were initially prescreened through 40- and 325-mesh sieves and passed through heat exchangers to duplicate standard water temperatures expected at the processing plant. The results demonstrated that acceptable quality permeates were produced that could be recycled back to the original systems. All permeates achieved turbidity readings of less than 50 NTU, with many less than 1 NTU (Table 7). All had plate counts of less than 10 microorganisms per milliliter. After 90 minutes of operation, flux rates as high as 110 to 440 L/ m^2h were achieved depending on the water and filter conditions used.

Table 6. Effect of screening, DE filtration through a 1.0 square foot pressure leaf filter and UV irradiation on the quality of chiller overflow water (Sheldon and Carawan, 11)[1]

Filtration Time (min)	Water Quality Parameters: % Transmission (500 nm)	COD (mg/L)	Aerobic plate count log_{10}cfu/ml
0	25.1	1370	3.76
30	96.4	486	2.77
60	95.6	509	2.54
120	95.7	520	2.16
210	96.2	525	1.67
Mean[2]	96.0	510	2.28
% Reduction[3]		62.8	96.7

[1]Pressure leaf filter, 90 gm of Celite 512 precoat (Manville Products Corp.), 5:1 ratio of DE to SS body feed, 2.84 liters per minute flow rate, N = 2.
[2]Mean of 30, 60, 120, and 210 min samples.
[3]Percent reduction of mean value relative to the 0 time sample.

Furthermore, flux rates were easily restored within 15 minutes of in-line cleaning at 78 to 80 C with a detergent cleaner. They concluded that microfiltration is a promising method for reconditioning process water for reuse.

In addition to the physical methods summarized above, Chang and Sheldon (4) tested several water treatment systems including direct ozonation and a combination of ozonation with either slow sand filtration, dissolved air flotation or DE filtration for their ability to recondition broiler process waters. The quality of prechiller overflow water was significantly improved with all treatments examined, surpassing the USDA's recycling requirements in nearly all trials. A combination of screening, DE filtration and ozonation yielded the highest quality water. With this treatment, significant reductions in COD, total solids and the total microbial load, including coliform bacteria and salmonellae of 87, 65 and 99.9 percent, respectively, were achieved in the reconditioned prechiller water (Table 8). Percentage of light transmission at 500 nm (%T) of treated water increased to 97 percent of tap water and compared favorably with %T of potable water. This same water treatment was tested on final carcass rinse and neck chiller overflow waters. The quality of these treated waters was also significantly improved. They concluded that poultry process waters could be effectively reconditioned for recycling by screening, DE filtration and ozonation. Furthermore, wastewater organic loads discharged to wastewater treatment facilities could be effectively reduced by implementing these tested reconditioning practices.

Table 7. Effect of microfiltration through ceramic filters on the quality of food process waters (Hart *et al.*, 6)

Sample[1]	Water Quality Parameters: Turbidity (NTU)	Aerobic Plate Count log_{10}/ml	Total Solids (%)	Nitrogen (%)	Fat (%)
Chiller water					
Process	170-680	7.60	0.14	0.009	0.05
Permeate	6.4	<1.0	0.07	0.003	0.025
Scald water					
Process	170-680	5.78	0.14	0.020	0.02
Permeate	35	<1.0	0.08	0.021	0.014
Frank brine					
Process	170-680	3.56	15.72	0.025	
Permeate	1.85	<0.90	14.75	0.025	

[1]0.45-micron filter used for all samples except for total solids, nitrogen and fat parameters for scald water where a 0.20-micron filter was used; range of 170 to 680 NTU reported for all process waters tested.

In conclusion, this review has identified and summarized past and present research studies that have examined various water treatment systems for reconditioning poultry and other selected food process waters. Based on the USDA criteria established for recycling poultry chiller water, several effective treatments are available to the food industry for reconditioning process water. By far, the use of diatomaceous earth filtration appears to predominate the literature as one of the most effective and economical treatments for reconditioning these process waters. It is my belief that food processors must initiate some form of water conservation and recycling program. The benefits of these programs include: (1) improving the competitive position of the processor, especially those in drought-strickened areas; (2) lowering processing costs through reductions in water use, wastewater surcharges and energy costs; (3) reducing the environmental pollution potential; and (4) improving the public image of food processors.

The two ultimate questions that food processors should ask to determine whether recycling and reuse of process waters is warranted are: 1. Is sufficient potable water available locally to meet current and future needs? and 2. Is treatment costs for reconditioning process water more than the sum of the initial cost of water plus the cost for discharging the wastewater effluent into the sewer? If the answer to these questions is no, then it is my belief that water recycling and reuse is warranted.

Table 8. Effect of combining screening, diatomaceous earth (DE) filtration and ozonation on the quality of reconditioned broiler process waters (Chang and Sheldon, 4)

	Water Quality Parameters		
Sample[1]	% Transmission (500 nm)	COD (mg/L)	Aerobic plate count $\log_{10}$cfu/ml
Chiller water1			
Process	37.0	1570	3.9
Reconditioned	97.0	206	<0.3
Neck chiller water[2]			
Process	1.7	3825	4.4
Reconditioned	80.1	805	1.0
Final carcass rinse water[3]			
Process	60.9	690	4.8
Reconditioned	99.6	53	0

[1]Combination of prescreening through cheesecloth, 5-minute filtration and 15-minute ozonation (2.3 percent ozone by wt.), n=6.
[2]Combination of prescreening through cheesecloth, 10-minute filtration and 15-minute ozonation (2.43 percent ozone by wt.), n=6.
[3]Combination of prescreening through cheesecloth, 10-minute filtration and 15-minute ozonation (2.54% ozone by wt.), n=6.

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Corporate and/or Plant Environmental Policy

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Food processors have generally thought that they were a "clean" processing industry. However, as the body of environmental law has continued to evolve and grow, food processors have found themselves with greater and greater exposure to non-compliance and aggressive enforcement actions. Further, management or corporate boards have dictated that company operations must be done in a more environmentally responsible manner. Some of these decisions have been made as marketing tools, but others have been made out of a sincere belief that everyone must do their part if our world is to saved from environmental destruction.

LAWS AND REGULATIONS

Important federal statutes have been enacted or expanded during the last two decades. Each statute has been followed by regulations that now exceed 40,000 pages. The number of regulations are expected to double in the next several years. A selected list of these is presented in Table 1 with their acronyms. This body of law continues to grow, and states and local governments either pass laws or develop regulations in response to the federal initiatives or local interests.

Table 1.

Statute	Acrg
Water Quality Act	WQA
Resource Conservation and Recovery Act	RCRA
Clean Air Act	CAA
Comprehensive Environmental Response, Compensation & Liability Act	CERCLA
Safe Drinking Water Act	SDWA
Federal Insecticide, Fungicide & Rodenticide Act	FIFRA
Toxic Substances Control Act	TSCA

ENFORCEMENT

Arbuckle(1990a) noted that historically certain laws affecting business conduct have been aggressively enforced, but others have not. He concluded that in areas such as environmental law, where prosecutions have been infrequent or confined to particularly egregious violations, rigorous institutional mechanisms to assure full compliance and protect the company and its personnel are not yet fully developed. Then he described the transition of environmental law into the category of "Heavy Duty Individual Enforcement." Arbuckle summarized the following statistics regarding federal civil and criminal enforcement and concluded that is clear that prudent management cannot fail to diligently look after environmental compliance duties.

Civil Enforcement — more than 6,200 federal administrative orders were issued in fiscal years 1987 and 1988. In fiscal year 1989, the total increased to 4,150. In excess of 350 civil enforcement cases are referred by EPA to the Department of Justice (DOJ) in a typical year. Fines assessed in these cases have ranged as high as $36 million. Since the environmental crimes unit of the DOJ was established, there has been a significant increase in the number of criminal prosecutions under the environmental laws. From October 1983 to 1990, DOJ records indicate that:

- 429 individuals were indicted
- 194 corporations were indicted
- 333 individuals were convicted
- 146 corporations were convicted
- $28,189 in criminal fines have been paid
- More than 122 years of actual time served
- 315 years of time have been sentenced

Arbuckle says (1) that criminal prosecutions can focus on individuals as well as organizations and (2) that organizations cannot insulate individuals from the consequences of their conduct. Further, he reported that the criminal provisions in the environmental laws provide a strong basis for prosecutions. The Clean Water Act (CWA) includes the following:

1. Section 309(c) penalizes "willful" or "negligent" violation of effluent limitations or permit conditions by "any person," defined to include "any responsible corporate officer."
2. Penalties: Fines range from $2,500 and $25,000 per day and/or up to one year incarceration for first offenses. For second or subsequent offenses, fines range from $50,000 per day and/or up to two years incarceration. Section 309 also criminalizes the making of false statements. Penalties are a fine of up to $10,000 and/or incarceration for up to six months.
3. Example: United States v. Frezzo Brothers, Inc., 461 F. Supp. 266 (E.D. Pa. 1978) aff'd 602 F. 2d 1123 (3d Cir. 1979) cert denied 404 U.S. 1074 (1980). Defendants, the corporation and individuals who owned or were officers of the company were convicted of willfully or negligently discharging runoff from composting operations.

Specifically, the CWA includes the following:
33 U.S.C.A 1319(c) Clean Water Act Section 309(c)

1. Any person who willfully or negligently violates section 1311, 1312, 1316, 1317, or 1318 of this title, or any permit condition or limitation implementing any of such sections in a permit issued under section 1342 of this title by the Administrator or by a State or in a permit issued under section 1344 of this title by a State, shall be punished by a fine of not less than $2,500 nor more than $25,000 per day of violation, or by imprisonment for not more than one year, or by both. If the conviction is for a violation committed after a first conviction of such person under this paragraph. Punishment shall be by a fine of not more than $50,000 per day of violation, or by imprisonment for not more than two years, or by both.

2. Any person who knowingly makes any false statement, representation or certification in any application, record, report, plan or other document filed or required to be maintained under this chapter or who falsifies, tampers with or knowingly renders inaccurate any monitoring device or method required to be maintained under this chapter, shall upon conviction be punished by a fine of not more than $10,000 or by imprisonment for not more than six months, or by both

Arbuckle explained how non-environmental laws are also available to support environmental criminal prosecution. These include the following:

A. False statements (18 U.S.C. Section 1001)

   1. Person who knowingly and willfully makes false statements to federal government is subject to a fine of up to $10,000 and/or imprisonment up to five years.
   2. Example: The indictment of the Penwalt company and its plant manager for failure to accurately report the volume and composition of a chemical spill.

B. Mail Fraud (18 U.S.C. Section 1341) and Wire Fraud (18 U.S.C. Section 1343)

   1. Penalizes use of mails, airwaves or interstate wires in connection with a "scheme or artifice" to defraud or obtain money or property by means of false or fraudulent representations.
   2. Example: United States v. Gold, 470 F. Supp. 1366 (N.D. Ill. 1979). Chemical corporation and its officers indicted for making false statements to EPA.

C. Conspiracy (18 U.S.C. Section 371)

   1. Can be used if two or more corporate employees conspire to violate environmental laws. Penalties include fines up to $10,000 and/or imprisonment up to five years.
   2. Example — United States v. Olin Corp., 465 F. Supp. 1120 (W.D.N.Y. 1979). Defendants charged with violation of conspiracy with plan to defraud EPA regarding mercury discharges into the Niagara River.

REGULATORY MANAGEMENT

Egan(1991) concluded that regulatory management is founded on the twin concepts of a proactive approach and the preemption of problems. He identified the major principles as the following:

- Anticipates
  - Issues
  - Requirements
  - Impacts
- Develop
  - Action plans
  - Resources
- Implement positive efforts
  - Preempt problems
  - Preempt imposed solutions

Egan concluded that the proactive/preemptive concept is the difference between being controlled and being in control.

Arbuckle(1990a) reported that the development of an institutionalized appropriate management structure committed to scrupulous compliance with environmental requirements would be the appropriate mechanism for avoiding environmental liability. He noted that there are a number of factors to consider in developing an environmental law compliance program (Arbuckle, 1990b). He suggested that companies that are developing programs to assure compliance with the environmental laws and to cope with enforcement actions should begin by asking the following question.

> **What concrete steps can be taken now to make it less likely that violations will occur and assure that, if violations do occur, the officers and employee directly involved will not be individual targets of enforcement action?**

Arbuckle identified the best answer as an appropriate corporate management structure, carefully formulated with a view to environmental compliance objectives and diligently fulfilled. The structure must be conducive to:

1. The development, maintenance and communication of appropriate plans and programs for the achievement of suitable environmental compliance objectives;

2. The effective and timely implementation of those plans and programs; and

3. The documentation of a suitable level of attention, care and diligence by responsible, high level corporate officers and other members of the company.

He identified the seven parts of an appropriate structure (Table 2).

Jarman (1991) provided an interesting outline of his approach to managing environmental issues (Table 3). His first priority was to get management acceptance and support. He provided several questions to provide background information and seek management understanding. These included the following:

> What are the environmental issues and/or regulations of most concern to your company?
>
> What departments in your company are involved with some aspect of environmental affairs?
>
> Are the responsibilities for compliance with environmental laws and regulations clearly understood and assigned?
>
> Have the legal liabilities associated with compliance with environmental laws and regulations been reviewed and discussed with corporate officers? operational managers? employees?

POLICIES AND IMPLEMENTATION

The development of a corporate policy may well be the cornerstone of an effective environmental management program. Three examples of corporate policies were selected to guide those who may wish to explore the development of similar statements. The Kraft statement is displayed in Table 4. The Borden statement is repeated in Table 5. The Weston Foods example is given in Table 6.

Table 2. Arbuckle's Suggested Management Structure

1. Development of compliance plans and programs communicated upstream to senior management and downstream to employees via training programs and refresher courses.
2. Adequate implementation of these plans.
3. Documentation by responsible high level officials of a suitable degree of diligence and care concerning these programs.
4. Delineated lines of responsibility.
5. Track potentially harmful substances and their fate and the permit status of the company.
6. Develop and use compliance and procedures manuals.
7. Adopt a written corporate policy regarding environmental offenses and the right to defense costs.

Table 3. Jarman's Approach to Managing Environmental Issues - Elements of Environmental Management Programs

I. Management Acceptance and Support
  A. Corporate
  B. Operational

II. Company Policy
  A. Environmental Principles
  B. Scope and Objectives
    1. Compliance
    2. Facility Planning
    3. Facility Operations
    4. Marketing and Customer Relations
    5. Community and Public Relations
    6. Product Development
  C. Implementation Guidance
  D. Public Scrutiny

III. Organizing an Environmental Program
  A. Organization
    1. Centralized
    2. Decentralized
    3. Representation
    4. Decision-making and Reporting
    5. Dedicated Staff
    6. Staff Network
    7. Communications
      a. Training
      b. Policy and Programs
      c. Information and Developments
  B. Regulatory Compliance
    1. Assignment of Responsibilities
    2. Networking and Coordination
    3. Information Management
    4. Liability and Enforcement
    5. Planning and Training
  C. Environmental Audits
    1. Management Support
    2. Scope
    3. Organization and Conduct
    4. Legal Issues
  D. Employee Participation
    1. Communication
    2. Training
    3. Rewards
  E. Public Information and Right-to-Know
    1. Informing Publics
      a. Community
      b. Customers
      c. Consumers
      d. Shareholders
    2. Public Participation and Confidence
  F. External Programs
    1. Financial Support
    2. Public Service

Table 4. Kraft Environmental Policy

Basic Policy

It is the policy of Kraft Inc. to conduct its activities with due concern for the human and natural environment. This is to be accomplished in a manner that will benefit the present and future well-being of the communities in each country in which Kraft maintains business interests. The corporation and its affiliates shall, at all times, operate as good corporate citizens and comply with all applicable federal, state and local environmental laws and regulations.

Responsibility

Each business group shall be responsible for conducting its operations in a manner that assures compliance with environmental laws and with Kraft's policy. Each business group shall maintain an environmental management and compliance program appropriate to its operations in fulfillment of this responsibility. Environmental factors shall be taken into consideration in the development of all business plans.

Corporate Environmental Affairs is responsible for providing program management direction, establishing policy guidelines, advising business groups of regulatory requirements and assisting Kraft business groups in meeting their compliance responsibilities.

Reports

The following environmental regulatory events shall be promptly communicated to the Director, Environmental Affairs and Law Department: 1) regulatory agency permit notice; 2) reports on test results, internal or agency, indicating permit non-compliance; 3) notice of non-compliance with regulation or permit; 4) negotiation or order involving regulation or permit compliance; 5) an environmental related incident which could result in a negative impact on the corporation.

Table 5. Borden Principles of Environmental Responsibility

As responsible corporate citizens, we recognize the need to harmonize our operations with increasing environmental requirements. We take a serious view of our environmental responsibilities in handling and using raw materials, in manufacturing our products and in packaging and distributing what we make.

We must continue to make consistent, measurable progress in fulfilling those responsibilities worldwide, updating our practices to reflect advances in knowledge and technology and following these principles:

1. To maintain compliance with governmental and community standards of environmental excellence.
2. To manufacture products using materials and packages determined to be good choices for consumer health, safety and environmental quality.
3. To maintain programs to minimize energy use per unit of output.
4. To aggressively minimize waste through source reduction, process control, recycle/reuse, changes in operational procedure and byproduct innovation.
5. To engineer facility expansions and modernization designed to approach and achieve zero discharge of pollutants: air, water and solid waste media.
6. To select and retain outside consultants, contractors, disposers, treaters, handlers, shippers and suppliers based on their commitment to environmental excellence.
7. To examine consistently and with the most reliable technology, the impact our operations have on public health and the environment, and the ecological impact of our packaging and products.
8. To operate our facilities in a manner that is open, honest and cooperative with employees, neighbors and governmental authorities.
9. To include scientifically knowledgeable members on our board of directors and provide them with regular reports from the company's top environmental management.
10. To staff our operations with professionally qualified people to ensure that these principles are observed and that creative solutions to environmental challenges are vigorously and effectively pursued.

The Kraft Inc. policy (Table 4) includes the basic policy, responsibility, and reporting requirements. The prompt reporting requirement gives appropriate corporate officials the ability to assure a proper response.

The Borden principles (Table 5) give a broad outline of how environmental affairs will be conducted. The principle to engineer facilities to approach and achieve zero discharge of pollutants is perhaps the most notable. It will be interesting to follow Borden's future designs and track any additional costs associated with this decision.

Weston Foods has the most complete and explicit policy and program. The policy is given in Table 6. The program and guidelines are given in Table 7. Then specific actions are mandated and are given in Table 8. The specific requirement that management and the board of directors annually review environmental compliance is an assurance that the policy is fully implemented and working.

DISCUSSION

Aquatic food processors should be even more interested in the environment than other food processors. This is because the processing resource is dependent on adequate quantities of quality water. However, there is no indication that the managers of such companies have more aggressively pursued environmental programs than have other food processors.

The following is offered as a partial response in how to properly address environmental issues. A corporate environmental program should include the following:

1. Develop a corporate environmental policy.
   a. It must be clear, concise, easily understood and distributed to all.
   b. Require each division and plant to develop their own environmental policy and procedures to assure compliance with corporate policy.
   c. There should be an annual review and report of progress.
2. Develop a corporate Environmental Management Manual.
3. Train the appropriate corporate, divisional, and plant managers in all necessary environmental matters. Establish policies so that everyone knows how to respond properly to all situations.
4. Perform an audit of each facility to establish baseline data and to identify areas of concern. Plan to address needed areas as soon as possible with an order of address based on the potential and possibility for human and environmental harm, and working within budgetary limitations.
5. Each plant should monitor critical parameters and seek compliance with necessary programs (federal, state and local).
   a. Water/Wastewater
      Read water use meters daily.
      Monitor sewer discharge (flow, load).
      Examine sewer and surcharge bills monthly.
   b. Air
      Review developing state and EPA regulatory programs.
   c. Stormwater
      Obtain permits if necessary.
   d. SARA
      A program detailing use and release of hazardous materials.
   e. UST's
      Underground storage tanks must be documented, removed or monitored.
   f. Others
6. Goals should be set for each of the items monitored. Consider goals such as gallons of water per thousand pounds of products, etc.
7. A procedure should be developed for obtaining permits and assuring compliance.
   a. Obtain compliance reports for cities and states where plants are located.
   b. Decide who should sign permits.
      When must they be renewed?

Table 6. Weston Foods Environmental Policy

Resource, Environment and Waste Management Policy

George Weston Limited and its subsidiary companies (Weston) are committed to complying with all laws applicable to the operations and activities of West. Consistent with such policy, Weston believes in managing and conducting its business operations in a manner that is in the long-term best interest of Weston, the communities in which it is involved and its shareholders, customers and employees. As a consequence of such, the following specific policy has been adopted by Weston.

— Weston, its directors, officers and employees will at all times strive to comply with all applicable laws and regulations relating the environment.

— Weston, through its operating companies, will develop, maintain and implement policies, procedures and management systems to monitor its operations with a view to protecting the environment. Where not in compliance with existing regulations, programs and procedures will be instituted to ensure compliance.

— Weston operating management shall review environmental operating practices and procedures at least once a year to ensure compliance with this policy.

— Weston, through its operations will strive to incorporate in its environmental practices, the best available technology that is economically achievable.

— All senior operating management shall be responsible for ensuring compliance with the policy including the establishment of the programs and reporting requirements throughout their organization necessary to do so.

— The Weston Board of Directors will review annually a corporate report from the Operating Group Presidents on environmental practices throughout their group.

Weston recognizes that as a corporation, its directors, officers and employees are part of a larger community and as such, must make every effort to protect the interests of that community. Although it is impossible in any policy to cover the full spectrum of activities, procedures and requirements, it is possible to provide guidelines and enable employees to understand the type of conduct considered desirable and acceptable in the course of their duties on behalf of Weston.

Table 7. Weston Foods Environmental Protection Program

All Weston Foods Employees have a basic responsibility to take every precaution available to protect the environment as a part of their daily, hourly routine.

This responsibility is equally shared by all directors, executives, operating management and supervisors.

To promote awareness of this responsibility and be consistent with this program, each operating division shall:

— Implement an environmental protection program to ensure compliance with relevant environmental laws.

— Establish remedial and contingency plans to handle spills or accidents.

— Address any environmental concerns brought to the operation's attention either by the public, government authorities or representatives of the company and ensure that they are dealt with forthwith.

Implementation Guidelines

The following actions are recommended for directors in terms of implementing the above policy:

— adopt and circulate a policy and supporting operation strategy;

— require operating management to set up a system ensuring compliance with environmental laws and reporting periodically to the board on the operation of the system and any significant non-compliance in a timely manner;

— review the environmental compliance report provided by management;

— substantiate that management is promptly addressing environmental concerns.

The following actions have been suggested for operating management:

— implement the environmental policies and strategy established by the board of directors;

— establish an environmental protection system in terms of technical safeguards, monitoring, etc.;

—carry out environmental audits routinely;

— review compliance with environmental laws at reasonable intervals in light of changes in procedures and standards;

— ensure that environmental concerns are brought to senior management's attention and are promptly addressed or if appropriate, brought to the attention of the board of directors or other appropriate officers.

Table 8. Weston Foods Specific Actions

More specifically, these actions should consist of:

Adopting Policy and Strategy

The board of directors of each major operating corporation must adopt a policy and environmental protection strategy consistent with Weston's overall policy.

Management Responsibilities

Determine who at the senior level of operations is responsible for meeting the objectives and implementing the programs. This must include a determination of who reports and oversees the implementation of the objectives. A clear allocation of responsibility and reporting is important.

Survey

Undertake a complete review of operations or facilities. There should, for example, a detailed examination and evaluation of where spills could occur, when spills may have occurred and how they can be prevented. A survey of existing courses of action for cleaning up spills is also necessary.

Operating Procedures

Detailed written operative procedures should, where practical, be prepared. A manual may be developed that would include instructions on record keeping, training procedures and the methods to facilitate rapid cleanup.

Communications Strategy

This should include procedures for the distribution of information on environmental protection. The details of the needs with respect to inspecting, reporting and recording should be communicated. It should also include awareness programs to ensure that the employees understand and appreciate what needs to be done to prevent impairment of the environment.

Waste Reduction Management Program

Develop a waste management plan with specific goals to reduce waste production and avoid environmental mishaps.

Reporting to the Board of Directors

A policy of reporting to the board of directors on a regular basis must be adopted. That report should include a survey and evaluation of the environmental management program and the reporting of any significant environmental problem.

Serious Problems

Any serious problems that are identified during an environmental survey may warrant a detailed plan of action to resolve the specific problem.

c. Decide who should keep compliance files.
How will monitoring be done?
Who will send in the reports?

d. Determine a mechanism for answering regulatory requests.

e. Develop a spill prevention and containment plan.

8. Extend training to supervisors and key employees.

   a. Determine suitable training aids.

   b. Decide if an incentive program would help.

   c. Decide if employee awareness materials are necessary.
   Bulletin board
   Patches, stickers
   Newsletter

9. Appoint a Water/Waste or Environmental Supervisor for each plant.

10. Appoint an Environmental Manager for the corporation.

11. For each plant, examine the processes for water and waste reduction:

    a. Appoint a team with production, sanitation, maintenance and management representatives to review the processes and procedures for pollution prevention alternatives.

    b. Take slides and/or video of the processes.
    To document areas needing improvement
    To show proper procedures
    To document progress and improvements

    c. Examine processes and practices to reduce waste and prevent pollution.

It is important to develop a vision, mission and a strategic plan to address current and emerging environmental issues. For example, a company should establish a commitment to reduce wastes at the source. Obviously, this strategy is less costly and better environmentally than adopting conventional "end-of-the-pipe" technologies. Managers of food processing corporations have developed environmental programs and these efforts will be useful to others as they seek to help protect our world.

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Prospects For Biotechnology in the Seafood Industry

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Marine biotechnology is a broad, diverse and interesting field. It is defined in very different ways by legislators, fish farmers, seafood processors and academic scientists. My own definition and viewpoint have their foundations in basic biomedical research and have been colored by personal encounters with the problems and challenges in the transition from basic research discoveries to "real world" applications. As a professor of cell biology at Duke University, I teach undergraduate and graduate students about the cellular and molecular adaptations of organisms to marine and freshwater environments. These environments are frequently changing. They are often hostile, and sometimes they are made stressful by metallic and non-metallic industrial pollutants. Parenthetically, I often tell students that the heavy metals our bodies contain are believed to have originated in exploding stars. We are, according to this view, creatures of stardust, yet we confront very earthly problems. Metal pollution is somewhat paradoxical. At high concentration, the heavy metals are life threatening; and many environmental issues revolve around how to deal with their toxic effects. At the other extreme, we recognize that life as we know it requires many of these heavy metal elements. Exquisite adaptive processes that operate at the cellular and molecular level utilize, regulate and compartmentalize the metals that make life possible. The requirement for metals at low concentration, at levels that living organisms can handle effectively and usefully, and the problems of toxicity at levels above the manageable threshold, challenge society at many stages. Similar concerns arise with many other chemicals that are produced by industrial processes. As I bring examples of biotechnological advances that are relevant to environmental pollution to your attention, I wish to advance a balanced approach that couples human health and environmental health. I believe what is needed is a "biorational" approach to environmental management. The concept of "no-risk" or "totally safe" ways of dealing with industrial chemicals and other potential environmental pollutants is not tenable. It is possible, however, to search for ways to solve societal problems while promoting human and environmental health.

APPLICATIONS OF BIOTECHNOLOGY TO THE SEAFOOD INDUSTRY

There is growing awareness and concern that the natural beauty and productive potential of marine and freshwater resources are increasingly threatened by environmental pollution. The oceans, once believed to be an infinite sink for human waste products, are now the topic of heightened discussion and legislative action — action recommended to stop or remedy the situations that led a recent Time Magazine cover article to focus on "Our Filthy Seas." As directors of the Duke University Marine Biomedical Center, my husband and I have a long-standing interest in the human and environmental health consequences of environmental pollution. Our center, funded by the National Institute of Environmental Health Sciences, focuses on the fundamental mechanisms underlying the adverse effects of environmental contaminants and strives to develop new aquatic models for toxicology testing as well as new and improved methods for assessing environmental problems. I would like to share with you now some of the ways that basic research conducted by scientists at the Marine Biomedical Center have led to applications of potential impact in the seafood industry.

About seven years ago, we were introduced to Orky, a killer whale who lives in Sea World on the West Coast. We were interested in determining whether his blood proteins have functional properties that reflect his ability to survive periods of oxygen deprivation during deep dives. Orky was a willing participant in these experiments. By lifting his tail out of the water, he allowed our colleagues on the West Coast to take blood samples for analysis. These samples allowed us to learn about how his hemoglobin helps him during long dives and how conditions of environmental-pollution stress altered his blood proteins. In the latter regard, we are investigating the hypothesis that hemoglobin forms adducts upon exposure to environmental contaminants. Measurement of these hemoglobin adducts may be a useful and non-destructive means of assaying for pollutant stress conditions. These measurements would be useful in fish from natural and intensive aquaculture settings. Those who are concerned with fish health or the environmental conditions in which fish live may find hemoglobin-adduct formation to be a convenient and non-destructive dosimeter to guide them in their endeavors.

A second avenue of biotechnological application to the seafood industry lies within the realm of high-value products that may be derived from the organisms being cultured or harvested from marine and freshwater systems. A product derived from the swim bladders of fish is used to create a special glue for restoring Egyptian mummies. We became aware of this when we were contacted by people whose supply of sturgeon swim bladders failed them. They were desperately seeking another source. We contacted a seafood market that sold gray trout swim bladders as a special product. This product is considered a delicacy by some people, particularly when fried to the crispness of potato chips. As a result of our efforts, museum curators were able to obtain swim bladders and make more mummy glue. Other high-value products may eventually be derived from marine and freshwater harvesting or culture.

PROBLEMS OF OXYGEN SUPPLY AND DEMAND

Humans cannot survive underwater without an external oxygen supply. Fish, which need oxygen for survival just as much as we do, "breathe" water and use hemoglobin to extract the dissolved oxygen. In addition, many fish pump gaseous oxygen into their swim bladders. This pumping is achieved by specialized fish hemoglobins that use pH changes to unload oxygen. When we proposed a project o the U.S. Navy to study the pH-dependent unloading of oxygen into fish swim bladders, we added a rationale to our grant proposal that it might be possible to use hemoglobin as a "pump" to extract oxygen from seawater for human use underwater. This "pie in the sky" speculation became a prospect for further industrial development when, in 1976, we discovered the Hemosponge, a form of immobilized hemoglobin and polyurethane that made a matrix which did not impair the hemoglobin functionality. We showed that is was feasible to load oxygen onto a Hemosponge and that it was possible subsequently to unload the oxygen in gaseous form for further use. This concept is currently being explored by the Aquanautics Corporation, a San Francisco firm, who purchased our patents from Duke University. The Aquanautics process, which uses an electrochemical method for unloading oxygen from synthetic oxygen carriers, has potential application in intensive aquaculture where the density of organisms often exceeds available oxygen supply. Growers frequently increase oxygen availability by pumping pure oxygen into the culture tanks or pools. Less expensive methods for delivering oxygen to organisms under intensive culture may be a biotechnological advance of great benefit to the industry.

A fascinating development that arose from the Hemosponge technology is bottle caps having oxygen-scavenging capability. "Smart Caps," marketed by the Aquanautics Corporation, are being used by several beer manufacturers to extend the shelf life and flavor of their product. This technology, spun from the Hemosponge, also has potential applications in the seafood industry where oxidative degradation might be prevented by packaging that lowers the oxygen concentration in processed shellfish and finfish. As I will discuss in more detail later, the use of immobilized biomolecules to alter the environment is one of the advances of biotechnology that holds great promise in the area of environmental remediation and in other aspects of the marine sciences where non-polluting approaches to environmental management are desired.

Another Marine Biomedical Center application of interest to the seafood industry lies in the area of taste receptors in fish. Having demonstrated that immobilized enzymes could work for oxygen extraction, we were asked whether or not immobilized materials might be used to improve baits for sportfishing. By focusing on the taste receptors of the fish, it was demonstrated that a combination of low-molecular-weight materials could, in fact, stimulate the feeding response in such freshwater fish as largemouth bass, perch and other sport fish. The resulting product, whose research and development was sponsored by Mann's Bait Company, is being marketed under the trade name of FS-454. In laboratory tests, plastic worms coated with FS-454 were taken more readily than plastic worms coated with other products. We believe that further investigation at the basic research level has a high potential for improving fish food. By tailoring the surface of feeds to meet the discriminating nature of the taste receptors of the species being cultured, it should prove possible to use highly nutritious but less costly ingredients to provide nutrition to aquaculture species. Two graduates from the Duke University Business School seized on this idea and began marketing what they called Biosponge Fish Feeds. We have been participants and interested onlookers as the challenge of new technology and limited financial backing has met the demands of the marketplace. Other speakers at this conference have addressed the impact of diet on cultured species. In some ways, we indeed "are what we eat." I am convinced that with improved methodologies, the finfish and shellfish produced by aquaculture can be optimized to meet the needs of people having special dietary requirements. There is, among the population at large, an increasing desire to enjoy the benefits of diets rich in seafood. This increase in popular demand may promote the basic studies that will allow further refinement of aquaculture feeds and the nutritional tailoring of seafood products.

LINKS BETWEEN HUMAN HEALTH AND ENVIRONMENTAL HEALTH

The seafood industry is an outstanding example of a case where human and environmental health are inextricably linked. Good growing conditions for seafood are a prerequisite for a good product for human consumption. Managing the level of effluents from seafood growing and manufacturing plants is of great concern with regard to downstream uses of the released water. The need for better ways of purifying input and output water for aquaculture use is readily apparent. When large bodies of water require treatment to purify them of contaminants or to modify their nutrient load, the biotechnological advances made in the area of engineered proteins and immobilized enzymes may play an economically important role. Many of these biotechnological advances are being discussed by groups concerned with the problems and prospects of what is being called "bioremediation."

BIOREMEDIATION AND ENVIROMENTAL HEALTH

Bioremediation is by no means a new development. Biological organisms have been utilized in treatment of waste waters and in sewage treatment plants for many years. There are many other examples of long-term and profitable partnerships with microorganisms for industrial and societal advantage. What is truly new is the ability to engineer organisms genetically and select from colonies those particularly desirable variants that meet the needs for remedies of environmental pollution. There have been two recent workshops whose proceedings are directly relevant to this topic. The first was an EPA-sponsored workshop, held in April 1991. Panelists were asked to identify the most important questions in the field, questions whose answers would allow bioremediation to deal more readily with pressing environmental problems (1). Briefly, the four primary research needs identified were (i) determining factors governing the availability of pollutants for bioremediation and devising ways to increase their availability for destruction; (ii) improving the design of processes for bioremediation;

(iii) overcoming problems associated with scale-up from simple laboratory systems to field operations; and (iv) developing innovative and novel bioremediation processes. The panelists of the EPA Bioremediation Action Committee argued that the results of accelerated research in these four fields should greatly expand the utility and scope of use of bioremediation for the cleanup of contaminated waters, soils and aquifers. These techniques are clearly applicable to those engaged in aquaculture and mariculture.

The second workshop of interest, held at Rutgers University in July 1991, focused on how laboratory-scale experiments involving bioremediation can be transitioned into large-scale application (2). The conferees recognized the need to identify bioremediation technologies that meet the specific needs of a given area and its contaminants. No single solution will fit all cases. In summarizing the available bioremediation technologies and the difficulties and approaches for their use, the panelists at this workshop pointed out some of the distinct advantages of using bioremediation treatments for contaminated waters. They indicated that modifications of long-standing techniques of conventional waste treatment and innovative new methods are now available. Quoting from that report, the bioremediation approaches now available include: "enhancing indigenous microbial activity by adding specially formulated fertilizer to beaches and soils contaminated with oil or other carbon-rich wastes; land farming and composting techniques for degradation of refinery waste and military explosives; the degradation of chlorinated compounds in soils by the activity of microbial enzymes; treatment of polychlorinated biphenyls in soils and sediments with microorganisms; and degradation of recalcitrant compounds from lagoon sludges and contaminated soils in slurry reactors or other biological processing systems." It is clear that some of these approaches are applicable to the seafood industry, while others are better suited for maintaining the quality of marine and freshwater resources to enhance the long-term productivity of our aquatic resources.

A thinking gap presently exists between those concerned with environmental issues and those concerned with human health problems. In the seafood industry this gap cannot be allowed to exist for long without seriously impeding development of the industry. There needs to be a better appreciation that good environmental health and good human health are mutually desirable and interdependent objectives. You can not have one without the other. As we consider the options for global stewardship, it is my hope that the existing gap between those concerned with preservation of the environment and those interested in lessening human health problems be recognized as an artificial and undesirable separation. Interdisciplinary approaches that recognize the linkage between human and environmental health will surely be of immediate and practical benefit. Recognition of this linkage will further the objectives of the seafood industry and facilitate a "biorational" approach to using the tools of biotechnology in the seafood industry.

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Utilizing Scraps from Blue Crab and Calico Scallop Processing Plants

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Processing scraps from blue crab and calico scallop processing plants in Florida have always been landfilled. Since these scraps are highly organic and putrescible, they have created an environmental landfill problem. Various options have been examined to deal with these and other seafood processing byproducts. These range from specific analyses including dehydration for use as meal along with other handling methods (1,5) and as a feed stuff for swine (9) to a complete overview of all seafood waste management problems nationwide (10).

Blue crab scraps produced in Florida annually range from 1,300 to 2,200 tons. Blue crabs yield 20 percent water when cooked, 12 to 14 percent meat, 35 percent shell (carapace) and 31 to 33 percent remaining body parts in scraps. Most of the waste management problem occurs in contiguous Dixie, Franklin, Taylor and Wakulla counties of northwest peninsular Florida. In Wakulla county, scraps from blue crab processing plants have represented about one-fifth of the total waste stream landfill volume and consumed about 25 percent of the solid waste budget.

Calico scallop production is normally highly concentrated in Brevard county on the Atlantic coast. Production on a daily, weekly, monthly and annual basis is inconsistent and unpredictable. Typical annual production ranges from 2 million to 15 million pounds (edible meat weight), with one recent year reaching 30 million pounds. Processing requires large amounts of water, with the waste product including bycatch from the vessels, processing effluents, shell and raw viscera. Solid waste can represent more than 80 percent by weight of the original vessel production. The shells from calico scallop plants have found potential use as oyster cultch and as fill in spoil areas, but the viscera and liquids have been a landfill and treatment problem. Waste alternatives examined included in-plant controls including waste restrictions and segregation, alternative screening and recycling; secondary and innovative secondary treatment facilities; and landfilling or ocean disposal, use as oyster cultch or animal feed, refining current ocean dumping operations and controlling odor, and sludge disposal from treatment facilities.

The Florida legislature in 1988 mandated that solutions to problems created by landfilling blue crab and calico scallop processing plant scraps be found. A number of demonstration projects were conducted after agreement by the Department of Environmental Regulation staff, county officials, seafood industry leaders, private consultants and university faculty (6). This paper presents an overview and results of these projects. Topics covered include:

- In-plant methods for blue crab waste control
- Wet extrusion
- Compacting
- Anaerobic bioconversion
- Composting
- Blue crabs
- Calico scallops
- Blue crab compost marketing
- Blue crab compost as a soil amendment
- Nematode control using blue crab compost

IN-PLANT METHODS FOR BLUE CRAB WASTES

Three methods were examined to improve in-plant handling of blue crab wastes. These included wet extrusion into a food pellet for aquaculture, compacting and grinding to reduce volume and moisture, and anaerobic bioconversion to produce methane gas.

Wet Extrusion

Blue crab processing scraps were used to produce two types of pellets (2). Crab scraps were mixed with soybean meal (48% TKN), potato starch and herring oil in two formulas to form a sinking feed pellet. One formula contained 45 percent crab, 41 percent meal, 10 percent starch and 4 percent oil, whereas the second contained 35 percent crab, 60 percent meal, 5 percent starch and no oil. Without herring oil, pellets did not form properly. The pellets using herring oil were accepted by spiny lobsters during feeding, but molded too quickly for feeding trials with shrimp and catfish. The moisture content of the pellets was high, and they tended to float following storage. There does not appear to be a potential use of crab scraps without additional tests.

Compacting

A custom-built compactor patterned after shrimp plant units was used in a crab plant to examine moisture, volume reduction and compactability of crab scraps as follows: with screens versus without screens; ground (using a hammermill) versus unground and at variable compression times. Fluids extracted were analyzed for COD, TKN and ammonia. Compacting was examined as an alternative to reduce waste volume leaving the plant and as a prior step to other handling uses. The volume reduction of crab scraps was highest via grinding alone, at 50 percent. Compacting without the screens achieved the best volume and weight reductions for ground (25.0 percent at six minutes) and unground (28.6 percent at five minutes) crab scrap. Ground scraps held their compressed form much better (2).

Grinding using a hammermill appears to be the best method for volume reduction at the plant level and could be implemented immediately using existing plant manpower. This does not eliminate the waste stream but changes its form and makes storage easier. Compacting creates excess fluid that could be a problem if discharged into septic systems or wastewater treatment systems. The liquid fraction of the waste stream contained 256 grams per liter of COD, compared to standard sewage wastewater that contains 300 milligrams per liter of COD.

Anaerobic Bioconversion

The characteristics of blue crab scraps for use as an anaerobic bioconversion feedstock in the production of methane gas was also studied. The investigation focused on physical and chemical analyses of the waste and assessment of the ultimate conversion and rate of conversion via biochemical development, along with optimization using bench scale digesters. Sample analysis indicated an average total solid concentration of 33 percent for the total waste stream and a volatile solids concentration of 50 percent dry weight for the total solids (7). This indicates a very high average ash content (50 percent) for the waste stream. For the liquid function, comparable results were 10 percent and 70 percent, respectively.

COMPOSTING

Composting projects were conducted to test and implement an alternative to continued landfilling of scrap byproducts from blue crab and scallop processing plants.

Blue Crab

Open Windrow: A large-scale demonstration project for composting blue crabs was conducted at the Taylor County landfill utilizing all crab wastes from Taylor, Wakulla and Leon counties for a two-month period (3). Eight windrows of material were composted using a WILDCATTM turning machine powered by a large tractor. A total of 1,067 tons of material were composted, of which 380 tons (36 percent) were crab scrap. Cypress sawdust (431 tons), wood knots and shives (148 tons), and pine bark (42 tons) were the principal sources of carbonaceous material. The eight windrows of materials were formulated using the following six combinations:

- fresh cypress sawdust and crab scraps
- fresh cypress sawdust and crab scraps treated with phosphate
- aged cypress sawdust and crab scraps
- pine bark and crab scraps
- knots and shives and crab scraps
- yard trimmings, wood chips, crab scraps and manure

All materials tested, with the exception of knots and shives, appeared to have qualities which in the context of a proper mix would be useful or desirable for composting. All compost windrows were analyzed on a scheduled basis to document changes taking place during the composting process. Initial mix moisture content, pH, organic matter content, carbon-nitrogen ratios and ammonium content were monitored.

Core and surface temperature measurements were recorded every other day throughout the composting term. Fresh cypress sawdust windrows sustained the longest period of active heating, although aged cypress windrows showed higher earlier average temperatures. Heating was measured for 125 days, but the cypress windrows completed active composting in about 60 days. Pine bark windrows lost heating ability in about 50 days as did the knots and shives windrows, although the latter had some of the highest recorded temperatures of all windrows and a higher-than-ambient temperature for 100 days. Windrows with yard trimmings maintained the lowest temperatures of all windrows, and heated for only 50 days. Periodic rainfall may also have affected the heating times and levels of some sites. All windrows ranged from 21 to 36 days above 55 C except for the yard trimmings, which had only three days above this temperature. On the average, the composts appear stable after approximately 75 days.

All windrows were sampled at the end of composting. They differed from the initial compost in color, odor and texture. Each was darker, humus-like and fine-crumbly. Average moisture content across all piles was 44 percent, similar to the initial compost. Even with some rainfall occurring, the compost lost water, a desirable result to yield a marketable product. Finished compost data on water content, pH, organic matter content, TKN percent, C:N ratios, NH_3, P, K, Ca, soluble salts and CO_2 were also provided (3).

Analysis on the average composition of all the blue crab composts indicated several important facts. A total of 53 percent of the organic matter was decomposed or 28 percent of the total solids. Total nitrogen loss was 46 percent, and 49 percent of the compost volume was reduced, based on initial versus final volume measurements.

Traditional disposal costs have risen so significantly that a new framework is now available to assess the economic feasibility of composting. A composting operation (in contrast to landfilling) that exists on a break-even basis may be justified. The concept of composting as "value added" and the potential of using compost as a soil amendment gives rise to new support for the composting option. A limited economic analysis for a proposed compost operation in Taylor County was also provided (3). Economic factors considered were site preparation costs, required equipment, operating costs, sources of raw product, transportation costs, tipping fees, proposed markets and land requirements. Based on the assumptions outlined in the report, total annual costs of a compost operation to produce 5,000 tons of final product would be $103,000, or $29.49 per ton of crab scrap handled. Revenues that would be generated from a nominal tipping fee and bulk and bagged compost sales were estimated at $107,000, yielding a net revenue of $4,000. Composting of blue crab scrap appears to be a feasible alternative for the area in which the demonstration project occurred.

<u>Static Pile</u>: This demonstration used a "low technology" approach that has been used for fish scrap composting in Wisconsin. It was examined because of its lower cost and less frequent handling characteristics. Overall, the low technology system of blending coarse chips with crab scraps worked extremely well. Where little turning is done, the mix ratios must be adjusted upwards to reduce the potential for poor aeration and to guard against odor generation (4).

Each day crab scraps were dumped off trucks directly onto the ends of an active compost windrow and blended into the windrow. A mixer was used for large volumes and a bucket loader for smaller amounts. For this method, the proper ratios of coarse bark and chips to crab scrap appear to be 2 volumes wood to 1 volume crab scrap. At the end of the process, the compost passed through a tub-grinder which produced a dark humus-like product. This final step was not necessary in the open-windrow procedure because the compost was turned daily.

Laboratory analysis was conducted on the crap scrap compost to provide information on water content, pH, organic matter content, TKN percent, C:N ratios, N, P, K and other measures (4). This product should not be viewed as a fertilizer since the N, P, K ratio was .9:.5:1 but as a low-grade soil amendment. The final C:N ratio was 25.

Calico Scallops

A total of 96 tons of scallop viscera were composted in early 1991. Complementary materials used included 1,200 cubic yards of pine bark, sawdust and tree trimmings; 128 tons of seaweed; 24 tons of rejected citrus pulp; 25 tons of water hyacinth weed; and 14 tons of horse manure (4). The viscera was of two principal forms: raw viscera and viscera/shell mix. The principal wood products used were log bark and log chips from a home manufacturing plant and cypress sawdust from a mill.

A mechanical-lift SCATTM compost turner was used to turn the windrows. This process does not chop to any extent like the WILDCATTM machine, but this did not pose a problem due to the scallop viscera. The compost piles showed a quick rise in temperature after the scallop viscera was added, but did not reach temperatures over 120 F, probably because water became a limiting factor. The SCATTM turner oxygenated the piles well, which reduced odors, but the intensive lifting and air-exposure of the compost means a lowering of the temperature, which fell by 30 degrees after each turning.

The beginning nitrogen content of the viscera was very high at 14.2 percent. The viscera shell mix was one fourth that level. The final compost seemed somewhat course because of wood fragments, so the final product was screened. The coarse yard trimming piles performed the best, resulting in more than 70 percent fine material, which is preferred for use as a soil amendment and for potting mixes. The course materials are best for mulch-type landscaping operations. The nutrient composition was also changed after screening. The density increased, nitrogen content increased and C:N decreased, resulting in a more stable product. The final analysis for four scallop viscera piles using various sources of the organic materials gave N, P, K values ranging as follows: N, .3 to .5; P, .07 to .13; K, .08 to .9.

Scallop viscera, with and without cracked shells and by-catch, can be readily composted and converted into a soil-humus product. Because of the high BOD of viscera, frequent turnings are needed or a course fraction of wood is necessary. The SCATTM machine-turning technology used provided excellent aeration of the piles and controlled composting adequately.

COMPOST MARKETING

Blue Crabs

A marketing program also was developed for the blue crab compost produced by the open windrow method (8). Potential uses such as garden and farm centers, nurseries, greenhouses, landscapers, farmers, organic farmers, golf courses and contractors were examined. A pilot marketing program was established in six north Florida counties and sales of the compost have occurred in bulk form and bagged for retail outlets. Fourteen retail outlets and several public service organizations were involved in the test sales project. By the end of 1990, compost sales totaled $8,558 (wholesale value). They sold 311 bags (40 pounds each), primarily through farm and feed supplies at a wholesale price of $3 per bag. The retail price was $6 per bag. Bulk sales have been 305 cubic yards at $25 per yard. An estimated 200 cubic yards and 100 bags remain to be sold, but the supply has been controlled to maintain a constant supply to the market (C. Greenfield, 1991, Suwannee River Resource Conservation and Development Council, Live Oak, FL, personal communication). Adequate demand exists in the six-county north Florida area to annually sell the entire compost production possible from the blue crab scraps of Taylor, Wakulla and Leon counties.

Other forms of use for the static-pile crab compost and for the calico-scallop compost are being examined. A free compost day was held for the static-pile compost as a way to measure product acceptability. In four hours, 63 vehicles loaded 85,060 pounds of compost which homeowners and gardeners used as potting soil and as a soil amendment (12).

Calico Scallops

The calico scallop compost will be used in demonstration projects as a soil amendment for roadside wildflower projects, in home gardens and as a possible amendment to mixes used to start young citrus trees (B. Mahan, 1991, Brevard County Sea Grant Extension Agent, Cocoa, FL, personal communication). This will help establish demand and uses for the compost.

BLUE CRAB COMPOST USED AS A SOIL AMENDMENT

Blue crab scraps have interesting chemical/biochemical properties, including a high chitin content that may prove effective in immobilizing not only those metals (including Fe, Al, and Cu) contained in the scraps but also associated trace metals from other compost constituents including sewage sludge. A study to characterize the responses of sorghum/sudan grass to varying applications of raw and composted blue crab scraps, in comparison to fertilized and non-fertilized control treatments in field and greenhouse tests, was conducted (11).

The field plot portion of the test was an unreplicated demonstration effort, comparing the growth, relative yields, and plant composition of traditionally fertilized, raw crab scrap amended and compost amended plot areas. The greenhouse study was a replicated variable-rate study in which soil and plant composition, and plant yields were compared for various rates of raw crab scraps, crab compost, traditionally fertilized and unamended/unfertilized plots. The greenhouse studies included an analysis of the soil and plants for resultant values of N, P, K, Ca, Mg and B for all treatments and soil sample and plant analyses for P and N. Plant yield increases were made for the field tests (11).

Raw crab scraps offer considerable potential as a soil amendment for crop production at sites where the initial odor and fly problems from unincorporated portions are tolerable. They would seem to be acceptable, for example, in relatively remote sites (removed from human residences) where crops of a low-input, low-maintenance nature are being grown. This would include pine plantation replanting areas, which are common in Taylor County. The compost product, though more desirable from an aesthetics standpoint, is of limited value as a nutrient-supplying amendment. Long-term effects on soil organic matter levels and adequacy of nutrient supply for more slow-growing crops, including pine plantations, are other considerations which may be of value but which could not be evaluated via the current studies.

NEMATODE CONTROL USING BLUE CRAB COMPOST

Chitin amendments significantly reduce populations of the soybean cyst nematode, the southern and peanut root-knot nematode, and the citrus nematode. Chitin is contained in several materials used to control nematodes and in crustacean exoskeletons such as blue crabs. Tests were conducted to determine the effect of compost made of blue crab scrap and cypress sawdust on the reproduction of Javanese root-knot nematodes(13).

Two greenhouse pot experiments were conducted using the "Homestead" tomato, along with field microplot tests using the "Rutgers" tomato. All tests used various levels of the Javanese root-knot nematode for inoculation to determine the effect of various levels of blue crab compost on nematode control. In both greenhouse tests, crab scrap compost had a significant effect on the foliar and root weights of tomatoes compared to the control treatment. The observed increases varied depending on the rate of nematode inoculation and percentage of compost added to the soil. In the field microplot study, no significant differences between compost levels and the control treatment were observed for plant top weights, although a trend toward greater yield was observed in the compost treatments (13).

In both greenhouse tests, the 20 percent compost application rate was the lowest level of compost that produced large reductions in root galling and nematode reproduction. Pure chitin produces results at extremely lower levels (less than 1 percent). The depletion of nitrogenous compounds and reduction of energy sources through composting probably reduced chitin concentrations and the nematode suppressive characteristics of the crab scrap as well. The 20 percent level of crab scrap compost represents an application rate of more than 200 mt/ha, which would not be economical for nematode control in commercial agriculture. The crab scrap compost has the same limitations for nematode control as many other materials containing low C:N ratios. The greatest potential for crab scrap compost for nematode suppression would be for container grown plants and organic home gardens, where higher loading rates are common.

BLUE CRAB COMPOST AND WATER QUALITY

Agricultural areas in Florida are commonly underlain by sandy, well-drained soils that have low organic matter and low moisture retention capacity. Thus, ground water is highly susceptible to contamination from applied insecticides, herbicides and fertilizer nutrients. Compost made from crab scrap may impact the quality of the ground water in two ways: decomposition of crab scrap may add organic compounds, chemical residues or trace elements to ground water; and crab scrap compost may provide a means of enhancing the retention and/or degradation of pesticides and nutrients in the upper portion of the soil profile. Early data indicate that arsenic, selenium and manganese in the crab compost could be at significant levels to create a potential hazard, although the work has not been completed (14).

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Fish Protein Hydrolysates and Their Uses

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Fish protein hydrolysis may be approached from the viewpoint of the fish processor, who is looking for alternatives to the landfill. Or it may be approached from the viewpoint of the researcher or entrepreneur interested in product development for the feed, food or biotechnology markets. Although there may be some tension between these viewpoints, one of which emphasizes the simplicity of hydrolysis and the other of which utilizes its complexity, there is no contradiction. One of the reasons why hydrolysis is so powerful and intriguing is that, like all good technologies, it is actually a spectrum of processes offering different things to different people.

Fish protein hydrolysis (FPH) refers to any process in which the fish flesh is broken down by protein-digesting enzymes. These enzymes may be present naturally in the fish viscera, or they may be purchased commercially and added during the process. Digestion may go sufficiently far to turn the fish flesh to liquid, or it may be carried out under controlled conditions such as are used in curing herring to soften the texture and develop flavors (1). This paper is limited to hydrolyses-producing liquids. However, those are immensely varied. Table 1 lists those seafood-based products currently being manufactured and marketed utilizing hydrolysis technology.

Table 1. Hydrolysed Fish-Based Products Currently Manufactured

Fertilizers
Aquaculture Feeds
Aquaculture Attractants
Baby Pig Feeds
Calf Milk Replacers
Peptones for Microbial Growth Media
Flavor Extracts
Premature Infant Diets

The simplest form of hydrolysis is often called "ensiling" and the resulting product is called "fish silage" (2,3,4). Ensiling is one of those processes where nature does almost all of the work. If you grind the fish or fish waste, add a sufficient quantity of the proper acid to prevent spoilage and mix well so that each piece of fish is in contact with acid, the enzymes naturally present in the fish will slowly liquefy the fish flesh. All that you have to do is stir the mass of acidified, ground fish thoroughly every day or so. The rate at which liquefaction occurs will vary with the temperature; it may be complete in a week or less in August but take more than a month in January. This process works best when viscera are present. However, if the only fish available has been gutted at sea, an acid-resistant protease (protein-digesting enzyme) may be purchased and added to the ensiled material. True ensiling tends to be small-scale, partly because it is difficult to hold and stir very large quantities of material for long periods of time and partly because this is a simple technology with low entry costs, which is realistic for small producers. Indeed, you can actually carry this process out in your backyard in barrels. Variations on ensiling technology are carried out on a very large scale, particularly in Scandinavia. For example, a Norwegian firm offers an ensiling unit, capable of grinding, mixing and acidifying 25 tons of fish per hour. However, operations at this scale use heat to speed up digestion, and may also add such steps as pasteurization and condensation.

As the process becomes more complex, it requires more work, more equipment and more capital. However, the resulting products are more consistent and more saleable. Figure 1 shows a simple process for the manufacture of reasonably high quality liquid hydrolysate on a small to moderate scale.

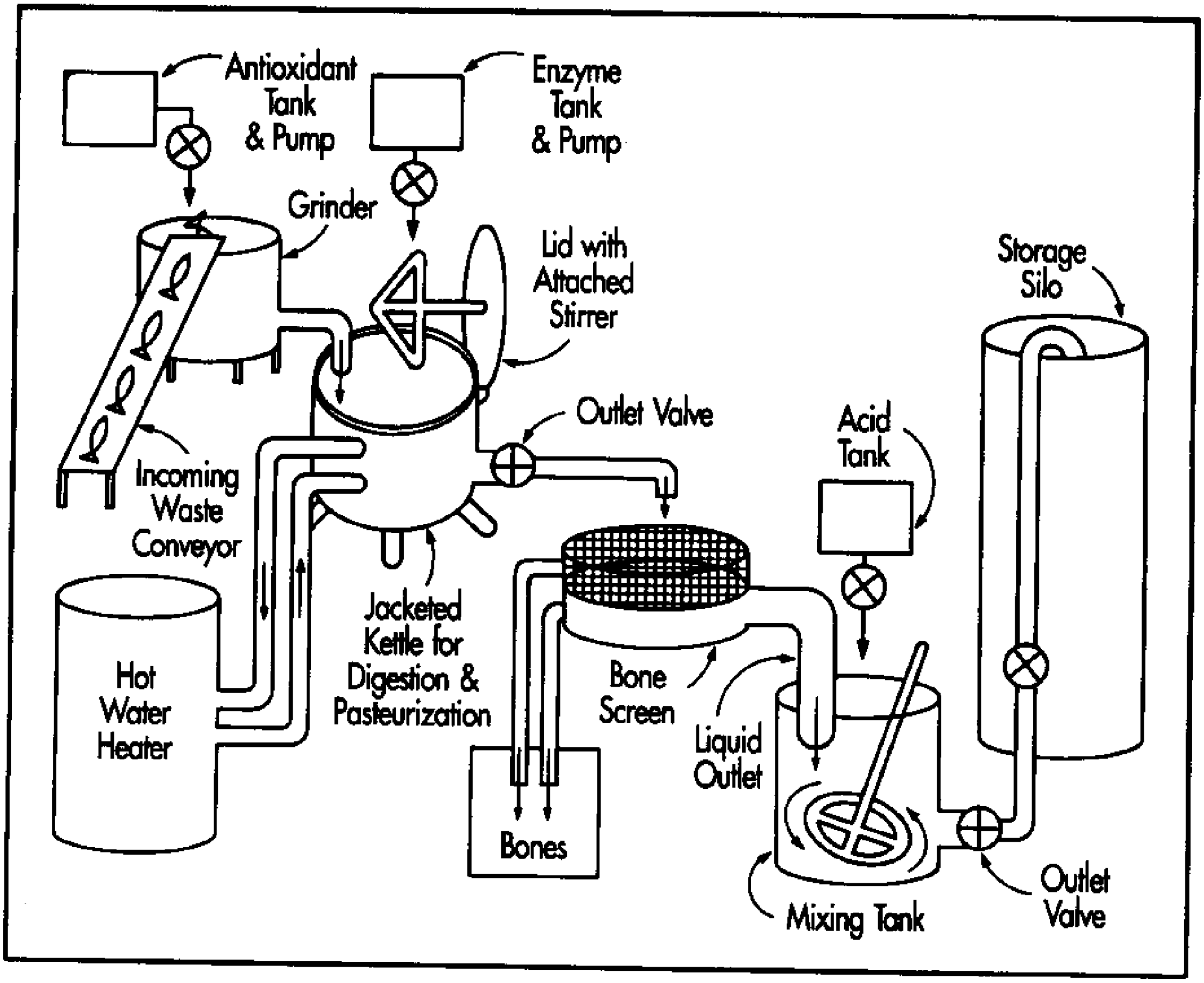

Figure 1. A Process for Simple Fish Protein Hydrolysis

In the heart of this process, the ground fish is digested in a jacketed kettle, where steam, hot water or oil can be applied, and time and temperature can be at least roughly monitored. Under optimal conditions, fish can be liquefied in as little as fifteen minutes. When the desired level of digestion has been reached, the temperature may be raised to pasteurize the product and to inactivate the enzymes and stop further digestion. The use of a kettle is not optimal for several reasons. One is that temperature changes occur slowly in large kettles. These changes are particularly slow if heat is applied through hot water (as opposed to steam) so that by the time the mass of liquid fish has been brought up to pasteurization temperature, it may be over-digested. The stirring mechanism of a kettle may have difficulty overcoming the resistance of a mass of ground fish without viscera, which has the consistency of hamburger. In addition, if wastes with large quantities of bone are digested, the bone may clog up the outlet valve and require manual removal. Despite these problems, the kettle has been included because it provides the system with the advantages of not requiring steam generation and of being easily assembled from widely available used components. The use of a steam-injected augured trough, or comparable digestion mechanism, would solve these problems and permit a system of this sort to handle reasonably large quantities of material— perhaps 20 tons per day. However, even using a kettle, the differences between this process and ensiling are significant.

One difference is the speed with which the material passes through the entire process and completes digestion. With hydrolysis, the processed material can be packaged and sent out to customers at the end of each day. With ensiling, many days' production must be stored on site, stirred and monitored because digestion proceeds so slowly. In winter, the stored silage may amount to a month or more of production (Southern areas have advantages over the North in this respect) so that space and logistics are limiting factors in ensiling.

Another difference is consistency. It is easier to manufacture a consistent product with hydrolysis than with ensiling. By keeping time and temperature constant, you can offer customers the same product day in and day out. The use of commercial, as opposed to visceral enzymes, also increased product uniformity. The ensiled product is not only difficult to ship out at the same stage of digestion each time. But, even after the customer has received it, it will continue to go on digesting itself.

Digestion of feeds is like medicine; if a little is good, a lot is not necessarily better. Proteins are composed of units called amino acids. Most animal nutritionists currently agree that single amino acids are not ideal in feeds and that small groups of amino acids, called polypeptides, are usually absorbed better. Even more important, as digestion continues, some amino acids will be broken down further to non-protein nitrogen, which has no feed value for most animals. This loss of value over time in fish silage is illustrated in Figure 2, taken from a paper by Stone and Hardy (5).

This figure shows what happens over six weeks of ensiling. The black columns represent protein; the dotted columns, polypeptides; the white columns, free amino acids; and the diagonally striped columns, ammonia. After six weeks of self-digestion, almost 10 percent of the total nitrogen is in the form of ammonia and about a third is in the form of free amino acids. At this point, this material might make an excellent foliar fertilizer, but it has lost a significant fraction of its nutritional value as an animal feed. In fact, its nutritional value is lower than what this figure shows because particular amino acids are more likely to be freed than others so that the amino acid profile is degrading with the general protein quality.

The next figure, taken from the same paper, shows that this does not happen with a controlled hydrolysis, including a pasteurization step. After enzyme inactivation, the material is stable and no loss in protein quality is detectable. In Figure 3, the vertical axis shows the average size of polypeptides in amino acid residues, and the horizontal axis shows time of storage. There are three columns at each sampling time: the dotted column depicts a silage similar to the one studied in Figure 3 stored at pH 4. The black column depicts a silage stored at pH 2. At this acidity, most of the enzymes are inactivated so protein breakdown occurs very slowly. The diagonally striped column depicts the hydrolysate in which no changes at all are seen.

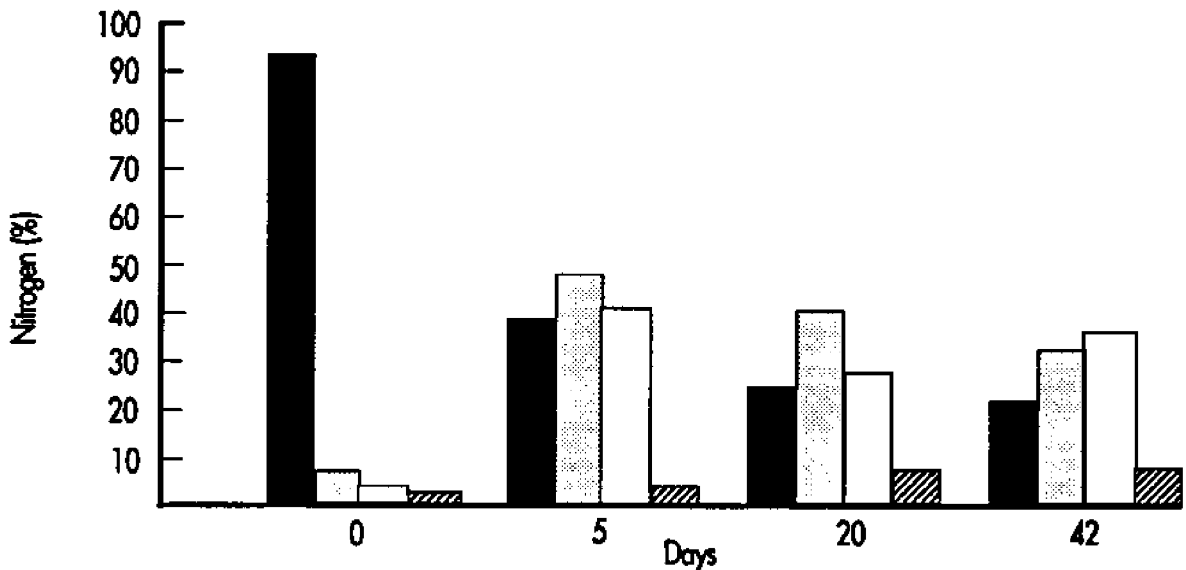

Figure 2. Protein Degradation as a Function of Time in Fish Silage at pH 4.0, Stored for 42 Days at Room Temperature. (Figure taken from Stone and Hardy)

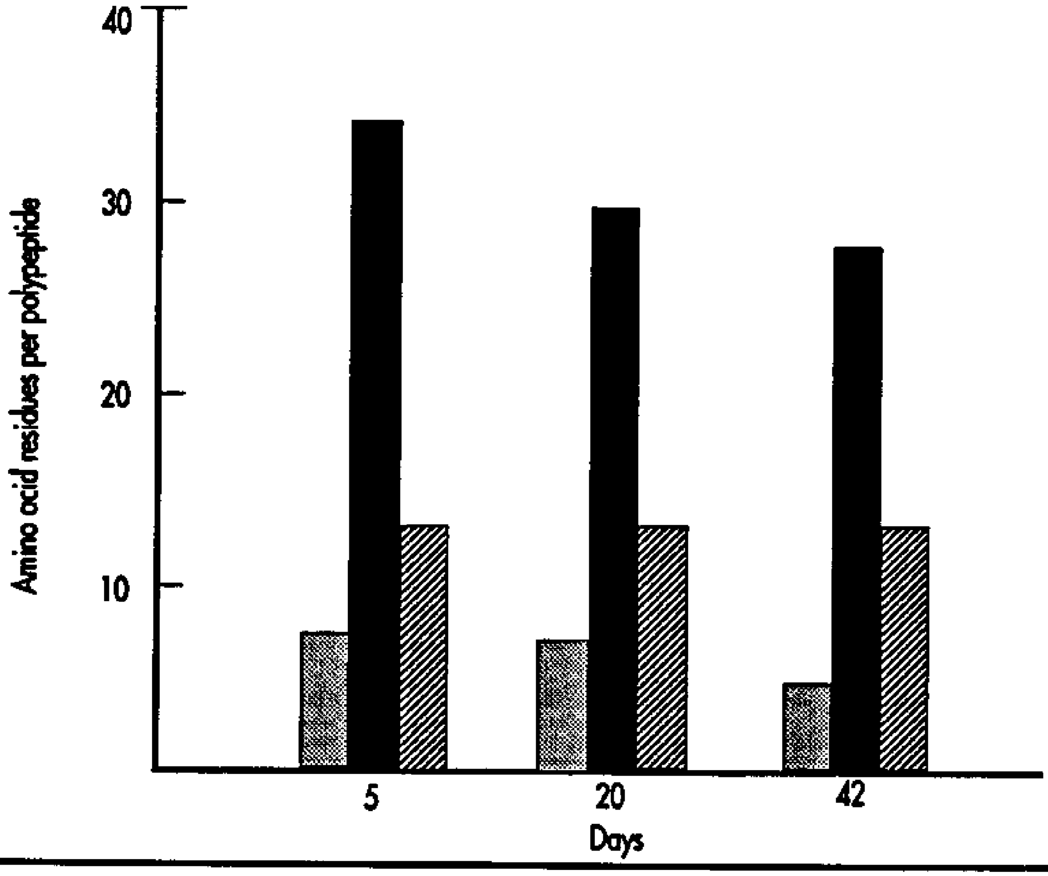

Figure 3. Average Length of Polypeptide Fractions of Silage and Hydrolysate Over Time. (Figure taken from Stone and Hardy)

Although storage at pH 2 greatly reduces degradation of the fish proteins, this is not an attractive option for several reasons. First, it takes a tremendous quantity of acid to get the product to that point. Second, it is quite corrosive, which creates difficulties in storing and handling the product. Third, the product must be neutralized before being fed, which adds to its cost. And, finally, only a strong acid can get the product to this pH, and strong acids are too dangerous to be used by operations utilizing hand labor.

Fish processing wastes, particularly those from filleting operations, often contain extremely high proportions of bone. In acid silage, as time goes on, much of that bone dissolves in the acid used as a preservative. As the bone dissolves, it neutralizes the acid. In experiments like those graphically depicted in Figures 2 and 3, which show changes in an acid silage at pH 4 over time, a graduate student is measuring the pH of the silage every few days and adding acid to keep it from rising. In a commercial process, to ensure that the pH did not rise above 4, one would have to start out at a pH of 3.5 or 3, depending upon the amount of ash in the raw material. However, in hydrolysis, most of the bone is screened out as soon as digestion is complete. The advantages of this are twofold, comprising first, lower acid costs, and second, lower ash levels in the final product. An earlier session (Joe Zublena, Nutrient Management with Land Application Systems) discussed the importance of excess phosphorus in water pollution. By screening out bone, one can offer a product lower in phosphorus. This is of particular importance in the aquaculture feed market where phosphorus levels are starting to be limited by legislation (6). In addition, it permits the recovery of protein from filleting wastes, where ash levels can be as high as 50 percent of the raw material on a dry weight basis. (The bone removed by screening may be dried and sold as bone meal.)

Whole fish are generally about 75 to 80 percent water, and silages and hydrolysates made from fish start out with the same water content. This lowers their value and increases their storage and transportation costs. On the other hand, a wet product, stabilized by acidification, is far cheaper and easier to produce than a concentrated or dry one and provides an economically viable way to turn small amounts of wastes into saleable products. Indeed, the ability to stabilize a wet product is one of the major advantages offered by hydrolysis technology as against that of fish meal. Not only does this ability radically alter the economics of scale of production, but it permits the product to undergo initial processing and stabilization at a number of sites, including those at sea, with subsequent transport to a central facility for concentration and/or drying. In planning hydrolysis facilities, an important question is, at what size does concentration become economically feasible? Our rough-and-ready answer would be somewhere around 25,000 pounds per day of raw material.

In general, the removal of water by evaporation is more economical, both in terms of capital costs and energy costs per pound of water removed, than is drying. Also, evaporators are designed to deal with rapidly flowing materials containing large quantities of water. But dryers are designed to deal with more viscous materials containing lower quantities of water. In designing a hydrolysis plant, it would make sense to use evaporators to remove as much water as possible, whether the end product was to be a concentrate or a dry powder. The amount of water which evaporators can remove varies with the viscosity of the material; in the case of fish hydrolysates, one can usually reach about 50 percent solids. (Intuitively, going from 75 percent water to 50 percent water does not seem like a large reduction. However, it is an enormous reduction; each pound of concentrate is derived from three to four pounds of incoming raw material. To do the calculation, it is necessary to know that protein represents about 15 percent of the raw material. If the end product is 50 percent solids and that solids content is largely protein, the total quantity of end product will be twice the initial protein content or 30 percent of the raw material. Thus, the ratio of water removed by evaporation to the water removed by drying is about 4:1.) One reason that evaporation is so much more efficient than drying is that evaporators can be staged, permitting heat to be reused. Dryer design, at least up until this time, has not utilized staging. However, a corollary to this is that evaporators too small to be staged are not necessarily more efficient than dryers.

In plants large enough to have staged evaporation, the economies of scale can be very rewarding. In a plant which we designed recently with the GSE Corporation of Clearwater, Fla., a machinery line for up to 150,000 pounds of raw material per day can be handled by a single worker per shift, with an energy cost for finished concentrated product of $10 per ton. Adding a dryer to this plant increases the energy cost of a ton of finished product to $34 per ton. However, one should note that one ton of dry product starts out as almost two tons of concentrate or close to seven tons of raw material. In addition to economic advantages, large automated plants can have process advantages as well. Because of the rapidity with which the material reaches temperature and the tightness of process control, very consistent and high quality products can be produced and a variety of product types can be developed and marketed.

As Figures 2 and 3 make clear, hydrolysates are composed of a complex mix of proteins, peptides, amino acids and non-protein nitrogen. In addition, they frequently contain little clumps of digestion-resistant tissue. As you push the system, for example, by increasing digestion time, you can increase the proportion of single amino acids and small peptides, but you never reach homogeneity (3). (Note: this statement is true for enzyme digestions; hydrolyses carried out by strong acids can result in a uniform set of single amino acids. However, this is not a biological process and is not of interest for large-scale biomass utilization.)

All natural foods contain free amino acids, as well as peptides and proteins. It is the type and proportion of these smaller molecules that impart to foods much of their distinctive flavors (7,8). For example, glycine, one of the very few amino acids which tastes sweet, has been shown to be an important component of the distinctive flavors of crab and lobster (9). As more free amino acids and small peptides are created by hydrolysis, flavor is intensified, sometimes beyond the desired level. Thus, for ordinary feed uses, where the hydrolysate will be a major protein source and used at high inclusion rates, digestion should be kept to the absolute minimum required for liquefaction. The opposite side of the coin is to utilize hydrolysates at low inclusion rates as flavor enhancers and attractants. In this case, one may wish to push the digestion process a little harder and increase the proportion of smaller molecules.

Protein hydrolysis, in a number of guises, has been used for a long time to generate very complex flavors for human food. Some examples in seafood are the manufacture of Southeast Asian fish sauces and the curing of herring (1,3). (Both of these are examples of autolysis, which utilizes the enzymes already present in the raw material.) A more recent example is the use of enzyme hydrolysis by the French company ISNARD-Lyraz on a variety of seafood wastes of carefully monitored quality to create natural extracts for flavoring soups, sauces, etc.(10) These hydrolysates are concentrated by vacuum evaporation and preserved only by refrigeration. The company prices their products at about $4 to $15 per pound and finds that their market is growing and their operation is profitable.

Hydrolysates are widely used for palatability enhancement of dry cat and dog foods, but the hydrolysates in this market are made from meat and poultry byproducts. Some years ago, when there was an active U.S. tuna canning industry on the West Coast, a tuna "digest" was a popular pet food palatability enhancer. However, our attempts to clarify if this product was an actual digest or merely concentrated blood and stickwater from the canning and/or tuna meal manufacture have not been successful.

In aquaculture feeds, the situation is potentially much more complex than that of human or pet food because of the large number and systematic variability of the species being fed. However, the use of hydrolysates has been limited to species of high value which are problem eaters, such as salmon or shrimp. In fact, two kinds of "flavors," to use that word loosely, are being incorporated into aquaculture feeds, and hydrolysates are used for both purposes. One type is analogous to human food flavor; i.e., what the animal tastes when it takes the food into its mouth. In feeding salmon, this is a key element. Atlantic salmon will lunge at food as soon as they see it, but, if it does not taste right, they will spit it out again. Worst of all, if salmon really dislike what they taste, they will sometimes refuse to eat at all, ultimately dying of starvation. The other type of flavor is more analogous to aroma; that is, the small molecules that leach from the feed into the water and act as attractants, stimulating the animal to move towards the feed and ingest it. This is most important with bottom feeders, like shrimp or crayfish, which are very slow at getting around to their food and need olfactory cues to distinguish it from the mud in which it is sitting.

In the Pacific rim, where the majority of shrimp culture is carried out, fish protein hydrolysate is said to be increasingly used in shrimp feeds at a level of about 5 percent. It seems to carry out both flavor functions. Since it is rich in small molecules which leach out of the feed and diffuse through the water, it acts as an attractant. The portion remaining in the feed improves palatability, thus permitting the inclusion of up to 40 percent soybean meal in the diet, despite the fact that shrimp do not like soy. It is cheaper to include 5 percent fish protein hydrolysate at 75 cents per pound plus 40 percent soy at 12 cents per pound, than to replace both ingredients with fish meal at 20 to 25 cents per pound. The product used for this purpose is a spray-dried enzyme hydrolysate manufactured in Boulogne-sur-Mer, France by the Coopérative de Traitement des Produits de la Pêche. This product, also known as "Soprapêche," has been manufactured for a quarter of a century and is widely used in France for calf milk replacers and in this country as an appetite enhancer in baby pig feeds, at inclusion rates of 3 to 5 percent.

A different approach is utilized by Bioproducts, a company in Warrenton, Ore., which specializes in salmon hatchery feeds, comprised largely of concentrated fish hydrolysates, which they manufacture. In Norway, a modified fish silage, stabilized with formic acid, is widely used in salmon growout feeds.

It is clear that much of the research that has been carried out on the use of hydrolysates in feed has been done by industry. Although many of these companies have been remarkably helpful in sharing their knowledge, they are clearly going to draw the line at sharing their trade secrets. At this time, we know very little about the effects of processing aids such as different enzymes and even acids on the palatability of hydrolysates to different species. Although much of the power of hydrolysis technology resides in its immense flexibility, permitting the production of wet, dry or concentrated products for entry into a number of markets, that flexibility is still incompletely understood and utilized. A tremendous amount of research remains to be done on these complicated and varied products, and both researchers and industry have important contributions to make.

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Films and Fibers from Chitosan

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Chitin and its free amine form chitosan are novel polysaccharides that occur in significant quantities in shellfish wastes. Chitin is also considered the second most plentiful organic compound on earth, although it is considerably underutilized. Chitin/chitosan may be less advanced than cellulose with regard to research and utilization, but it has recently attracted much attention in basic and applied research fields, including biochemistry, polymer chemistry and biomedicine. Chitosan can be regarded as a new type of polymeric material, more chemically versatile than cellulose. The uses of these materials was recently reviewed by Sandford [9] and Parisher [7].

These polymers are particularly interesting in terms of their biocompatibility. For example, chitin is now believed to have wound-healing properties. Both chitin and chitosan are being used as substrates for complexing other biological compounds. These properties plus the potential for making high performance fibers from liquid crystalline solutions [2] suggests that these biopolymers have tremendous potential for development.

At N.C. State University, we have a major research effort underway to develop uses for chitin and its derivative, chitosan. We have a team of two faculty and five graduate students working in this area, with funding from various sources and collaborators in several other countries. Currently, we are researching the use of crab shell waste from North Carolina operations; however, the most important sources of these wastes exist in the Northwest, particularly Alaska.

In this paper, we will review our ongoing projects regarding the preparation of chitosan fibers and films, the equilibrium dye-sorption properties of chitosan film and the use of crude chitin for the decolorization of textile dye-mill wastewaters.

CHITOSAN FIBERS

In our laboratory, we recently reported the preparation of cross-linked chitosan fibers [Wei, Y.C., S. Hudson, J. Mayer and D. Kaplan. The Cross-Linking of Chitosan Fibers. J. Polym. Sci., Polym. Chem. Ed, in press]. It is our objective to improve the functional properties of this material. Chitosan is the deacetylated form of chitin, which is a linear polymer of acetylamino-D-glucose. Chitosan is less easily defined, as it is difficult to fully deacetylate chitin. Chitosan is a preferred form of the polymer. It is a more tractable material to process into fibers or films than chitin. A drawback of chitosan is its enhanced hydrophilicity compared to chitin, which results in considerable loss of tensile strength when wet.

Epichlorohydrin (ECH) was selected as a convenient base catalyzed cross-linking agent. An advantage of ECH is that it does not eliminate the cationic amine function of chitosan. Most notably, the cross-linking by ECH significantly improves the wet strength of the chitosan films [6]. A similar effect is also described here for the cross-linked fibers.

Materials and Methods

Powdered crab-shell chitin was obtained from Sigma Chemical Co. The chitosan used for fiber preparation was obtained by the hydrolysis of chitin. Two-hundred grams of chitin powder were added to 50 percent NaOH (2000 mL) in a 3-liter flask. The mixture was purged with nitrogen and stirred for two hours at 100 C. The reactor was then placed in an ice bath and cooled to room temperature. The chitosan was filtered off, repeatedly washed until the filtrate was neutral at pH 7, then washed with ether and air dried. The process was repeated to increase the degree of deacetylation.

Chitosan filament was wet spun by following the methods described by G.C. East et. al. [3]. A spin dope was prepared by dissolving 5 percent w/v chitosan in 5 percent v/v aq acetic acid. The coagulating bath was 1 M NaOH. Spinnerette dimensions were 0.25 mm diameter and a capillary length to diameter ratio of 2. A piston/ram device was employed to extrude the fibers at room temperature.

The use of ECH to cross-link amylose was reported by Luby [5]. Fibers were cross-linked in the wet state only. A 38-centimeter length of fiber was tied as a single loop and placed in a large tube containing the ECH solution, purged with N_2 and sealed. The standard conditions employed used 0.067 M NaOH (pH 10) and a reaction temperature of 40 C. The reaction time, tension and ECH concentration were varied.

Results and Discussion

Table 1 shows the effects of ECH concentration during cross-linking on the tensile properties. As the ECH concentration is increased, the tenacity increased for each of the two series of treatments. However, increasing the concentrations above 1.0×10^{-2}M did not produce a further increase in tenacity in the case of four hours of cross-linking. For the wet fibers, it is evident that a significant increase in toughness of the fibers is observed by the large increase in the elongation to failure. Again, it is noted that there is not a deleterious effect on the dry fiber properties as a result of the cross-linking.

In summary, chitosan fibers and films are readily cross-linked by ECH, which results in changes in the mechanical properties of these materials. There is a considerable relative improvement in the tensile strength of the films compared to the fibers. This is interpreted to reflect the differing morphology of the film compared to the fiber. It is expected that the fiber will have a more oriented fibrous structure than the films. Thus it is observed that cross-linking the films has a more profound effect on the tenacity of the poorly oriented film than for the fibers. The wet strength of the fibers is considerably improved, whereas cross-linking has a negligible effect on the dry fiber properties.

CHITOSAN DYEING ISOTHERMS

The application of color via dyestuffs to fibers and films is key to the development of new packaging materials. Chitosan has the potential to be useful as a renewable, naturally derived polymeric material. However, dyeing

Table 1. The Effect of ECH Concentration on Fiber Tensile Properties.

[ECH] x 10^2M	Reaction Time (hr)	Swelling Ratio	Tensile Properties (dry/wet) Tenacity (g/d)	Elongation (%)	Modulus (g/d)
0.125	4	soluble	1.32/ND	9.9/ND	73/4/ND
0.25	4	81.0	1.30/0.36	9.4/42.4	61.2/0.8
0.50	4	25.0	1.32/0.77	8.7/33.5	48.1/1.9
0.75	4	17.4	1.44/0.70	10.2/30.7	55.9/2.0
1.00	4	11.1	1.45/0.89	10.6/22.0	61.0/4.5
1.00	1	24.4	1.24/0.81	9.1/38.1	52.6/2.2
1.50	1	21.4	1.42/1.01	9.6/25.2	58.6/5.9
2.00	4	8.5	1.45/1.15	8.9/22.4	59.1/11
2.00	1	18.4	1.44/1.02	8.9/22.8	59.1/5.3
3.00	1	5.6	1.46/1.07	9.2/22.0	53.4/11
Control Fiber			1.36/0.68	10.4/15.0	66.5/7.3

The chitosan fiber was cross-linked with ECH in 0.067 M NAOH under no tension at 40 C.

data reported for chitosan fibers and films still seems to be limited in scope [4]. In previous work, we reported the measurement of direct dye diffusion coefficients in chitosan [1]. In fact, we found that chitosan is easily dyed with several dye classes, including acid, fiber reactive and direct dyes. Here we report the isothermal dyeing behavior of chitosan films with a number of direct dyes including: Direct Yellow 105, Direct Green 26, Direct Black 80, Direct Black 22, Direct Red 81, Direct Red 24, Direct Blue 98 and Direct Violet 47.

Materials and Methods

Chitosan films were cast on glass plates using a doctor knife and a 5 percent (w/v) of chitosan in 90 percent formic acid (aq). The solutions were filtered, under pressure, through a seven micron-pore-size sintered metal frit prior to casting. After drying at room temperature, the films were lifted off the glass and placed in 0.05M sodium methoxide in methanol to convert the chitosan formate salt back to the free amine form of chitosan. All dyes were commercial product samples from Sandoz Chemical Co., except for Green 26 which was obtained from Ciba Geigy. Each dye was used without further purification.

Dyeing Isotherms

Solutions of the dyestuffs were made up in distilled, deionized water. The chitosan films were cut up into pieces of approximately 10 cm^2. The dye solutions and the chitosan films were combined in glass stoppered tubes and agitated in a shaker bath. The temperature was kept constant with a circulating propylene glycol bath, controlled by a Haake E1 Controller.

For each dye, the concentration that gave 20 percent transmission at the wave length of maximum absorbance (lambda max) was determined. These solutions were then made up and used as the stock solutions for the dyeings. Absorbance was measured on a Perkin Elmer UV/VIS 559A spectrophotometer. The Beer Lambert Law calibration curve was determined for each dye.

The time to equilibrium dye exhaustion was determined for each dye. A period of 72 hours was found to be adequate for obtaining equilibrium. Following each dyeing, the dye bath was concentrated to a standard volume and the dye concentration remaining in the bath was determined. The equilibrium dye concentration in the film was determined by dissolving the film to the standard volume in 5 percent aqueous acetic acid and determining the absorbance. The partition ratio of the dye in the film to the dye in the bath is then easily determined. For several of the dyes, the pH had to be adjusted to maintain solubility. The formation of insoluble salts involving dye and chitosan also caused problems with some of the dyes.

Results and Discussion

Clear, tough, flexible films are readily obtained by casting chitosan from volatile solvents such as formic acid. Although the films weaken in water more so than cellophane, chitosan can be cross-linked to improve its wet strength as noted earlier. To further assess the suitability of chitosan as a packaging material, we undertook the present study to determine the affinity of direct dyes towards chitosan film.

In a previous study, we found that the diffusion coefficients for the direct dyes, Red 81, Green 26, Blue 75 and Black 22, had values in chitosan that are in the same range for cellulose (4.48 x 10 -11 to 4.54 x 10 -10 cm 2 at 60 C and pH 9) [1]. Dyeing data for several food colorants on films of pure chitosan is reported by Knorr [4]. Also, the use of chitosan as a pretreatment applied to cotton fabrics to improve dye coverage has been reported [8]. Here we report the equilibrium sorption data for several direct dyes on films of pure chitosan.

For each of the direct dyes employed in this study, an isotherm at 60 C was determined. The adsorption isotherms were determined to fit the Freundlich equation, which has the form :

$$[D]f = k [D]bx$$

where [D] is the dye concentration in the film and the bath respectively, k is the partition ratio and x is a fraction. From the log vs log plots of the concentrations, x was determined to be 0.7. Cellophane was used as a control, with a value of x = 0.5. Values for k and the standard affinity of the dye for the film are shown in Table 2. It is noted that for each dye the partition ratio, k, is greater for chitosan than for cellulose.

Table 2. Dye Adsorption Isotherm Data for Chitosan and Cellulose.

Dye	Chitosan T = 60 C k	-(RTlnk)/x (kcal/mol)	Cellulose T = 60 C k	-(RTlnk)/x (kcal/mol)
Green 26	222	5.1	—	
Black 80	573	6.0	104	5.7
Red 81	60	3.9	17	3.7
Yellow 105	599	6.0	252	7.3
Blue 98	833	6.4	75	5.7
Black 22	318	5.5	63	5.5
Red 24	319	5.5	50	5.1
Violet 47	679	6.2	89	5.9

TEXTILE WASTEWATER TREATMENT WITH CHITIN

The textile industry is the largest industrial wastewater producer in the Southeast. In North Carolina, there are at least 45 permitted facilities operated by textiles and related (e.g.fiber, dyestuff, textile chemical specialty) industries. These are permitted to discharge over 64 million gallons per day (MGD) or about 1/4 trillion gallons annually. In addition, there are about 100 permitted Publicly Owned Treatment Works (POTW's) in North Carolina to which textiles is a major contributor, ranging in size up to 40 MGD.

Major current environmental concerns for the future for the textile industry include

Stormwater
Aquatic toxicity
Toxic air emissions
Color in wastewater
Salt discharge limitations

These issues are not all currently regulated, but each is being written into permits as time goes on. In fact, some mills are now being required to monitor color by testing their effluent for APHA (Pt-Co) color units.

Of course, there are significant problems with the APHA color measurement as a means of monitoring color pollutant discharges in industrial wastewater. For the example mill, many different dyes were used with APHA color characteristics which vary greatly. Also, much apparent color is removed by the filtering step in the method. Thus the APHA color data do not necessarily reflect the appearance of the water, and color is in essence an aesthetic pollutant. In view of the high variation of color value with respect to dye concentration for different dyes, it is very difficult for a dyer to know how much dye waste is "too much" for compliance with a particular limit in the wastewater.

The first and most important step in color pollution control is a good source reduction program. Examples of some strategies for this are shown in Table 3. These are the primary line of defense of a textile manufacturer against color discharges. The example mill cited here uses good source reduction practices.

As a second phase of color pollution control, one must consider treatment of those color wastes that cannot be eliminated or reduced at the source. There are several treatment strategies which have been studied:

- Biodegradation
- Destruction of color by oxidation or reduction (eg ozone, chlorine, aerobic processes)
- Precipitation or co-precipitation (eg polymeric or iron hydroxide)
- Sorption (eg polymer or activated carbon)

Many studies have been done on the subject of color destruction by bio or chemical degradation, including ozonation, chlorination, UV irradiation, reduction and other methods. In some cases, these have reported successful decolorization of wastewater. In these treatment processes, one expects to decolorize the waste by somehow destroying the chromophore of the colorant. It has been suggested that the products of such treatment strategies can be more harmful than the dyes themselves.

In the case of chlorination or oxidation, the process of color destruction potentially can produce harmful materials in the effluent. Sorption or precipitation methods do not leave these potentially harmful residues in the water.

Another method that is practiced for color removal is the use of carbon as a sorption agent. This, in combination with biological treatment, can lead to satisfactory color removal in many cases. In one example, a POTW that treats a large amount of colored textile wastewater had results which are typical for decolorization using tertiary activated carbon sorption. A reduction of about 75 percent in APHA color resulted from the secondary activated sludge treatment. Further reduction of about 20 percent was obtained from carbon sorption. Final effluent color was only about 5 percent of influent. Whether or not this will satisfy the permit requirement that this shall result in "no noticeable change in color of the receiving waters" is unknown. This would, of course, depend on the momentary characteristics (amount and color) of the receiving waters.

One particularly interesting alternative treatment method currently being investigated in our laboratories is sorption of color using chitin. Utilization of chitosan as a flocculent and absorbent in water treatment processes has been demonstrated in several industries [7]. At present, we are engaged in developing these crab shell wastes as a means of eliminating color from industrial discharges from textile dyeing operations.

The dye sorption properties we observed in the laboratory for chitosan are remarkable. The mixtures with which we are working consist of partially (up to 80 percent) N-deacetylated(chitosan) products obtained from crab shell wastes. The unusual dye sorption properties of chitin and chitosan result from the presence of (a) cellulose-like polysaccharide structural features, (b) nylon/wool-like - NH_2 groups and (c) the N-acetamide feature. We have observed that the polymer has the ability to rapidly absorb essentially all the color from a dye bath, leaving the residual dyebath completely clear, even when dyes with low physical affinity (eg fiber reactive and certain direct dyes) are used. All dye classes except basic dyes are strongly absorbed. Even disperse dyes are essentially 100 percent exhausted.

Our studies thus far have centered mainly on the dyeing of high-quality fibers and films of chitosan as noted earlier. We found that exhaustion of dyebaths of acid, direct and fiber reactive dyes, is essentially 100 percent even when no salt is used. With the exception of basic dyes, all classes tested thus far have been essentially quantitatively sorbed by the polymer. Preliminary studies have been done on all classes, and specific data has been carefully measured for direct dyes. We are collecting affinity data for other classes, including fiber reactive. Our current studies for wastewater decolorization use the less refined versions of chitin/chitosan, starting with the received crab meal. This meal is progressively treated with acid for demineralization and caustic for deproteinization. In our laboratory studies, acid and direct dye mixtures (which initially had APHA color of over 1,000 units) were completely decolorized by these forms of crab-shell wastes. At the time of this writing, further studies are underway to optimize the application conditions as well as to determine the effectiveness on a wide variety of dye wastes.

At present, the example POTW (cited earlier) is treating wastewater with activated carbon and polymer flocculent at a cost of $1,200 per day. We plan to scale-up our experiments to the point of on-site evaluations. We are confident that we will develop from this some improved treatment methods for textile wastewater in terms of cost and performance. Simultaneously we will be providing a method of waste source reduction for the seafood processing industry.

Table 3. Typical Color Source Reduction Activities.

I. Administrative Controls

Employee training/attitude
Color waste monitoring
Reward system for source reduction efforts
Purchasing policy (returnable containers)
Incoming dye VQC procedures & chemical

II. Engineering Controls

Implements, containers (design, adequacy cleanup)
Dispensing method (auto dosing systems)
Segregation of color waste
Primary control measures (drag-out)
Floor drain, drum washer controls
Dyebath renovation/reuse

III. Process/Product Design

Shade/fiber selection
Exhaustion (dye process - temperature, time, salt, pH, liquor ratio, etc.)
Dye class selection
Equipment selection
Redye reduction
Optimized fixation
Minimize specialty chemicals in dye bath

IV. Work Practices

Dry capture (vacuum, broom and dustpan)
Avoid batch dumps of dye mixes
Screen and squeegee cleaning
Orderly housekeeping and work practices

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The Environment and Seafood Processing

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Seafood processors across the United States are facing serious and urgent problems in meeting requirements of county, state and national regulations for protection of the environment from solid, liquid, and air-borne wastes. These regulations are not uniform. They are not enforced uniformly across jurisdictions, and they are changing. Penalties for violation of these regulations can be severe. Heavy fines can be levied against companies and individuals. Rapidly rising costs for treating water and sewage are accruing to governmental entities. Because they transfer these costs to industry, disposal and treatment of processing wastes in public facilities is no longer feasible for many commercial operations. Some governmental jurisdictions no longer accept seafood wastes for disposal in landfills.

For the seafood industry in the United States to remain competitive and viable on its current scale, it must quickly accommodate increasingly stringent and changing environmental regulations. Longer term, it must replace production of wastes with production of secondary products. In many cases, the need to recover byproducts will prove to be an opportunity for greater economic return. Most seafood processors have neither the expertise or financial resources to address the requirements for change, short-term or long-term, that are brought on by environmental regulations. Thus the National Sea Grant College Program and other programs, such as the Cooperative Extension Service of the U.S. Department of Agriculture and the National Coastal Resources Research and Development Institute, have the responsibility and motivation to provide technical assistance.

Sea Grant has conducted programs of research and outreach over several years that have made technical advancements on several fronts and aided the seafood industry. Most efforts have been by state or region. Helping the industry to comply with environmental regulations offers an opportunity to demonstrate coordination of efforts in addressing problems and issues across the network. By taking new approaches to research and outreach, these efforts can become greater than the simple sum of the individual parts.

Some of the problems facing industry can be addressed through standard practices for good manufacturing. But many processors do not know how to implement these practices, do not know what regulations apply to their operation, do not know the basic characteristics of their operation (how much water they use, what its quality is incoming and outgoing) and do not know what benefits can be gained from water conservation and other basic practices. Current engineering technology is able to address some of the problems. But appropriate technology must be selected or adapted, and this is not a trivial undertaking. Many of the problems and issues relating to waste management and environmental quality must be addressed through interdisciplinary efforts - engineering, economics, seafood science and technology, soil science and chemistry. Bench-scale and pilot-scale experiments and demonstration projects will be required to address some issues, show the value of new approaches to resolving problems and define where the next steps in research must be taken. All research and demonstration efforts should have outreach and communication built in from the beginning.

RECOMMENDATIONS

The National Sea Grant Office should take immediate steps to formulate and describe a program of outreach and research, coordinated across the Sea Grant network, to address problems and opportunities related to waste management and byproduct recovery in the seafood processing industry. This program and plan will have the following three primary purposes:

(1) to enhance the effectiveness of current state and regional efforts through centralized coordination and planning,

(2) to help the seafood industry face and solve urgent

problems that threaten to put many processors out of business soon, and

(3) to develop a plan that will be persuasive in justifying a program of outreach and research that will provide a level of effort adequate for helping to keep the U.S. seafood industry competitive in the long-term.

In formulating this plan, the National Sea Grant Office should find a way to take an inventory state by state of the seafood processing industry and the problems facing it. How many processors are there? What are they producing? How many people do they employ? What is their contribution to the economy? How much water do they use? How much effluent and solid waste do they produce?

In addressing short-term problems of the industry, researchers and advisory agents and specialists would find useful a standard set of reference materials. Thus, an early goal should be to produce a set of manuals and guides that could be used by processors in any state or region. The following might be among them:

• A simple statement of the requirements of federal regulations and associated penalties, relating to environmental quality, that affect seafood processors.

• A simple statement of the requirements of state and county regulations and associated penalties, relating to environmental quality, that affect seafood processors.

• Basic principles of water conservation and dry cleanup in processing.

• Guidelines for determining whether a processing plant is in compliance with environmental regulations.

• A guide to commercial firms and governmental laboratories that can provide analyses of samples of waste and effluents and of associated environmental samples.

Speakers List

1. **James R. Oliver**, Agricultural Advisor to the governor of North Carolina — (No Paper Submitted — NPS)

2. **Mike Street**, N.C. Division of Marine Fisheries — Protecting Environmental Quality Today

3. **B.J. Copeland**, UNC Sea Grant College Program — Sea Grant and Fisheries Environment

4. **Roger Crickenberger**, N.C. Cooperative Extension Service (NPS)

5. **George Everett**, Director of the N.C. Division of Environmental Management (NPS)

6. **Randall Waite**, N.C. Department of Environment, Health and Natural Resources — Overview of the Albemarle-Pamlico Estuarine Study

7. **David Engel**, National Marine Fisheries Service — NMFS Environmental Research in the Southeastern United States

8. **Roy Martin**, National Fisheries Institute (NPS)

9. **Bob Carter**, Southeast Waste Reduction Resource Center — EPA: Pollution Prevention Strategy and Related Legislative Acts

10. **Gary Hunt**, N.C. Office of Waste Reduction — North Carolina's Pollution Prevention Program: A Model (NPS)

11. **Susan Goldhor**, The Center for Applied Regional Studies — New England Seafood Processors and the Environment

12. **Robert Jones**, Southeastern Fisheries Association — A Report on an Incident that Impacts the Gulf and South Atlantic Seafood Processors and the Environment

13. **Donald E. Kramer**, Alaska Sea Grant College Program — North Pacific Seafood Processors and the Environment

14. **Edd Valentine**, Georgia Technical Research Institute — Pretreatment and Treatment Technologies for Seafood Processors (NPS)

15. **Joseph Zublena**, Dept. of Soil Science, N.C. State University — Nutrient Management With Land Application Systems

16. **Albert A. Cocci**, ADI Systems Inc. — Anaerobic Treatment of Clam Processing Wastewater

17. **W. James Catallo**, Institute for Environmental Studies, Louisiana State University — Bioremediation: Theory and Applications to Seafood Industry Wastes

18. **Brian W. Sheldon**, Department of Food Science, N.C. State University — Process Water Filtration and Treatment for Reuse

19. **Gary Rodrick**, Dept. Food Science and Human Nutrition, University of Florida — Depuration Practices and Water Pollution (NPS)

20. **Frank Sizemore**, Patton, Boggs and Blow, PA — Environmental Laws — Aggressive Compliance in Response to Aggressive Enforcement (NPS)

21. **Roger N. Schecter**, N.C. Div. of Coastal Management — North Carolina's Coastal Management Program (NPS)

22. **Tom M. Losordo**, Dept. Zoology, North Carolina State University — Future Needs and Concerns in Aquaculture (NPS)

23. **Roy E. Carawan**, Dept. of Food Science, N.C. State University — Corporate and/or Plant Environmental Policy

24. **Al Perry**, Gulf Coast Research Laboratory — Seafood Processors in the Coastal Area (NPS)

25. **Celia Bonaventura**, Duke University Marine Biomedical Center — Prospects for Biotechnology in the Seafood Industry

26. **James Cato**, Florida Sea Grant College Program — Utilizing Scraps from Blue Crab and Calico Scallop Processing Plants

27. **Susan Goldhor**, The Center for Applied Regional Studies — Fish Protein Hydrolysates and Their Uses

28. **Sam Hudson**, College of Textiles, N.C. State University — Films and Fibers from Chitosan

29. **Wayne Skaggs**, Dept of Biological and Agricultural Engineering, N.C. State University — Agricultural Non-Point Source Contamination to Significant Estuaries (NPS)

30. **Andy Weber**, U.S. Department of Agriculture — U.S. Department of Agriculture's Water Quality Plan (NPS)

31. **Ken Eagleson**, N.C. Div. of Environmental Management — Chronic and Acute Toxicity, Water Quality Testing (NPS)

32. **David Attaway**, National Sea Grant College Program — The Environment and Seafood Processing

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Processing Plant Waste Management Guidelines for Aquatic Fishery Products

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The quantity and quality of water has received much public attention. As a result, lawmakers are considering, or have already passed, environmentally conscious legislation such as the Clean Water Act (CWA). Seafood processors must address the technological and economic impact of environmental issues on their future.

Public concerns have prompted new economic, regulatory and political changes that will alter the attitude about water use in the food industry. Water use is very important to the aquatic fishery products industry. Clean water is essential for production of raw products. Processing water use includes washing products, scalding, making brines, cooking, cooling, cleaning and sanitation. Water is also an ingredient in some further processed products.

Three areas of water use are of concern. These concerns are (1) the availability of water of sufficient quality for the intended use, (2) the depletion or loss of water associated with use, and (3) the disposal of industrial wastes — both processing residuals and wastewater treatment process residuals. Each area has technological, economic, regulatory and public image factors. These factors combined, make these areas of concern critical to the location and continued operation of many food plants. The aquatic fisheries production, harvesting and processing industries will feel the effects of many of these issues.

WATER AND WASTEWATER REGULATIONS

Drinking Groundwater

The 1986 Safe Drinking Water Act, prior amendments and the 1974 Safe Drinking Water Act mandate certain responsibilities and establish the Environmental Protection Agency (EPA) as the regulatory agency. The 1974 act mandates that all public water supplies must meet EPA safety criteria. The 1986 amendments mandate that EPA set action levels on 83 pollutants by 1989. The Food and Drug Administration (FDA) is responsible for processing water for food plants and using the Good Manufacturing Practices (GMPs) (21 CFR 110.37(a)). The U.S. Department of Agriculture (USDA) regulates water use and reuse in meat and poultry processing plants. The aquatic products industry is regulated voluntarily by the U.S. Department of the Commerce. The agency with prime responsibility for regulating the aquatic fishery products industry is the U.S. Department of Health and Human Services FDA. Shellfish is controlled by FDA and the state public health officials. However, under these regulations, EPA (40 CFR 141) is responsible for regulating drinking water for employees if more than 24 employees occupy the plant. Lead pipe and lead soldered joints are prohibited under these amendments.

Some states are setting water quality standards more stringent than EPA's in response to consumer pressure. EPA studies are underway to determine the quality of our water supplies and the level of contaminants, including agricultural chemicals such as herbicides and pesticides in our groundwater. Further, EPA regulates pesticides and recommends action levels to FDA for enforcement.

Not only are consumer groups demanding action, they are taking steps to force future responses from our elected officials. Recently, the Center for Response Law and the New York Public Interest Research Group reported that 2,110 contaminants were found in a study of 3,422 U.S. water systems. Some 190 contaminants are suspected or known to be harmful to health. A food plant manager may have to justify using water containing a known carcinogen. Such action would cause legal liability for him and his company. Similarly, are fisheries managers responsible if they harvest fish with known toxicants?

Waste/Wastewater

Wastewater from food processing plants is regulated by EPA and state statutes. Plant managers with direct discharges or applications of wastes and wastewater must get the required permits and file the necessary reports. Many food plants discharge to municipalities and are regulated by local, state and federal regulations through the EPA Pretreatment Program. New concerns include Proposition 65 in California, stormwater permits, biomonitoring, community-right-to-know and underground storage tanks. Key references are listed in Table 1.

TABLE 1. Issues and Information

Environmental Issue	Reference/Information
Surface Water Discharge	NPDES Permit 40 CFR 122 and 123 EPA 202 475-8310
Biomonitoring	Journal of WPCF(Jan. 1987)
Stormwater Permits	Federal Register Nov. 16, 1990
Municipal Discharge	40 CFR 403
Nonhazardous Waste to Land (state's control)	40 CFR 257
Sewerage Sludge to Land	40 CFR 257EPA February 6, 1989 Proposal
Hazardous Substances	40 CFR 117,302,370 40 CFR 372
Community-Right-to-Know	40 CFR 370, 372
Underground Storage Tanks	PL 98-616, 40 CFR 280, 281
PCB's	40 CFR 761
Asbestos	40 CFR 61 EPA 800 368-5888
Employee Drinking Water	40 CFR 141
Accidental Release Reporting	40 CFR 117, 302 NRC 800 424-8802
Municipal Solid Waste	EPA's Agenda for Action EPA 800 424-9346

During the mid-seventies the federal environmental regulatory program expanded to cover virtually all discharges to surface waters. This expansion focused on oxygen-demanding pollutants and toxic and hazardous pollutants.

Most of these changes became mandatory with the CWA amendments of 1977. In 1987, the act was again extensively amended to include changes that tightened the focus on toxic dischargers. Also, water quality permitting was strengthened to include discharges such as storm water, which were largely unregulated in the past. These amendments also served to strengthen the act's enforcement mechanisms.

EPA regulatory officials have developed and tested all the regulatory tools, gadgets and mechanisms for the CWA. EPA, along with the attorney general's office, have a long and reasonably distinguished enforcement history. This combination of stricter limits and enforcement is having an ever-increasing impact on actions taken, fines paid and expenditures.

Section 309 makes CWA's enforcement provisions formidable. A chief attribute of the CWA enforcement philosophy is the extent to which individual criminal prosecution, or the threat thereof, is relied upon as a deterrent. Under the amendments, purposeful or negligent violation of any of the act's major requirements is a crime attributable to the corporation and to the individuals responsible. Included are failure to obtain a permit, failure to give notice when required, failure to monitor properly and failure to report thereon. Inaccurate monitoring through negligence or the intentional falsification of reports are actions dealt with severely. The act's criminal enforcement provisions are supplemented by an increased civil penalty authority, a provision for administrative penalty proceedings and an expansive provision for citizens' suits.

All the waste and wastewater regulations force state/local actions and responses. The current climate is one of increased litigation and cost. Examples of actions against food processors in the last several years include:

- Citizens' Suits

  Chesapeake Bay Foundation vs. Gwaltney
  $1.3 million fine proposed against meat processor

  Note-This suit was filed to help protect the Chesapeake Bay, one of the nation's prime breeding grounds for a variety of aquatic fishery products.

- Discharge Violations

  Nabisco Plant - Washington State
  $300,000 fine
  $250,000 reserve trust
  $ 5,000 fine and one-year incarceration for plant manager

  Ocean Spray - Middleborough, CN
  $2.1 million corporate fines proposed — fines and incarceration for officers considered

  Coca-Cola - Massachusetts
  $200,000 fine

WATER USE

Only 6 percent of our rainwater is usable. The rest is lost to evaporation (70 percent) and runoff (24 percent). Of the usable water, industry uses 3 percent; agriculture, 2.5 percent; and municipalities, 0.5 percent. Industries within municipalities may account for almost 50 percent of the municipal use.

Reports indicate that 25 percent of the nation's groundwater is used faster than it is replaced. Groundwater supplies are threatened by leaking landfills, leaking underground tanks, pesticides and fertilizers.

Water Cost

Water cost for food processors has not been a major concern in the past. Even today most food plants pay less than $3 per thousand gallons of water used. Some poultry plants use more than 5 million gallons of water per day. Water and wastewater costs for such a plant could approach $4 million annually. Most aquatic products processing plants use much less water.

Water Use

Water use for food processing is calculated as either the total amount of water used for the product or the amount of water needed for processing alone. The author categorizes food plants depending on water use per day (Table 2). Most aquatic products processing plants would be classified in the small category although there are a few large plants.

Table 2. Water Use in Food Processing Plants

Category	Water Use Per Day (gal)
Small	20,000
Medium	20,000 — 100,000
Large	100,000 — 1,000,000
Very Large	> 1,000,000

Table 3 presents the amount of water used to produce a specific amount of product. Biological processes require large quantities of water. For instance, water needed to produce a bushel of corn may be 6,000 gallons while a bushel of soybeans may require 23,000 gallons. It is estimated that 7,000 gallons of water are necessary to produce one pound of steak. Trout and catfish production require large quantities of water.

Water needed for the food processing industry is not as large as for agricultural production. For example, it requires 6 to 10 gallons of water to produce one gallon of beer, 8 to 13 gallons for each fryer, 20 to 35 gallons for a turkey, and 1 gallon for each pound of hamburger (Table 4). Shrimp peeling, cooking and freezing requires about 22 gallons of water for each pound.

Table 3. Water Use Necessary for Agricultural Production

Product	Quantity	Water Use (gal)
Bread	Loaf	115
Potatoes	20 lbs.	1,200
Eggs	Dozen	1,440
Steak	l lb.	7,000
Milk	Gal.	9,500

Table 4. Water Use in Food Processing

Item	Quality Water Used for Processing (Gal)
Fryer (1)	8 - 13
Turkey (1)	20 - 35
Sweet potatoes [can #303 (1 lb.)]	1 - 4
Apples [can #303 (1 lb.)]	1 - 2
Green beans [can #303 (1 lb.)]	1 - 2
Hamburger (1 lb.)	0.5 - 1
Pork chops (1 lb.)	1 - 2
Beer (1 gal.)	6 - 10
Milk (1 gal.)	1 - 3
Shrimp (1 lb.)	22

Water Quality

Water quality is important in processing. For example, food processing plants are concerned about organic and inorganic impurities and bacterial content. Potable water is required for all water used in the final preparation of foods intended for human consumption. Some latitude exists in that recirculated or reconditioned water may be used for some purposes.

Because of the importance of standardizing water quality in their products, soft drink manufacturers have long subjected their water supplies to rigorous treatment. Soft drink production plants typically take water through coagulation, disinfection, pH adjustment and carbon filtration steps to remove hydrocarbons and chlorine from water. Other water treatment technologies that food plants could use include ion exchange, membrane filtration, ultra-violet disinfection, air stripping and biological (bacterial) conversion. In the future, the aquatic products processing industry may need to treat incoming water.

WASTEWATER

Introduction

The volume and characteristics of food processing effluents often exhibit extreme variability. The BOD_5 may be as low as 100 mg/l or as high as 200,000 mg/l. The BOD_5 of seafood processing plant effluents is sometimes as high as 2,000 mg/l. Suspended solids, almost completely absent from some wastes, may be found in concentration as high as 120,000 mg/l. The waste may be highly alkaline (pH 11.0) or highly acidic (pH 3.5). Nutrients such as nitrogen and phosphorous may be absent or they may be present in quantities in excess of those necessary to promote good environmental conditions for biological treatment.

Treatment of wastewater from aquatic products processing plants can be costly and complex. High strength wastewaters and highly variable seasonal loadings make many treatment schemes ineffective and not cost efficient. The locations of new plants is highly dependent on wastewater disposal. As the processing industry for aquatic products expands in the future this limitation may hamper growth.

A majority of the pollutants of concern in the aquatic products processing industry are organic and compatible with most biological treatment methodologies as well as land disposal. However, the use of chemicals (chlorine for sanitation and cleaning or sodium chloride for pickling operations) causes unique disposal problems.

The enactment and enforcement of sewer-use ordinances, pretreatment ordinances and surcharge ordinances threaten the economic viability of many suburban and urban food processing plants. As more municipalities require pretreatment, developing improvements in the processes becomes necessary. The best pretreatment schemes involve the utilization of pollution prevention techniques to reduce pollution at the source and recycling water to minimize potable water needs and wastewater. Existing pretreatment processes for aquatic fisheries processing include screening, clarification or dissolved air flotation (DAF). The disposal of the residue from these processes is expensive and difficult.

Toxins are not often a worry for the managers of most aquatic processing plants. However, as regulations become more restrictive and analysis techniques more sensitive, a number of wastewaters such as those with highly alkaline or acidic wastes, copper, zinc, chrome, laboratory wastes and sanitizing solutions containing chlorine will adversely affect the food processing industry—including aquatic products processors.

BOD_5

Biochemical oxygen demand (BOD_5) is the test used for monitoring wastewater from food processing plants. The BOD_5 test is a biological test used to indicate the amount of oxygen necessary to enable the biochemical oxidation of wastewater. The test is widely used because oxygen deficiency is often the cause of polluted water and fish kills. Oxygen supply is usually the greatest expense in wastewater treatment.

BOD_5 from food plants is directly related to food products in the wastewater. In fact, BOD_5 can be estimated in food plant wastewaters by determining the fat, protein and carbohydrates in a particular wastewater and using the following factors:

Food Component	lbs BOD_5/lb Food Component
Carbohydrates	0.65
Fats	0.89
Protein	1.03

Any waste parameter such as BOD_5 is usually reported in terms of ppm or mg/l, which are equivalent measures. To determine the amount (waste load) of any given parameter, the following formula is used:

Waste Load Formula

$$\text{lbs waste} = \frac{8.34\,(\text{CONC})\,(\text{FLOW})}{1{,}000{,}000}$$

where CONC = concentration (mg/l, or ppm)
FLOW = volume of wastewater

Example: We have a food plant that processes 20 days per month with a wastewater discharge of 1.5 million gal/day with a BOD_5 = 2,750 mg/l. What is the monthly waste load?

For One Month

$$\text{FLOW} = 1{,}500{,}000 \text{ gal/day} \times 20 \text{ days} = 30{,}000{,}000 \text{ gal}$$

$$\text{Waste Load} = \frac{8.34\,(\text{CONC})\,(\text{FLOW})}{1{,}000{,}000}$$

$$BOD_5\ (\text{lbs/month}) = \frac{8.34\,(2{,}750)\,(30{,}000{,}000)}{1{,}000{,}000}$$

$$BOD_5 = 688{,}050 \text{ lbs/month}$$

How can we use this information? If the plant discharges to a city that charges 20 cents per pound of BOD_5, what is the monthly bill?

Bill = 688,050 lbs BOD_5/month x \$0.20/lb BOD
Bill = \$137,610.00 per month

Costs

Costs for wastewater include those for pretreatment, for treatment and for disposal to Publicly Owned Treatment Works (POTWs). In the last 25 years, municipal water and sewer bills, have increased fourfold to tenfold. At the same time, restrictions on waste discharge are being imposed with new and/or expanded municipal ordinances.

Disposal to POTWs

In the disposal of wastewater from food processing plants to POTWs, there are three types of costs incurred: the cost of pretreatment, the cost of residual or sludge disposal and the cost of discharge. Discharge costs include sewer and surcharge costs. Currently sewer costs average about \$1.50 per 1,000 gallons but range from 20 cents to about \$6 per 1,000 gallons. Surcharges are levied for waste loads discharged above the prescribed limit. Surcharges are charged for BOD5, TSS, FOG, phosphates, TKN, etc. BOD_5 costs range from 2.5 cents to \$2 per pound while TSS surcharges range to almost \$3 per pound of excess suspended solids.

Treatment

Costs for treating food plant wastes vary depending on the size and complexity of the operation. Common treatment processes include land disposal, anaerobic ponds, aerobic ponds, activated sludge, clarifiers, trickling filters and rotating biological contractors (RBCs). The costs for analysis, permits records and report filing are becoming significant.

Pretreatment/Sewer Use Ordinances/Local Limits/ Permits

Pretreatment and sewer-use ordinances can impose significant restrictions on food plants. The costs for pretreatment processes are expensive, and technology is not yet available to meet the new restrictive limits imposed by many ordinances.

Pretreatment Regulations

The EPA in 1978 issued the federal pretreatment regulations. The objectives of the pretreatment regulations are to prevent the pass-through of pollutants that interfere with treatment systems. This assures treatment efficiency, protects treatment system workers and improves or enhances recycling and reclamation processes. Amendments subsequent to 1978 include those passed in 1981, 1987 and 1988, and those proposed in 1988. Industries located in municipalities that discharge wastewater to the local POTW were previously only responsible to the local sewer-use ordinance. Not only do these new regulations make the acceptance of, and compliance with limitations in a plant-specific permit a local matter, they also subject corporations to state and federal reviews, oversights, and possibly non-compliance actions. Most companies are not likely to have rigorous institutional mechanisms to assure full compliance and to protect the company and its personnel. Plant specific permits are now being rapidly developed throughout the country to replace sewer-use ordinance limitations. Most plants have found significant compliance problems with this process. The only way for an industry to guarantee that the pretreatment requirements placed on its discharge are reasonable is to take an active role in the development and implementation of the POTW's program.

The general pretreatment regulations require all POTWs that are designed to receive flows of 5 million gallons or more per day to develop and implement a local pretreatment program. Also, POTWs that are designed for less than 5 million gallons per day but receive significant industrial discharges can be required to develop a local pretreatment program at the discretion of the pretreatment "approval authority" (either the state or EPA). POTWs that are required to develop and implement local pretreatment programs must design their local programs around two general types of pretreatment standards, categorical standards and prohibited discharge standards.

Categorical pretreatment standards are developed by EPA for specific classes of industrial users. These limitations are based on the wastewater treatment technologies available to the industry class and the economic ability of the industry class to install the technology. Categorical standards apply to all industrial users in the industry class unless local limits, site specific limitations developed by the POTW, are more stringent.

Prohibited discharge standards ban the discharge of certain types of waste to the POTW. Specific bans are placed on pH, temperature, explosive pollutants and obstructive pollutants. In addition, general prohibitions are placed on any pollutant that can interfere with POTW operations or pass through the POTW into the receiving water. As part of the development of a local pretreatment program, the POTW must develop specific local limitations to implement the general prohibitions.

EPA's decision to delegate pretreatment program responsibility to local POTWs was made for several reasons. Most POTWs were already familiar with local industrial users. Many POTWs had some existing industrial client relationships through billing/surcharge programs. And, perhaps most compelling, the POTW's NPDES permit served as an ideal vehicle for requiring program development and implementation. There are, however, several problems that occur when POTWs are required to develop and implement a complicated regulatory program. Most of these problems directly affect the industrial user.

The problems with pretreatment program implementation by local POTWs begin with a lack of training and experience in a variety of areas. Development and implementation of an effective pretreatment program requires expert knowledge in environmental law, environmental engineering, environmental chemistry and industrial engineering. Most POTWs look to the wastewater treatment plant (WWTP) staff to develop and implement their pretreatment program, but it is very rare that the WWTP staff has the required skills. EPA and individual states try to compensate for the POTW's lack of skill by supplying technical support documents such as example ordinances, example permits and various procedure manuals. Once the POTW has these documents in hand, they often find it easier to adopt the government's generalized guidance word for word rather than develop their own policies using site specific criteria.

Ordinance

The purpose of a sewer-use ordinance is to give the POTW the legal authority to carry out the various functions required by the general pretreatment regulations. These functions include issuing industrial user permits, inspections, monitoring and enforcement. EPA's Guidance Manual For POTW Pretreatment Program Development advises POTWs to review the current ordinance and, if modifications are needed, provides a model ordinance. Further, since the model is intended only as a guide, POTWs should modify the model to address local concerns. Unfortunately, most towns tend to adopt the model without significant changes.

As part of industry's role in the pretreatment program, a plant should participate in the local process of sewer-use ordinance modification. In many towns, this process includes a public notification that the ordinance is being changed, a mailed notice to affected industrial users and one or two readings at the monthly council meetings. The industry should find out the standard notification procedures in its town. If the only opportunity for public comment on ordinance changes is given during two council meetings, the industry should make sure that they receive a copy of the council meeting agenda prior to each meeting. When sewer-use ordinance modifications are on the agenda, the plant should obtain a copy and complete a thorough review of the draft.

Local Limits

As part of the development of a pretreatment program, each POTW must develop specific local limits in accordance with 40 CFR 403.5(c). In some cases, towns have found it easier to determine their local limits by conducting a poll of other POTWs and adopting the most common limits. As long as these limits are stringent enough to protect the WWTP and the receiving stream, they are approved by the approval authority. If the limits are too stringent, the approval authority usually assumes that the POTW is reserving capacity for future use. Therefore, the first request that an industry should make when reviewing its permit or the sewer-use ordinance limits is to see the calculations on which the limits are based.

If the POTW has adopted local limits derived from site-specific information, they are said to have technically based local limits. The process for developing technically based local limits involves determining the maximum amount of each pollutant acceptable to the influent (or headworks) of the WWTP while still protecting the receiving water, the WWTP itself and the POTW's sludge disposal options. This process is called a headworks analysis. As usual, EPA has supplied POTWs with enough guidance via procedures manuals and computer programs to enable a POTW to complete a headworks analysis with a minimum of site specific information. Therefore, when an industry asks about the origin of local limits, they may be told that the town has technically based limits and be presented with a computer printout of the headworks analysis. Such a response from the POTW should not be the end of the industry's questions on local limits but rather the beginning of a detailed review of the headworks analysis.

The headworks analysis can be divided into three sections: pass-through calculations, interference calculations and sludge calculations. An allowable influent load is calculated for each of the three sections. The three allowable influent loads are then compared and the most restrictive calculation is used as the basis for the final local limits.

Summary

The only way to implement a fully effective pretreatment program is for federal and state regulators, local POTWs and industrial users to cooperate toward achieving a mutual goal: the protection of the receiving water and the town's wastewater treatment investment. To maintain the best possible cooperation, all parties involved must have a thorough knowledge of the general pretreatment requirements and an understanding of how these requirements helped to develop the POTW's site-specific pretreatment program. Industries must take responsibility for understanding the pretreatment program and, in some cases, for educating the POTW in alternative ways to implement its pretreatment program. Industries that do take an active role in the development and implementation of their POTW's pretreatment program may find that local pretreatment standards and requirements are more stringent than those required by federal regulation or those needed to protect the WWTP and the receiving water. The aquatic fisheries processing industry needs to ensure that the nation's waters are protected at the same time they need to be sure that they can comply with these regulations.

ATTITUDE

Top management is responsible for a firm's accomplishments in the environmental field. Management's attitude is responsible for water-use reductions and waste elimination. The lowest cost-control measures usually are those that attack the problem at its source. No change for a food plant can be implemented successfully without management attention.

A thorough understanding of the production process can help to eliminate excessive water use and waste. Many authors have indicated that waste problems in food plants can best be solved by developing byproducts for animal feed. Animal feed byproducts often do not provide economical solutions. Also, the solutions provided often only alleviate or offer temporary solutions until the byproduct market dies.

Joseph T. Ling (3-M Company) noted that we must mandate conservation-oriented technology which means utilizing a minimum of resources while creating a minimum of pollution. The authors of a booklet on water and waste management in food processing noted that the traditional sanitary engineering approach of developing treatment processes would not solve the waste-control problems of the modern food industry. The authors concluded that a lack of communication between engineers and processors usually was the reason for this lack of success.

Many note the sufficient supply of quality water as an impending national crisis. Drought conditions together with the increasing demands of an expanding population and growing industrial needs underscore the importance of adequate supplies of high quality water. Conservation and industrial water use are inextricably linked with other state and national concerns for environmental quality, energy conservation, agricultural production needs, industrial development, municipal requirements and recreational and wildlife needs.

MANAGEMENT

Management and Process Changes

The four factors directly related to pollution that would induce a food processing plant manager to incorporate management and process changes designed to reduce waste load are the following:

- Public image
- Cost reduction
- Efficiency
- Regulatory requirements

Public Image

Most food processing plants are very concerned about public image. They do not want to be recognized as a polluter because that has a very negative public image. Food plants processing under brand names are probably more concerned by this public perception.

Reducing waste load from a food plant not only can reduce costs, but in plants discharging to a municipality, it also helps the municipality reduce costs. Reduced loads for municipalities should reduce municipal treatment costs, minimize need for expansion of treatment facilities, help to maximize treatment efficiency and allow new citizens and businesses into POTW's with peak loading.

Efficiency

Food plants that reduce wastes often find they also increase plant efficiency. As wastes are eliminated and more byproduct is recovered, there is often more product packaged for sale.

Cost Reduction

Costs for water, sewer, surcharge and waste disposal are becoming significant expenditures for food processing plants. These costs have risen almost tenfold over the last several decades, possibly more than any other cost for food processing. A recent survey by Arthur Young led George Rafetelis to conclude that water costs could increase as much as 500 percent in the next five to 10 years.

Regulatory Requirements

External restraints are another factor that can influence a food plant to consider water and waste reduction programs. These restraints can include effluent restrictions on selected wastewater parameters such as BOD_5, chemical oxygen demand (COD), fats, oils and greases (FOG), total kjeldahl nitrogen (TKN) and flow. These restrictions can adversely affect plants.

AQUATIC PRODUCTS WASTEWATER CHARACTERISTICS

Introduction

The aquatic products processing industry is made up of the seafood industry with many small processing centers located along the U.S. coastlines, aquaculture centers such as trout in Idaho and catfish in Mississippi, and a number of larger plants located near industry and population centers. The industry involves the processing of numerous species of seafood including:

- mollusks (oysters, clams, scallops)
- crustaceans (crabs and lobsters)
- various species of saltwater and freshwater fish.

Seafood processors use the following major unit processes: washing, eviscerating, dressing, processing and rendering. Rendering of whole fish and fish byproducts produces fish meal, oil and solubles.

SEAFOOD INDUSTRIES

Bottom Fish

The most economically important bottom fish species that are primarily marketed fresh or frozen are:

- Haddock
- Halibut
- Cod
- Ocean Perch
- Whiting (silver hake)
- Flounder
- Hake
- Pollock

Industrial Fisheries

Menhaden, herring and alewives are oily fishes that comprise the bulk of the "industrial fisheries" in this country. They are rendered into meal, oils and solubles. The meal is used primarily as animal feed and fertilizer. The oil becomes an ingredient in paints, varnishes, resins and similar products. It is also added to animal feed or used for human consumption abroad. The solubles are either fed directly to animals or are dried and processed into meal.

Anadromous Fishery

The only significant U.S. commercial anadromous fishery is the salmon fishery. The five main species harvested in this country are:

- Chinook (king)
- Silver (coho)
- Chum
- Sockeye (red)
- Pink

The major portion of the salmon catch is canned.

Tuna

Tuna ranks as the number one seafood in the United States. Americans consume over one billion cans of tuna per year. Tuna are large migratory fish that feed on smaller macroscopic sea life.

Shrimp

The shrimp fishery in terms of total value is the most important in the United States. Currently the most important finished products are frozen and breaded shrimp.

Crabs

The blue crab is harvested on the Atlantic Coast, principally in the Chesapeake Bay area. The remaining harvest takes place on the Pacific Coast where Dungeness crab is the leading species followed by Alaskan king crab.

Clams

The surf clam is a relatively recent addition to the Atlantic Coast shellfish processing industry. The major industry growth occurred in the mid 1940s and in 1958 when new offshore beds near Long Island, N.Y., were discovered. Hard clams account for only 12 percent of the landings but about 50 percent of the value. The Chesapeake and Mid-Atlantic areas combine for much of the clam landings.

Aquaculture

Catfish is a rapidly expanding industry located primarily in the South. Trout is primarily located in Idaho with North Carolina and California developing segments. The hybrid striped bass is being explored.

SEAFOOD PROCESSING

Major types of wastes found in seafood processing wastewaters are blood, offal products, viscera, fins, fish heads, shells, skins and meat "fines." These wastes contribute significantly to the suspended solids concentration of the waste stream. However, much of the solids can be removed from the wastewater and collected for animal food.

Water Use

Tuna processing plants were reported to have wastewater discharge as high as 3.6 million GPD (Table 5). Bottom fish wastewater discharge ranged from 6,000 to 400,000 GPD. Fish meal plants ranged from 10,000 to 92,000 GPD in the survey.

Wastewater Characteristics

Carawan et al (3) reported on an EPA survey with BOD, COD, TSS and oil and grease (FOG) parameters. Bottom fish were found to have a BOD_5 of 200 to 1000 mg/l, COD of 400 to 2000 mg/l, TSS of 100 to 800 mg/l and FOG of 40 to 300 mg/l (Table 3). Fish meal plants were reported to have a BOD_5 of 100 to 24,000 mg/l, COD of 150 to 42,000 mg/l, TSS of 70 to 20,000 mg/l, and FOG of 20 to 5,000 mg/l, COD of 150 to 42,000 mg/l, TSS of 70 to 20,000 mg/l, and FOD of 20 to 5,000 mg/l. The higher numbers were representative of bailwater only. Tuna plants were reported to have a BOD_5 of 700 mg/l, COD of 1600 mg/l, TSS of 500 mg/l and FOG of 250 mg/l. Seafood processing wastewater was noted to sometimes contain high concentrations of chlorides from processing water and brine solutions and organic nitrogen (0-300 mg/l) from processing water.

FISH PROCESSING

<u>Tuna</u>. In an EPA report (8), the authors noted that the annual tuna catch averages about 400 million pounds, almost all of which is canned. They concluded that as much as 65 percent of the tuna is wasted in the canning process. The degree of wastage depends on the species being processed so variations will occur. They reported on a study that examined the waste from a tuna canning and byproduct rendering plant in detail for a five-day period. The following observations were made:

- The average waste flow was 6,000 gal/t of fish.
- Wastewater varied from 500 to 1,550 mg/l BOD5.
- The average daily COD ranged from 1,300 to 3,250 mg/l.
- The total solids averaged 17,000 mg/l of which 40 percent was organic.

Detailed average tuna wastewater characteristics are given in Table 6.

Table 5. Raw Wastewater Characteristics — Canned and Preserved Seafood Processing Industries

Subcategory	Flow(GPD)	BOD (mg/l)	COD (mg/l0	TSS (mg/l)	FOG (mg/l)
Farm-raised catfish	21M—45M	340	700	400	200
Conventional blue crab	700	4,400	6,300	620	220
Mechanized blue crab	20M—73M	600	1,000	330	150
Southern non-breaded shrimp	180M—240M	1,000	2,300	800	250
Breaded shrimp	150M—200M	720	1,200	800	—
Tuna processing	65M—3.6M	700	1,600	500	250
Fish Meal	92M—10M*	100—24M*	150—42M*	70—20M*	20—5M*
All salmon	58M—500M	253—2,600	300—5,500	120—1,400	20—550
Bottomfish and finfish (all)	6M—400M	200—1,000	400—2,000	100—800	40—300
All herring	29M	1,200—6,000	3,000—10,000	600—5,000	600—800
Hand-shucked clams	86M—170M	800—2,500	1,000—4,000	600—6,000	16—50
Mechanical clams	300M—3MM	500—1,200	700—1,500	200—400 2	0—25
All oysters	14M—320M	250—800	500—2,000	200—2,000	10—30
All scallops	1M—115M	200—10,000	300—11,000	27—4,000	15—25

*—Higher range is for bailwater only
M—1,000
MM—1,000,000

Table 6. Tuna Waste Characteristics

Parameters	Concentration(mg/l)	Load lbs/fish 1,000 lbs.
COD	2,273	64.5
BOD_5	895	24.0
TS	17,900	475.0
TSS	1,081	29.0
FOG	287	7.5

FINFISH HANDLING AND PROCESSING

Carawan and Thomas (12) surveyed the seafood industry in North Carolina. They examined finfish handling practices in North Carolina related to wastewater. Finfish primarily include flounder, croaker, trout, spot and bluefish. Unloading, washing and separating ice, sorting, grading and re-icing before shipping all constitute finfish handling. Most of the wastes were generated from the debris and ice removal in the washing tank.

Results of the survey (Table 7) found that total solids averaged 2.4, ash 1.11, organic solids 1.30 and BOD_5 0.23 lb/1,000 lb while water use was 110 gal/1,000 lb of fish handled. Table 8 illustrates the species differences found during handling of fish.

Scales may drop off during unloading, contributing large amounts of settleable solids to the waste load. Slime, blood and sand were also found to be part of the wastewater. Fish were strenuously washed, and removed materials were measured to gain an idea of maximum waste load.

Average BOD_5 of rinse tank wastewaters was 251 mg/l. Scales seemed to constitute the bulk of the solids in the effluent from the wash tanks surveyed. The scales and other solids were removed during screening with a 20-mesh screen. Results of screening tests are tabulated in Table 9. Some 74 to 90 percent of the settleable solids were removed with the screen.

North Carolina finfish processors use hand labor in processing flounder, trout and croaker. Carawan and Thomas (1981) examined three finfish processing plants. These three plants were processing 715 to 1,000 lb/hr of flounder, trout and croakers in the round or fillet. Raw effluent from these plants had the average characteristics as listed in Table 10. The average water use was 1.34 gal/lb and the wastewater BOD_5 was 190 mg/l.

Plant review confirmed that controlling waste solids greatly influenced the wastewater characteristics. Of 29 plants surveyed by Carawan and Thomas, nine sent their solids for dehydration, 12 used their solids for bait and eight plants disposed of all the material overboard.

One processor cooperated in an experiment where raw fish frame composting was tried as a disposal method. Grass cuttings, pine straw, horse manure and soil were mixed and composted for six weeks. Raw fish frames were added and completely decomposed within four weeks.

Table 7. Water Use and Wastewater in Finfish Handling

Parameter	Waste Load (lb>/1,000 lb)	
	Average	Range
Total Solids	2.40	.87—4.60
Ash	1.11	.53—2.15
Organic Solids	1.30	.34—2.44
BOD5	.23	.01—1.00
	(gal/1,000 lb)	
Wastewater	110	60—180

Table 8. Waste from Fish Handling

	Trout	Croaker (lbs/1,000 lbs)	Flounder
Total solids	6.56	4.08	3.20
Organic solids	4.06	1.98	1.36
Ash	2.50	2.10	1.34

Table 9. Effect on Screening on Fish Handling Wastewater

	Settleable Solids (mg/l)			
	Plant 1	Plant 2	Plant 3	Average
Effluent				
Raw	3.8	20.0	100	41
Screened	1.0	2.0	14	5.7
Removal (%)	74	90	86	86

Table 10. Water and Wastewater for N.C. Finfish Processors

	Rinse Tank	Mechanical Scaling	Fillet & Scaling	Cleanup	Total
			(lb./1,000 lb. raw fish)		
TS	2.08	4.74	3.44	0.27	10.53
Ash	0.37	2.03	1.37	0.12	3.89
OS	1.71	2.60	2.08	0.15	6.54
TSS	0.38	2.59	0.86	0.09	1.96
DS	0.71	1.85	2.96	0.13	5.65
BOD	0.59	0.56	0.86	0.10	2.11
FOG	0.10	0.30	0.71	0.03	1.14
			(gal./1,000 lb)		
Flow	544	318	457	16	1,335

Table 11. Sources of Waste in a Frozen Fish Factory

Description of Source

1. Fish handling onboard: manner in which fish are conveyed from nets to hold can reduce quality and yield from cut fish
2. Unloading fishing vessels: use of water to convey fish to wash tank for rinsing
3. Fish handling operations on land: conveyors from waste tank to processing rooms
4. Cleanup operations in processing room: wash down of processing equipment
5. Compressors/cooling tower water
6. Solid waste through mishandling of whole fish

Table 12. Bottom Fish Processing Wastewater Characteristics

Reference	BOD_5 (mg/l)	TSS (mg/l)	Flow (GPM)
A	640	300	105
B	192—640	—	320-410
C	1,726	—	132
D	—	750	45

BOTTOM FISH

Sources of waste in a bottom fish factory are identified in Table 11. Bottom fish processing wastewater characteristics are presented in Table 12. The average waste load for Reference B was 31 lb. BOD_5/1,000 lb. raw fish.

SALMON

Large salmon plants use less water for production than do small salmon plants (Table 13). Large salmon plants have less waste load than do small salmon plants.

Table 13. Salmon Wastewater Characteristics

Parameter	Large Salmon Processing Average	Small Salmon Processing Average
Flow-(gal/1,000 lb)	374	1,186
BOD-(lb/1,000 lb)	1.13	5.2
SS-(lb/1,000 lb)	1.3	2.2
Grease oil (lb/1,000 lb)	0.8	2.2

Gulf Shrimp Canning

Peelers use as much as 58.1 percent of the average water use in Gulf shrimp canning plants (11). The BOD 5 from these plants is 1,081 mg/l (11).

Table 14. Gulf Shrimp Canning, Water Use and Wastewater

Unit Operation	Percent of Average Flow
Peelers	58.1
Washers	8.8
Separators	6.9
Blancher	1.6
De-icing	4.2
Cooling/retort	12.1
Washdown	8.3

Blue Crabs Conventional (as contrasted with mechanical) blue crab processing has a flow of about 756 gal. per 1,000 pounds of crabs processed. The BOD_5 load is 2.67 lbs per 1,000 pounds of crabs, but the TSS load is 1.92 lbs.

Soft-Shell Clams Clam shucking has a wastewater discharge of about 164 gal per 1,000 pounds of clams processed. The BOD_5 and TSS loads are 2.49 and 0.74 lbs per 1,000 pounds of clams, respectively.

Atlantic Oysters Hard shucked (Atlantic oysters) processing requires about 2,868 gal per 1,000 pounds of oysters. The BOD_5 load is 25.24, but the TSS load is 8.73 lbs. per 1,000 pounds of oysters.

Table 16. Blue Crabs (Conventional Process)

Parameter	Unit	Mean
Flow ratio	(gal/1,000 lb)	756
Settleable solids	(mg/l)	2.79
TSS	(lbs/1,000 lb)	1.92
BOD_5	(lbs/1,000 lb)	2.67
FOG	(lbs/1,000 lb)	0.04
Phosphorus (total)	(lbs/1,000 lb)	0.04
$N\text{-}NH_3$	(lbs/1,000 lb)	0.04
TkN	(lbs/1,000 lb)	0.27
pH		7.63

Table 17. Soft-Shell Clams (Hand-Shucked)

Parameter	Unit	Mean
Flow ratio	(gal/1,000 lb)	164
Settleable solids	(mg/l)	1.40
TSS	(lbs/1,000 lb)	0.74
BOD_5	(lbs/1,000 lb)	2.49
FOG	(lbs/1,000 lb)	0.01
Phosphorus (total)	(lbs/1,000 lb)	0.04
$N\text{-}NH_3$	(lbs/1,000 lb)	0.01
TkN	(lbs/1,000 lb)	0.20
pH		7.11

Table 18. Atlantic Oysters (Hand-Sucked

Parameter	Unit	Mean
Flow ratio	(gal/1,000 lb)	2,868
Settleable solids	(mg/l)	1.66
TSS	(lbs/1,000 lb)	8.73
BOD_5	(lbs/1,000 lb)	25.24
FOG	(lbs/1,000 lb)	0.11
Phosphorus (total)	(lbs/1,000 lb)	0.28
$N\text{-}NH_3$	(lbs/1,000 lb)	0.08
TkN	(lbs/1,000 lb)	3.12
pH		7.15

JAPANESE FOOD FISH FACTORIES

The Japanese have an extensive background in processing fish into various food products. Japanese fish factories have calculated water use at 1,800 gal/1,000 lb. to 6,000 gal/1,000 lb. for the various types of plants. If the highest waste load and lowest volume are used for calculations of wastewater strength, the BOD_5 could exceed 7,000 mg/l for surimi processing. However, average values calculated from Japanese fish factories indicated BOD's of 750 mg/l for tuna, 240 mg/l for frozen fish, 205 mg/l for kamaboko and 3,625 mg/l for surimi. The wastewater parameters reported in Table 19 are also for Japanese fish products factories. Surimi plants would have a BOD_5 of 8,204 mg/L. Kamaboko plants would have a BOD_5 of 6,776 mg/l, and fish meal plants would have a BOD_5 of 18,400 mg/L. Another Japanese scientist reported that water use in surimi processing was 25 times the throughput. Thus, water use is 3,000 gal/1000 lb. fish or 27,300 gal/1000 lb. for surimi. This can be contrasted with the reported volume of 4,800 gal/1000 lb fish.

The Industrial Fisheries

In a properly managed menhaden rendering plant, wastewater quantities are small. The only inherently troublesome wastewater source is the fish pumping water. The other wastes result from spills and leakages, both of which can be minimized.

The menhaden is a small, oily fish of the herring family.

This fishery, largest in the United States, is located mainly in the Mid-Atlantic and Gulf states including North Carolina. Menhaden have been used primarily for the manufacture of fish meal, fish solubles and oil. The manufacturing process is (in most cases) highly mechanized.

The fish are caught in purse seines and pumped into the fish holds for transport to the plants. Then the fish are pumped from the holds, washed, automatically weighed and conveyed into the plant. Continuous steam cooking is normally employed. The cooked fish are then pressed to remove the oil and most of the water. This press water is screened to remove solids and centrifuged to separate the oil. The remaining water, called stickwater, is discharged or evaporated to produce condensed fish solubles. The solid residual from which the water and oil have been pressed is known as "pressed cake." The pressed cake is dried to about 10 percent moisture and then ground for fish meal.

The wastewaters from the production of fish meal, solubles and oil from herring, menhaden and alewives can be divided into two categories: high-volume, low-strength wastes and low-volume, high-strength wastes. The high-volume, low-strength wastes consist of the water used for unloading, fuming, transporting and handling the fish plus the wash-down water. The fuming flow has been estimated to be 200 gal/t of fish with suspended solids of 5,000 mg/l. The solids consist of blood, flesh, oil and fat. The above figures vary widely. Other estimates listed herring pump water flows of 250 gpm with total solids concentrations of 30,000 mg/l and oil concentrations of 4,000 mg/l. The boat's bilge water has been estimated to be 400 gal/t of fish with a suspended solids level of 10,000 mg/l.

The stickwaters comprise the strongest wastewater flows. The average BOD5 value for stickwater ranges from 56,000 to 112,000 mg/l, with average solids concentrations, mainly proteinaceous, ranging up to 6 percent. The fish processing industry has found the recovery of fish solubles from stickwater to be at least marginally profitable. In most instances, stickwater is now evaporated to produce condensed fish solubles. Volumes have been estimated to be about 120 gal/t of fish processed.

Dried scrap and meal are the most highly valued products from menhaden, although oil production was the initial reason for processing. Most of the scrap and meal is used as an animal feed supplement.

Summary

Wastewater from fish processing and industrial fisheries is very diverse and varies with management and process practices. Each plant is unique so generalizations about water use and wastewater characteristics are difficult. However, average numbers for water use and waste load appear to have value for each industrial category.

Table 19. Wastewater Parameters in Japanese Product Factories

Parameter	Factory Type		
	Surimi	Fish Meal	Kamaboko
	Wastewater Concentration (mg/l)		
BOD_5	8,204	18,400	6,776
COD	1,210	5,032	606
SS	757	1,683	578
Fat	541	1,743	149
NH_3-N	15	86	5
TkN	305	912	199

Table 20. Measures to Control Water Use, Product Loss and Waste Load

Number	Measure
1.	Management understanding, interest and support
2.	Installation of modern equipment and piping to reduce loss of product and maximize recovery of byproducts
3.	Appointment of water-waste supervisor
4.	Employee training
5.	Accurate records of water use and waste
6.	Scheduling to reduce water use and waste
7.	Proper cleaning procedures
8.	Wastewater monitoring
9.	Planned maintenance program to reduce losses and waste
10.	Planned quality control program to reduce losses and waste
11.	Planning systems for wasted product and byproducts
12.	Development of alternatives for wasted product recovery

METHODS OF REDUCTION

There are three proven ways to reduce water use, wastewater discharge, waste loads and product loss. One method is to operate the plant more efficiently. The second method is to institute process changes proven to reduce water use, product waste and waste loads. The third method is to install conventional pretreatment technologies such as clarifiers, separators and/or dissolved air flotation (DAF) units to remove settleable (floatable) solids. Measures to control water use, product loss and waste load are given in Table 20.

Pollution Prevention Pays Concept

Although many scientists and technical people have practiced pollution prevention, Joseph T. Ling of the 3M Company can be credited with first using the 3M Pollution Prevention Pays program.

Ling concluded that government, industry and the public are beginning to become aware of the shortcomings of conventional pollution controls, not to mention their cost. "Pollution Prevention Pays" utilizes the concept that the conservation approach should be used to eliminate the causes of pollution before spending money and resources for cleanup afterward. Ling defines the conservation approach as the practical application of knowledge, methods and means to provide the most rational use of resources to improve the environment.

Ling believes that the pollution prevention approach is hindered or precluded by many rigid environmental laws and regulations. One current example is municipal pretreatment ordinances with specific limits on the concentration of pollutants in wastewater discharge. For food processing plants, maximum concentration limits on compatible pollutants, such as BOD_5, often preclude water reuse and recycling. Studies indicate that plants with the least amount of water use per unit of product processed have the least amount of pollutants per unit of product processed. Thus, such ordinances may discourage water conservation and waste reduction practices.

Ling noted that pollution controls solve no problem; they only alter the problem. He notes there is a significant opportunity if realistic and effective solutions are sought for pollution problems.

Pretreatment of food plant wastewater does not really solve a pollution problem. Instead, pretreatment generates secondary nutrients (sludge) that must be disposed of properly to prevent moving the pollution to another location. As pretreatment or treatment requirements increase, resources are consumed and residues are produced. The costs incurred rise exponentially. Ling defined this environmental paradox as follows: "It takes resources to remove pollution. Pollution removal generates residue. It takes more resources to dispose of this residue and disposal of this residue also produces pollution."

Michael G. Royston recognized pollutants as material residues from industrial, domestic or agricultural processes that are discharged into the environment. He concluded that such materials could either be reused, or they should not have been produced in the first place. Royston noted that pollution acts as an indication of inefficient processes. He concluded that as inefficiencies are reduced, so is pollution reduced.

The aquatic products processing industry has an opportunity to increase plant efficiency, reduce pollution, conserve water (one of our most vital resources) and increase profitability. Knowledge, management commitment, thorough understanding of the processes and employee education are the key components of a successful program.

The Time To Act Is Now

Many changes are taking place in waste regulations. Water and waste costs are creeping steadily upward, and the increases promise to continue. It's important for aquatic fishery products processors to take action now to be prepared for limitations on water use and waste loads that are likely to occur in the not-so-distance future. Reduce your plant's waste load before it has a chance to become a costly burden. Follow the waste reduction hints suggested in Table 21.

Table 21. Waste Reduction Hints

- Reduce water use; most water used in processing becomes wastewater.
- Use screens and efficient systems for recovering solids.
- Install dry systems for solid waste collection.
- Collect solids from the floor and equipment by sweeping and shoveling the material into containers before actual cleanup begins. Do not use water hoses as brooms.
- Adopt the attitude that waste load reduction is one of the best business decisions a manager can make.
- Train employees in the concepts of pollution prevention, and show them how to perform their jobs in a way that will cut waste loads in your plant.

EXAMPLES

Groundfish. A Canadian study (13) compared extensive wastewater analysis for dry and wet-line processing of groundfish. The data indicates that wet line processing produces an effluent in excess of three times the dry effluent loadings. The authors concluded that the excess was due to the following:

A) Increased BOD_5, suspended solids and oil concentrations in the wet-line effluents support the theory that the longer water is in contact with fish solids, the higher the wastewater parameters will be.

B) Water consumption for wet processing was two to three times that required for dry processing.

They concluded that the widespread adoption of dry transporting techniques as opposed to fuming would save water and reduce wastes.

Frozen Fish. A research team (4) predicted that five process changes could prevent 250,000 lb. BOD_5 per year and eliminate the need for 15 million gallons of potable water annually. Initial costs to implement the changes would be $300,000. Annual costs would be about $300,000 per year with annual net savings approaching $900,000.

Shrimp Processing. The wastewater from most breaded seafood shrimp plants exceeds 2,000 mg/l of BOD_5. It often contains large amounts of organic matter, small particles of shrimp flesh, breading, soluble proteins and carbohydrates. Georgia researchers study how to reduce the pollutants and this was summarized (2).

Screening reduced the BOD_5 load from processing

Table 22. Comparison of Wet and Dry Line Groundfish Processing

Plant	Mean Wet Processing Load BOD_5 (lb/1,000 lb fish)	TSS	FOG	Mean Dry Processing Load BOD_5	TSS	FOG
1				5.7	2.4	1.0
2				2.7	1.6	0.75
3				1.3	0.98	0.13
4				5.0	1.0	1.0
5				7.9	22.5	
6	15.0	7.0	13.0			
7	18.0	34.0				
8	20.2	7.1				
9	18.8	12.0				
AVG.	18.0	15.0	13.0	4.5	5.6	0.72

operations by 38 percent, from 117 pounds to 72 lbs/ 1,000 lbs. of green, headless shrimp processed. The BOD5 load resulting from cleanup operations was decreased 53 percent, from 104 pounds to 49 pounds. The total BOD_5 load was reduced from 221 to 121 pounds per day. Thus screening decreased the total raw waste load at this plant by 45 percent.

Cleaning up production areas by dry methods before flushing them with water is another way to keep pollutants out of drains. Although screening had reduced waste loads greatly, plant managers and scientists wanted to see whether dry cleanup methods could cut the BOD_5 load even further.

The answer was yes! The waste load resulting from cleanup operations was reduced further from 49 pounds of BOD_5 per thousand pounds of shrimp processed to only 21 pounds, as the table shows. This decrease of 57 percent in cleanup load meant a further 13 percent decrease in overall BOD_5 load. Dry cleanup tips are presented in Table 24.

Before screening, the total BOD_5 load was high: 221 pounds per thousand pounds of shrimp processed. After the change to screening and dry cleanup, the total BOD_5 load dropped to only 92 lbs/ 1,000 lbs., a decrease of almost 60 percent.

Another study (15) of a shrimp canning plant found that an effective water and wastewater management program could result in a 60.1 percent reduction in BOD5 load. Further, the cost of such a program was estimated at 1.3 cents per pound BOD_5 as contracted with 65 cents for screening and 83 cents to $7.18 for DAF removal.

Table 23. Effect of Screening and Dry Cleanup on BOD5 Loads in a Shrimp Plant

Operation	Before	With Screening (lb BOD_5/1,000 lb shrimp)	With Dry Cleanup
Processing	117	72	71
Cleanup	104	49	21
Total	221	121	92

Table 24. TIPS FOR EFFECTIVE DRY CLEANUP

Collect any dripping batter by placing pans under breading tables.

Squeegee spilled batter into a pan from the floor so batter will not enter the drain during wet cleanup.

Empty batter tanks into barrels instead of pumping their contents into the drain.

Place trays under conveyor belts to catch particles of breading— a concentrated source of soluble and suspended BOD_5.

Place trays under machines to help keep breading off the floor.

Remove leftover breading from machines, such as sifters, by hand. Do not hose or air-gun so that it will not enter the drain.

Dry cleanup utensils should be cleaned and stored separately from regular wet cleanup gear.

Use a stiff broom to sweep breading from the floor. Scraping and then brushing is the only effective way to recover breading from under equipment.

Place salvaged breading in barrels so it can be given or sold for animal feeding; it is a good source of carbohydrates and energy.

Remove shrimp hulls by dry cleanup whenever possible. When left in contact with water, enzyme action turns them into a major source of pollution.

Install a hydro-sieve to remove any shrimp hulls and particles that enter the floor drains during wet cleanup. Collect material in a dumpster and dispose of it in an approved manner.

Look for opportunities to make use of waste materials. Sieved wastes containing shrimp hulls, breading and other particulate wastes can be rendered into meal for animal food if enough can be collected.

***REMEMBER: Keep breading off the floor and out of drains!

What Can You Do?

If you're the manager of a firm, you may have an opportunity to reduce wastes and save money. Reducing water use and waste load now could save you that much money next year. If water and sewer costs increase tenfold over the next decade, you may be able to save many dollars annually by 1998. Here are some suggestions to help you conserve:

- Ensure that plant managers measure water use daily or at each shift change.
- Emphasize to personnel at all levels that conserving water and reducing waste load are sound business practices.
- Appoint someone in each plant to be responsible for water conservation and waste reduction practices and for monitoring their effectiveness.
- Provide a training program for your managers and employees.
- Show your interest and example that you take water conservation and waste reduction seriously. Helping your personnel develop the proper attitude is 90 percent of the battle. It starts at the top.

DIRECT DISCHARGE

After you have implemented effective controls, direct discharge has been suggested as possible by some researchers and not possible by others. In fact, such determinations probably must be made on a site-specific basis. Current EPA requirements mandate screening, but various states and EPA offices seem to reach different conclusions in regard to specific requirements for seafood processors.

Researchers (17) studying the discharge from the tuna processors on Terminal Island, Cal,, noted that the processor's discharges enhanced the food chain. The researchers concluded that energy-rich effluents should be utilized by developing alternative methods for waste management and new regulatory concepts rather than imposing traditional secondary treatment.

Environment Canada researchers (13) concluded that all major effluents associated with fish processing are of sufficient strength to require some type of treatment. In the majority of cases, the removal of solids is adequate treatment to protect the receiving environment. This will prevent a buildup of sludge around the effluent outfall with its consequent effect on dissolved oxygen. Following screening the effluent should be discharged through an out fall that allows sufficient tidal flushing action to dilute the remaining effluent and thus minimize pollution problems.

Georgia researchers (18) studied the flushing of shrimp heads from the coastal waters surrounding Brunswick Harbor. They concluded that shrimp heads were flushed away from the areas where they were deposited within two to four days.

CONCLUSION

Aquatic products processing environmental issues will be prominent in the 1990s. Management must plan now to comply with new environmental regulations and to minimize costs and ensure the delivery of safe, nutritious fishery products to the consumer.

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Appendix A. Environment Canada Data

Environment Canada (13) have provided the fish processing industry with characterization and treatability data on their effluents. Although there is variation in the effluent loadings determined for each type of effluent, characterization results are summarized in Table 25.

Table 25. Summary of Environment Canada Characterization Data (Averages)

Fish Processed	BOD5 (lbs/1,000 lbs raw product)	Suspended solids (lbs/1,000 lbs raw product)
Groundfish Filleting		
a) Dry line	4.5	1.5
b) Wet line	18.0	15.0
Salmon Processing	28.2	19.7
Herring		
a) Filleting	22.0	21.0
b) Marinated	215.0	85.0
Shellfish		
a) Lobster	25.0	5.5
b) Crab	40.0	20.0
Freshwater fish		
a) Combined perch and smelt	4.5	2.3

Have you ever thought of the wastes that go down the drain in your plant as potential sources of profit? Many food processors have saved money by cutting water use and reducing the amount of waste material that finds its way into the sewer system. The result? Savings in water costs and sewer charges...and sometimes additional income from sale of recovered products and byproducts.

Why Worry About Waste Discharges

Every year seafood processing plants discharge millions of gallons of wastewater. As the industry continues to grow, so will the volume of water used, the amount of wastewater discharged and the waste load unless we take action now.

At the same time, processors will face increasing water costs, rising sewer charges and tighter restrictions on waste load parameters such as BOD5. Some plants will be faced with the possibility of a shutdown if they cannot meet legal restrictions, cope with limited water supply or meet increased costs for water and sewer service.

WHAT YOU CAN DO:

Here are some steps you can take to help avoid water and waste treatment problems in the future:

- Conserve water; every drop of water that goes down the drain becomes wastewater that must be treated.
- Reuse water whenever it's practical and permitted.
- Take steps to reduce loss of product during processing.
- Recover lost product and reuse this material whenever you can.
- If materials can't be reused, collect them for sale as salvage or animal feed.
- Don't let employees use hoses as "brooms" to sweep waste products into the drain. Use dry cleanup methods whenever possible.
- Emphasize to employees at all levels that conserving water and preventing pollution is important and does pay ... for everyone.

POLLUTION PREVENTION PAYS

For seafood processors...

- By reducing disposal and discharge costs
- By cutting production costs
- By reducing the cost of complying with regulations
- By producing income from the sale or reuse of recovered waste materials

For local governments...

- By reducing wastewater treatment costs
- By increasing capacity for industrial growth
- By lessening capital expenses for landfills and waste treatment plants
- By reducing enforcement costs

For citizens...

- By reducing risks to public health and environmental quality
- By improving the quality of community life
- By making business and industry more accountable

About Pollution Prevention

Pollution Prevention encourages innovative approaches to preventing industrial pollution. Instead of spending valuable resources on treating wastes, companies are encouraged to prevent waste materials from going down the drain—thus turning a liability into a potential asset.

Waste Reduction in Food Processing — A People Management Issue

Stephanie Richardson, Manager
North Carolina Pollution Prevention Program

The traditional approach to waste management in the food processing industry has been end-of-pipe treatment. With more stringent environmental regulations, ever-increasing waste treatment and disposal costs, and more intense public scrutiny, food processors have been forced to examine other management avenues.

The first step to any management program is to quantify the problem. In food processing, wastes are broken into two basic categories: direct and indirect. Direct wastes that are found in dumpsters and inedible containers can be further broken into intentional and unintentional wastes.

Unintentional wastes and indirect wastes (sludge) are those wastes that can be reduced with proper operation, maintenance and cleanup practices. These wastes, however, are often not considered wastes by plant employees. Therefore "proper" operation and cleanup practices may have different definitions to the management and the plant worker.

Through employee training programs and an active "people management" or involvement program, these wastes can be significantly reduced. Examples and results will be presented to prove the effectiveness of the people management approach to waste reduction.

The food processing industry is extremely diverse. The diversity of the industry is not only apparent by its vast array of final products but also by the waste it generates (3). Food processing waste is not considered to be a health hazard; however, the quantities generated can be formidable. Even the smallest seasonal food processing plant can have waste loads equivalent to a population of 15,000 to 25,000 people (3). Sludge generation from process wastewater treatment coupled with solid waste generation occurring during product handling and processing can result in wastes that are difficult and expensive to handle.

TYPES OF WASTE

An understanding of what a waste is and how and where it originates is required before an effective waste reduction plan can be implemented. In the food processing industry, there are direct and indirect wastes.

Direct

Direct wastes are wastes that can be accounted for in the dumpsters or inedible bins. These wastes occur as raw materials are stored, transferred or processed and can be classified as intentional or unintentional. Intentional wastes are expected wastes such as peelings and pits from vegetable processing, blood and bones from meat processing, bread and dough from bakeries and process wash-down water from all processes.

Unintentional wastes are those wastes resulting from poor inventory control, improper employee management and improper maintenance. Some examples include losses due to: spoilage while in storage, improper handling/transfer, improperly maintained production equipment and improperly supervised cleanup activities. Direct waste, whether intentional or unintentional, is comprised of lost raw ingredients and semi-processed or fully processed product.

Indirect

Direct waste lost down the process drains results in the creation of the indirect waste, sludge. Sludge is the solid waste produced from the treatment of process wastewater.

Sludge generation is dependent on the type of food being processed, type of wastewater treatment employed and amount of food lost into the drains. Sludge generation from the seasonal plant referenced in the introduction could range from 1,200 to 5,200 pounds/day (5).

Food products lost to the drains can be directly related to elevated levels of biochemical oxygen demand (BOD), total suspended solids (TSS) and fats, oils and grease (FOG). For example one pound of BOD is equivalent to 0.89 pounds of fat, 1.03 pounds of protein and 0.65 pounds of carbohydrate (1).

APPROACHES TO REDUCTION OPPORTUNITIES

Inaccurate record keeping or lack of disposal problems may have lulled management into thinking waste loads are within acceptable limits. If management realized that most efficiently run wet food processing plants only lose 2 to 5 percent of input material, they may have a concept of the losses they are incurring.

Lack of corporate commitment is the one most formidable obstacles to waste reduction. Establishment of a clear, concise corporate policy regarding waste reduction is therefore imperative (4). Employees can sense the true level of corporate commitment and will rise or fall to the level that is expected or allowed.

The next step toward waste reduction taken by many industries is a waste audit. This approach can be lengthy but results in detailed information being compiled on each waste stream and on available, economical waste reduction solutions. The solutions may include process modification, chemical/ingredient substitution, on-site or off-site recovery, reuse and recycle systems to name a few.

The food industry is unique in that the simple, low technology approaches of employee involvement and training about dry cleanup activities can have a dramatic effect on waste production. The basic concept of dry cleanup is to teach employees to treat their work area as they would their own kitchen.

Observation and Inquiry

The basic approach begins with observing work activities and asking questions. During the observation phase, it is often useful to video activities of each shift and each job. Video tapes can serve two purposes. The first is to help identify wasteful activities. Current accepted processes or cleanup activities may not appear as acceptable when viewed away from the process line. The second purpose is as an initial training tool for employees and later as a tool by which to judge progress.

It is best if each shift can be observed on more than one occasion. This will help to distinguish daily practices from infrequent or occasional practices. It will also provide an opportunity to question employees about the rationale behind wasteful activities.

Training

Training and employee involvement are interactive and cannot be separated. Employees are usually willing participants in a waste reduction plan once they realize what waste is and how their work practices can directly affect the environment, the plant profitability and ultimately their job security. Training is multifaceted and should be job specific. First, begin an education program. This program should include an explanation of what waste is (food as waste), its sources, and its effect on the public's perception of the plant and its product, the environment and plant profitability.

The second area involves "retraining" employees to correct wasteful methods. This may take close attention if the "Susie teaches Sallie" initial employee training method was used. The practice of only allowing line people to train new employees may have resulted in wasteful practices being taught to the new employee.

During the retraining segment, employees should be introduced to dry cleanup methodologies that are found in Table 1. Training should not to damage the employees' self-respect. Emphasis should be placed on new, better approaches to processing and cleaning for management and line personnel alike. Training should emphasize keeping food ingredients out of the drain.

Table 1. Dry Cleanup Activities

- Keep food ingredients/products off floors and out of drains.
- Use brooms/vacuums to remove dry spills from floors/ equipment.
- Use brushes to clean equipment and collect "brushed off" waste.
- Use squeegees, shovels or vacuums to remove liquid or semi-liquid ingredients/product from floors and equipment.
- Provide inedible bins/containers for all dry and liquid wastes.
- Squeegee out all vats and mixers prior to introducing water.
- Assure all lines/pumps are completely empty prior to cleaning.
- Never use hoses as brooms.
- Equip all hoses with high-pressure, low-volume, automatic shut-off nozzles and place flow restrictors on faucets.
- Use minimum allowable amounts of detergents/ disinfectants.
- Keep brooms, vacuums, shovels, squeegees and inedible bins accessible.

Related Activities

- Provide collection pans for drips/leaks until repairs are made.
- Provide screens for all floor drains.
- Never overfill vats or mixers.
- Never dump off-spec or excess product down the drain.
- Keep liquid and solid waste separate.
- Examine handling/transport procedures that result in spillage.
- Examine inventory control to assure spoilage is not occurring.
- Never leave faucets/hoses running.
- Evaluate all disinfectants/cleaners for BOD loading.

Corporate commitment to a reduction program should be apparent at training sessions. This can be accomplished by having representatives of top management at all training sessions. Management's responsibilities are listed in Table 2.

Table 2. Management Responsibilities

- Listen to employees.
- Establish a routine, preventative maintenance program.
- Assure prompt corrective action when waste is reported.
- Work with employees to design dry cleanup equipment as needed.
- Regularly tour the plant and talk with employees about waste.
- Provide recognition programs and follow-up training.
- Establish markets for process "wastes."
- Examine all reuse/recycle options.
- Schedule production to reduce required cleanup.
- Display/present progress reports to employees.
- Work toward non-process/office waste reduction.

The final area of training should include how to recognize waste streams and wasteful activities. Once identified, there should be a structure for taking actions to eliminate the waste.

At this point, the program can move ahead in a positive manner or fail. Lack of a follow-through structure will send a clear signal to employees that corporate commitment is limited.

Involvement

The structure that keeps employees involved by allowing reporting of wastes and observing actions taken to stop that waste is critical. Many food processing firms have discovered that the best follow-up to employee training is an employee suggestion/awards program. Such programs keep enthusiasm high, generate pride, cost little and offer large paybacks to the company.

One such program, People Against Waste (PAW), was created by Maola Milk and Ice Cream Co. in New Bern, N.C. This program is designed to involve employees in the waste reduction program and encourage them to search for waste sources.

The success of this program hinges on the prompt, detailed response sent to each employee submitting a waste reduction suggestion. No suggestion is considered too small for a response. This personal response is coupled with a visible award, a PAW lollipop, and the employee being recognized in a newsletter.

At the end of the month, top ideas receive additional recognition and awards, such as a percentage of the cost savings from the waste reduction, gift certificates for steak dinners or PAW caps. This program has been in effect approximately 18 months and has only cost $3,000. Savings resulting from PAW suggestions have more than paid for the program and are included in savings shown below in the dairy products example.

EXAMPLES

Employee training coupled with the dry cleanup approach appears simplistic — merely the use of good common sense. But, as the old cliche states, "the proof is in the pudding."

Breaded Meat

The Equity Group in Reidsville, N.C., manufactures 2.5 million chicken nuggets each day. Deboned chicken meat is blended, formed, battered, breaded, fried and frozen. Due to a combination of poor maintenance and cleanup procedures, an average of 55 pounds of meat, three pounds of tempura and 15 pounds of dry batter per line was lost to the sewer each shift (6). Additionally, over 4,000 pounds of waste per shift was landfilled.

In 1988 by improving maintenance, training employees and establishing markets for waste, 30 tons per week of solids (scrap, inedible product) that was going to the landfill, along with another 20 tons per week lost into the drains, is now being used as animal feed or being shipped to renderers (6). Additionally, BOD levels in wastewater were reduced 2,200 pounds/day. This translates to a sludge reduction of 120,000 to 402,000 pounds of sludge per year (5, 6).

These activities, though impressive, did not lower effluent characteristics enough to generate compliance with permit limits. And upgrade of the existing pretreatment facility did not help either. It was determined that additional employee training and involvement would be required.

In October 1989, each employee went through additional training. Each shift was divided in half. These smaller, more manageable groups reported to an in-plant conference room where they received training as to what waste was, where it came from, how it affected the environment and how its cost affected job stability. Most employees had not, until that time, thought of product or food as waste. They were further trained in dry cleanup procedures and water efficient work activities.

Training was conducted using language and terminologies consistent with the workers educational level. Additionally, a slide presentation was made depicting actual scenes from the work floor. This proved effective as employees were amazed at the waste that they saw.

This training was presented to all employees with slight modifications being made for maintenance and cleanup. Supervisors and management were also trained and instructed as to their role in the waste reduction plan. This training emphasized those points covered in Table 2.

The training resulted in an enthusiastic, cooperative work force. Waste loads showed marked reductions with TSS and BOD levels being reduced from the 2,500 mg/l range to the 300 mg/l range. This translates into a savings of more than $10,000/month in sewer surcharges.

The program, which continues as the Waste Awareness Program, was implemented in January 1990. This program keeps waste in the forefront of daily operations as well as implementing programs with specific purposes such as a water reduction program.

This is an on-going program. Like any similar program (example - safety), it will ebb and flow, but, with proper involvement and emphasis, it will always be a positive presence.

Dairy Products

Maola Milk & Ice Cream of New Bern, N.C., simultaneously implemented several waste reduction programs ranging from a milk loss prevention program (employee training/record keeping/improved maintenance) to process modifications. Reductions attributed to employee training and improved record keeping total 5,000 gallons/day of milk for a total annual BOD savings of 130,000 pounds (2). This could easily translate to a reduction in wastewater treatment sludge production of 19,500 to 65,000 pounds (5). This was equivalent to $210,000 net annual savings in sewer surcharges and product savings.

Additional BOD reduction due to process modification totalled 190,000 pounds/year for a potential sludge reduction of 28,500 to 95,000 pounds/year (2, 5). Annual associated cost savings for process modifications were $92,050.

PAW has been enthusiastically received by Maola employees. Established in April 1988 for the home office/plant, it has recently been expanded to all the branches.

Awards given include PAW of the Month, Outstanding PAW, PAW Stars, PAW Plus, Most Considerate PAW and Persistent PAW. All suggestions receive a written response and often involve the employee in formulating the corrective action.

Some examples of PAW suggestions include:
- A chiller water line that drained into a floor drain without chilling anything.
- Branches not properly rotating product, resulting in losses.
- A change in milk case bands that resulted in difficulty in handling and additional case warping which resulted in case jam-ups.
- Ice cream cup samples used in the laboratory were being put down the drain instead of inedible bins.
- Wasteful activities regarding computer printouts.

The PAW program with its PAW punch and cake ceremonies is just another of the many unique and fun programs that Maola has used to address a problem. Previous programs included Coli Busters to deal with bacteria problems and Pig Palace to deal with excessive product returns. All these "people management" programs have been successful because they involved the employees, were visible, and were not allowed to stagnate.

Snack Food

Bahlsen of America Inc. in Cary, N.C., produced over 5.5 million pounds of snack food during the first three weeks of August 1988. This corresponded to implementation of dry cleanup and recovery/reuse operations. During this period, 66,000 pounds of crackers were reworked into dough with an additional 209,000 pounds used in peanut butter. Another 132,000 pounds of second line products were recovered for sale in outlet stores. Recovered inedible waste totalled 803,000 pounds and was sold as animal feed for 2 to 4 cents/pound. Recovered products, both edible and inedible, had previously been landfilled. Due to the infancy of the program, effects on wastewater have not yet been calculated.

CONCLUSION

Waste reduction for food processors can be as simple as dry cleanup. Establishing markets for waste can result in new profit sources with wastes being reclassified as byproducts. This simple approach begins with employee training; therefore, waste reduction in food processing is first and foremost a people management issue.

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Waste Audit — A Self-Help Approach to Waste Reduction

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The reactionary approach to pollution—treatment and disposal—has been used for years. We are painfully aware that this attempt to control pollution is not now and never has been effective. It was not until enforcement of stricter environmental regulations that the realization became apparent that treating pollution merely moved pollutants from one media to another, and, that the only realistic approach was to prevent or reduce waste at its source.

Source reduction where possible, coupled with recovery, reuse and recycling of wastes that cannot be stopped, results in pollution prevention. Before this prevention can take place there must be a thorough understanding of what a waste is, where it comes from, what process practices create it and what technologies are available to eliminate it.

A waste audit can provide such an understanding. The six simple audit steps can help identify the types, sources and quantities of wastes being generated.(4) Additionally, it can pinpoint the practices and procedures that are resulting in waste generation. The final steps help to analyze the most cost-effective solution while providing the necessary waste management training to employees.

With more stringent limits being placed on industrial dischargers, the once simple biological treatment of food processing waste is becoming a major expense. Facing ever-increasing treatment costs, yet having the desire to remain a good corporate neighbor, has forced the industry to investigate alternate technologies for the elimination of waste.

One such technology is the concept of pollution prevention and source reduction. This concept forces the re-evaluation of operating procedures and re-education regarding "waste" streams. Recovery, reuse or sale of "waste" has in some cases resulted in new profit sources. The first best step to this technology, and ultimately total waste management, is a waste audit.

DEFINITION

A waste audit can be considered as a first step, self-help process for determining the practices, procedures and operating parameters that result in high waste loads, excess water usage, environmental non-compliance and reduced profitability.(3) An audit provides the basis for collection and evaluation of technical and economical data necessary to select appropriate waste reduction techniques.(1) By identifying sources, quantities and general types of waste, appropriate technology can be applied that will allow source reduction and/or recovery of lost product. This can have short and long-term positive economic and environmental effects.

Benefits of Audits

A waste audit can result in cost savings through reduced loss of raw ingredients or products, reduced treatment costs and reduced environmental fines or surcharges. Additionally, new profit sources can be found through recovery of "waste" for reuse either within the plant or elsewhere.

All food processors know the importance of being perceived as a good corporate neighbor. An intangible but very real benefit of a waste audit is the elimination or prevention of bad publicity due to environmental non-compliance. Perception of the product is more important in the food industry than in any other industry. Therefore, a plant with products and byproducts (not wastes) that has a good environmental policy and record will be perceived as having good and healthy products.

STEPS OF AN AUDIT

There are six basic steps in a waste audit. When followed and combined with an employee training program, these steps can lead to a more efficient and profitable facility.

Step 1 — Corporate Commitment.

The first step to a successful waste audit and ultimately a waste management plan is corporate commitment. The establishment of a clear, concise corporate commitment is imperative. Lack of corporate commitment is one of the most formidable opponents of waste reduction and proper waste management. Management's full commitment of time, personnel and financing is required if an effective program is to succeed.(4)

A detailed written corporate policy regarding waste reduction should be established. Such a policy should not only outline policies and procedures for dealing with waste but should also detail corporate and personnel responsibilities for all waste-related activities. Employees can sense the true degree of commitment set forth at the corporate level and will rise to or fall to whatever level is expected or allowed.

Step 2 — Team Selection

After establishing a written corporate policy and distributing it to all managers and supervisors, an audit team should be selected. A waste audit can be performed by a single person, an in-house team of employees or a team of hired consultants.

The team approach is preferable as it allows input from persons with a variety of perspectives and a broader knowledge base. Suggested team members are shown in Table 1. Team members should be treated as equals with all ideas and concerns being heard and evaluated for merit. The different areas of expertise represented by each team member will produce differing areas and levels of concern. Remember, management is not always aware of or familiar with daily operations and concerns of the process line or cleanup crews. The team leader should be technically competent and comfortable with the job. This comfort results from the knowledge that he has been given the authority to get the job done.(2)

Step 3 — Gather Background Data.

To understand the hows and whys of waste generation, a thorough understanding of the facility is required. This understanding can come from assemblage of all available background data.

There are four basic types of data that should be collected: production/process information, waste stream information, economic information and general information. Some sources of this information are listed in Table 2.(2)

For a more complete understanding of the facility and to construct a flow diagram (Step #4), assemble background data in tabular form as it is collected. This allows for easy transfer to the flow diagram and serves as a useful reference for future activities. An example is the listing, in tabular form, of each unit process with a functional description and associated inputs, outputs and waste streams. This listing should include, in addition to major equipment, all ancillary processes. Even though they may not have a direct effect on processing, they can have a direct effect on the waste stream (example, cooling tower discharges). Another example of information useful in tabular form is the route of raw material from purchasing through each process to shipment of final product.(4)

Step 4 — Flow Diagram and Plant Survey.

Based on the gathered background data, a detailed flow diagram of the plant should be constructed. This will put the information in a visual, usable form. All inputs and outputs should be identified as to the source, quantity, type and concentration.

All waste streams — liquid, solid, air — should be distinguished from product line. Cleaning/dumping and makeup activities should be noted along with any recovery/recycle/reuse efforts.

The background information, tabular information and labeled flow diagram will help identify any data conflicts, problem areas and needed monitoring locations. It will further identify wastes that are expensive to dispose of, are generated from expensive raw materials or are causing handling or discharge problems.(3) Using this information, conduct an actual in-plant survey. This survey is designed to verify existing data, find missing data and look for additional waste streams.

To understand problems faced by the facility, a complete knowledge of each unit process along with the interaction with other processes, is required. The tabular data compiled earlier on each unit process will be of help during this phase.

If detailed data is not available on waste streams or water usage or if new waste streams are identified during the survey, then sampling/monitoring should be conducted. Sampling/monitoring should be conducted over a period of time to assure accurate, representative samples. If a variety of products is run, separate sampling programs should be performed for each product. Water usage should be monitored to determine usage by shift and/or product. Data collected here can be added to the flow diagram and extrapolated to monthly or yearly figures.

In addition to collecting samples, it is important to observe all processes and cleanup operations from material receiving through product shipping. All shifts and activities should be observed on more than one occasion. The use of video cameras is also recommended. Video provides a useful reference that can be used as a training tool. By observing these process cleanup activities and talking with line personnel, obvious waste-generating practices, such as dumping bad batches into floor drains, may become apparent. Table 3 provides examples of information that can be obtained from an in-plant survey, and Table 4 lists some types of questions that should be asked and answered.(2,5)

Step 5 — Materials Balance.

Upon completion of the in-plant survey, all data should be reviewed and updated for accuracy and completeness. At this point, the following information should be available for each waste stream:

- point of origin
- current handling/treatment/disposal
- physical/chemical characteristics
- quantity generated
- rate of generation (lb/unit product)
- variations in generation rate
- potential for contamination or upset
- cost to manage (4)

With all collected data, in-plant survey information and results of monitoring/sampling, the materials balance can be performed. There are two basic balances performed, process-by-process and overall plant. It should be pointed out that these balances are mass quantities, i.e. basically what goes in minus what comes out equals waste generation.

The process-by-process balance should pinpoint areas of greatest waste generation and water usage. These areas/processes translate to points with the greatest potential for reduced water use, waste reduction potential, waste elimination potential and/or recover/reuse/recycle opportunities.

The second materials balance, the overall plant balance, considers activities not necessarily associated with a single unit process. Some areas to consider in this balance include but are not limited to:

- discharges to floor drains
- discharges to storm drains
- bypasses
- cleaners/disinfectants and biocides used
- operational, cleanup, maintenance procedures
- effects of outside personnel (delivery people and vehicles).(4)

These two balances will pinpoint obvious and obscure areas of waste and pollution generation.

Step #6. Evaluation of Reduction Alternatives.

The exact procedure used to identify, evaluate and select applicable reduction technologies will depend on the complexity of the plant and quantity and variety of wastes generated. Successful approaches have ranged from simple group discussions and manual evaluations by team members to complex and sophisticated computer modeling techniques. Approaches taken should contain the same basic four steps:

1. List all waste streams.
2. Identify potential waste reduction techniques for each stream (i.e. brainstorm).
3. Evaluate all technical, economic and regulatory (FDA) aspects of each technique.
4. Based on life cycle costs, select the most cost-effective reduction techniques.(2)

All ideas generated during step 2 should be considered. Often times the simplest or most far-fetched suggestions can have the most positive impact.

In addition to process evaluations for specific waste streams, overall facility-wide reduction plans should be formulated. The facility-wide plans can include such items as:

- recycling programs,
- material inventory/handling,
- maintenance/operating procedures,
- cleanup practices.

Upon identifying possible alternatives for consideration, an engineering (technical) and financial evaluation should be performed. The most cost-effective alternatives — technically and financially sound — based on life cycle costs should be selected for implementation. Technical feasibility evaluations should include consultations with all regulatory and health/safety agencies, effect on product, applicability, reliability, O & M requirements, ease of implementation, and waste reduction potential.(2)

Another part of the technical evaluation is the consideration of liability, both for the individual and company as a whole.

In addition to the technical analysis, a financial feasibility analysis must be performed. By using a life cycle cost analysis, a payback period can be calculated. All cost analysis should include capital expenditures and O & M costs and should be weighed against treatment and disposal costs. All costs associated with the alternative should be considered such as: initial cost, replacement cost, energy cost, chemical cost, operations cost, etc. These costs should be weighed against the obvious treatment and disposal cost, and not so obvious costs such as loss of raw material, loss of product, liability for waste generated, ever-changing and more complex environmental reporting requirements, more stringent environmental limits, public perception, actual treatment costs, tipping fees and personal, civil and criminal liability.

Once the complete technical and financial picture is complete, it will become apparent which alternatives can be implemented immediately and which will become long-range goals for an ongoing waste reduction plan. The alternatives which can be implemented immediately should provide the "breathing room" required for a more detailed engineering and administrative approach to the long-term alternatives.

IMPLEMENTATION/EMPLOYEE TRAINING/FOLLOW-UP

Implementation

The actual waste audit is now complete. Waste reduction alternatives have been selected. Establishing an implementation schedule is the first step that must be taken. The written corporate policy should have designated an employee responsible for setting a realistic implementation schedule, assuring the schedule is being met, assuring that there is no backsliding toward wasteful practices, and assuring environment compliance. This employee should be a champion, a true believer in waste reduction.

This schedule can serve three major purposes. The first is to allow tracking of the progress. The second is to keep the issue of waste reduction in the forefront of the company's daily activities. The third is a demonstration of "good faith" if there are current non-compliance or public relations problems associated with the facility.

Employee Training

The first alternative that should be implemented is an employee training program on dry cleanup procedures. Training programs should be process specific and activity specific and should outline expectations for all employees from management to cleanup. All employees should be included and involved. The importance of the training programs should be made apparent to the process line and cleanup personnel. Often this can be achieved by having upper management attend all training sessions.

Training sessions should be positive. Emphasis should be on a better approach. Most employees become willing, enthusiastic participants in a waste reduction program once they realize what a waste is and that their activities can have a positive effect on the environment, plant profitability and their own job security. Training programs should be repeated on a regular basis and should allow for input and questions by employees.

Training should emphasize keeping food stuffs off the floor and out of the drain by using broom and vacuums, not overfilling vats, not dumping leftover or off-spec product and not using hoses as brooms. Dry cleanup tools (brooms, shovels, vacuums) should be placed in areas offering easy access.

Follow-Up

There are two types of follow-up — employee related and waste related. Many food processing firms have discovered that the best follow-up to ongoing employee training is an employee suggestion/awards program. Such programs keep enthusiasm high, generate pride, cost little and offer large paybacks to the company.

One such program, People Against Waste (PAW), was created by Maola Milk and Ice Cream in New Bern, N.C. This program is designed to involve employees in the waste reduction program and encourage them to search for waste sources.

The success of this program hinges on the prompt and detailed response sent to each employee submitting a waste reduction suggestion. No suggestion is considered too small for response. This personal response is coupled with a visible reward, a PAW lollipop, and the employee being recognized in a newsletter.

At the end of the month, top ideas receive additional recognition and rewards ranging from money to steak dinner gift certificates to PAW caps. The awards increase for the best (most significant waste reduction) suggestions received during the year.

The keys to a program of this type being successful are having a champion for the cause of waste reduction and prompting detailed response to all suggestions. Remember, each employee, depending on his duties, will have different areas and levels of concern.

The second area of follow-up is waste related. Initial data obtained during the audit can serve as a baseline from which improvement can be measured. An ongoing waste sampling, water use monitoring program should be established.

Monitoring/sampling results can be evaluated per process, per shift or per unit product to determine the progress that is being made as well as to identify areas that need additional attention or tend to backslide. Such data, when presented understandably, can go a long way toward boosting employee pride and enthusiasm. One such presentation is a large, obviously located graph depicting water use, waste loads to the sewer and/or solid waste generation. Such graphs are visual reminders of a job well done or that backsliding is occurring. Company-wide rewards can be offered for achieving present goals marked on the graphs.

CONCLUSION

The food industry is an extremely diverse industry having a wide variety of products with differing inputs, processing techniques and market uses. The diversity of the industry is not only apparent by the vast array of final products but also by the wastes it creates. Food processing wastes are not considered hazardous; however, the quantities produced are formidable.(1) Due to the ever-increasing cost of treating and disposing of wastes, it has become glaringly obvious that emphasis must shift from treatment to prevention.

Identifying waste streams and technologies for reducing or eliminating them is the purpose of a waste audit. Many have found, however, that the simplest approach to waste reduction, dry cleanup, is the most effective approach for the food industry.

Using a waste audit, any food plant should be able to pinpoint waste generation points and eliminate or reduce them. The result being less waste, more profit, less liability and an improved public image.

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Table 1: Suggested Audit Team Composition

Personnel from:

- management
- engineering
- QA/QC
- shipping/receiving
- budget/finance
- treatment/pretreatment
- maintenance
- process line
- cleanup crew

Table 2. Sources of Background Information (2)

Production Process

- Plant flow diagrams and plant blueprints (as built)
- Sewer locations - process/domestic/storm/city
- Purchasing and shipping records
- Material safety data sheets
- Operating manuals
- Water-use records (by shift and during down times)
- Potable water locations
- Production records/schedules

Waste Stream Information

- Manifests, annual reports and related RCRA information, SARA reporting data
- Environmental monitoring reports
- Environmental permits (solid waste, hazardous waste, NPDES, pretreatment, air emissions)
- Information on any regulatory violations•o Location of all waste collection/storage points
- Diagram of all waste treatment units with operating manuals
- Alternate waste disposal option (animal food, renderer, etc.)

Economic Information

- Water and sewer costs (including pretreatment or on-site treatment)
- Solid and hazardous waste management costs
- o Labor, energy and raw product cost
- o Waste management contracts/billings

General Information

- Current recovery/reuse/recycle practices
- Previous environmental audits
- Vendor information

Table 3. Examples of Information from In-plant Survey (2)

Area	Information
Material delivery and storage	• Material transfer and handling procedures • Storage procedures • Evidence of leaks or spills • Inventory of materials • Condition of pipes, pumps, tanks, valves and storage/delivery area
Production process	• Exact sources of all process waste • Waste flow/quantity and concentration • Operational procedures • Source, quantity and concentration of intermittent waste streams (i.e., cleaning, batch dumps, etc.) • Condition of all process equipment including tanks, pumps, pipes, valves, etc. • Evidence of leaks or spills • Maintenance procedures and schedule • Potential sources of leaks and spills
Waste Management	• Operational procedures for waste treatment units • Quantity and concentration of all treated wastes and residues • Waste handling procedures • Efficiency of waste treatment units • Waste stream mixing

Table 4. Questions to ask (5)

1. Receiving/Shipping

- Is improper inventory control resulting in raw material spoilage before processing or final product spoilage prior to shipping?
- Is raw material lost during transfer activities?
- Does a single supplier repeatedly send off-spec materials?

2. Process Line Operating Procedures and Equipment Maintenance

- Is there loss of product due to improper equipment fit, leaking lines, pumps, valves, etc.?
- Are there spillages resulting from overfilling or mixing?
- Are there collection barrels or tanks for off-spec product? How are bad batches handled? Are they dumped down the drain?
- Are there drip pans to catch product, juices, peels, pits, etc., and how are the collected materials disposed of?
- Are there carry-over losses such as entrainment losses from vacuum pumps?
- Are dry ingredients allowed to pile up or blow around the facility?
- Do all employees know how to correctly operate their equipment?
- Is product lost to freeze-on or burn-on?
- Is residual product left in lines, vats, mixers and washed into drains?

3. Clean-up Activities

o Is all unused or off-spec product collected (kept out of drain)?
o Are dry clean-up activities employed prior to wash down?
o Are high pressure hoses with automatic shut off valves used?
o Do all floor drains have screens?
o Have all detergents and disinfectants been evaluated for their waste load contribution? Are minimum amounts used?

4. Miscellaneous

o Have all possible recycle/reuse methods for water, liquids and solids been investigated?
o Have alternate uses for non-reusable/recyclable foodstuffs been examined?
o Are lights left on during the day?

Low Tech Waste Reduction - The Equity Story

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The food processing industry is very diverse. The diversity of the industry is apparent not only by the vast array of final products but also by the waste generated. Food processing waste, though not considered to be a health hazard, can be formidable in the quantities generated. Even the smallest seasonal plant is capable of producing waste loads equivalent to a population of 15,000 to 25,000 people. Sludge generated from process wastewater treatment coupled with solid waste generation occurring during product handling and processing can result in wastes that are difficult and expensive to handle.

The increased cost of end-of-pipe treatment technologies and solid waste disposal coupled with the negative public impact of environmental non-compliance has forced the food industry to investigate alternate approaches to their waste problem. The approach that has proven financially and technically feasible is waste reduction. The food industry, more than any other industry, is fortunate in that low technology waste reduction is effective in reducing waste generation, water usage and the associated costs.

This paper will present the steps that have proven effective in reducing waste generation in food processing. This information will be validated by documented results from the Equity Group, a producer of breaded chicken nuggets, located in Reidsville, N.C.

TYPES OF WASTE

Before an effective waste reduction program can be implemented, an understanding of what a waste is, and how and where it originates is required. In food processing, waste can be broken into two categories: direct and indirect.

Direct wastes are those wastes that can be accounted for in the dumpster or inedible bins. These wastes occur as raw ingredients are stored, transferred and processed. Direct waste can be classified as intentional and unintentional.

Intentional wastes are wastes that are expected, such as peelings and pits from vegetable processing, blood and bones from meat processing, bread and dough from bakeries and wash-down water from all processors. Unintentional wastes are those wastes resulting from poor inventory control, improper employee management and improper storage. Examples of unintentional wastes include losses attributable to spoilage while in storage, to improperly supervised cleanup and to improper equipment maintenance, etc. Direct wastes, whether intentional or unintentional, are comprised of lost product ingredients and semi- or fully processed product.

Indirect waste is a result of direct waste lost down the drain. Product or raw ingredients lost down the drain result in wastewater that must be treated which leads to the formation of sludge.

Sludge generation is dependent on the type of food being processed, the type of wastewater treatment used and the amount of food lost down the drain. There is a direct correlation to food lost down the drain and wastewater strength and therefore the resulting sludge generation. One pound of Biochemical Oxygen Demand (BOD), the pollutant measure most used by municipalities, is equivalent to 0.89 pounds of fat, 1.03 pounds of protein and 0.65 pounds of carbohydrate.

IDENTIFYING REDUCTION OPPORTUNITIES

Inaccurate record keeping of waste disposal and treatment costs or lack of disposal problems have lulled management into thinking waste loads and water usage are within acceptable limits. As management realizes that efficiently run wet processing plants should only lose 2 to 5 percent of input ingredients, they become aware of the losses they are incurring. This coupled with increased wastewater treatment and solid waste disposal costs as well as public scrutiny have forced management to reevaluate operational procedure.

The best and quickest approach to identifying waste reduction opportunities is by conducting a waste audit or waste assessment. This approach can be performed in house or by outside consultants. There are six basic steps to this process.

First and foremost is corporate commitment. Lack of corporate commitment is the most formidable obstacle to waste reduction. The establishment of a clear, concise corporate policy regarding waste is imperative. Employees have a sixth sense when it comes to the true level of corporate commitment, and they will rise to or fall to the level that is expected of them.

Step two is choosing a team to conduct the audit or assessment. It can be conducted by an outside firm; however, plant employees know the facility better than anyone. Audits/assessments can be conducted by an individual; however, a team approach with members from every department will provide a better insight and broader base to work from. There should be representation from management, shipping/receiving, QA/QC, maintenance, process line, cleanup engineering, etc., and they should all be treated as equals. Additionally, if there is "sister" plant, it may be advisable to have a representative from that plant involved. This allows someone who has knowledge of the process but isn't involved with it on a day-to-day basis to look at it with "fresh eyes." Often times daily procedures are taken for granted. Additionally, it will provide for input from someone who has no fears, imaginary or otherwise, of repercussions.

The third step involves gathering of background information. This includes all available information from the following areas: production/processing, waste management, economic/financial and general (vendor information, previous studies etc.). This data should provide some correlations between waste produced, water usage per unit process or production activities that result in significant waste generation. Further it should indicate if inventory control (spoilage) has been a problem in the past or if environmental non-compliance is chronic.

Assemblage of this data will result in a formidable collection of material that must be put in a usable form. In step four, which is divided into two parts, the information gathered is used to establish a flow chart which tracks ingredients from the receiving dock through processing to product or waste. A simple flow chart that shows each input and output per process directs the team toward opportunity areas as well as identifying data gaps. In the second part of step two, the team should go into the plant and observe all actual operations and perform any monitoring that is needed to fill data gaps. If there are questions about a process or procedure, the team members should be free to talk with the line workers. Asking "why" or "why not" about given activities often reveals reasons of "because we've always done it this way" or "because I was told to." Sound technical reasoning will be lacking when wasteful practices are discovered. Another response includes: "I told management about the problem (situation), and they did nothing about it so why should I care?"

Step five requires that you take information that was gleaned from the survey and insert it into the flow chart and perform a mass balance. As the term implies, this is a "mass" balance. The desire here is not to account for every microbe of ingredient, product or waste; instead it is to get a feel for the amount of incoming ingredients, the amount of finished product and the amount left as waste. There are two basic mass balances that should be performed. The first is process by process. This will pinpoint individual processes that are the most wasteful and water intensive. The second balance is an overall plant one. This will evaluate activities that are not specific to an individual process such as cleanup, batch dumping, etc. This balance often identifies areas where a change in employee attitude is required.

Now that all the information has been assembled and the areas of concern identified, it is time to move to the sixth and final step — alternatives evaluation. Technical and economic evaluations are performed to determine the feasibility of waste reduction options. These options could include such approaches as chemical substitution, processes modification, on-site recycling programs, off-site recycling programs etc.

For the food industry, one of the most effective approaches is training employees about waste: what is it, where it comes from and how it affects the environment and their job. It also helps to retrain them in proper dry cleanup activities. For all industries, employee training should be the first option implemented with other approaches to follow. Employees are the first line of defense. Without their involvement, any waste reduction plan is doomed to failure. Employee training programs, improved maintenance programs, water reduction programs, employee involvement programs are all vital ingredients in the low technology approach to waste reduction.

THE EQUITY STORY

The Equity story began in June 1987 and is ongoing. Equity Group, located in Reidsville, N.C., was producing approximately 2.5 million breaded chicken nuggets daily. The process involved the grinding and blending of high quality chicken meat and the formation of chicken nuggets, which were battered, breaded, rebattered, fried, frozen and packaged. The plant, which employed 275 people on two production shifts and one cleanup shift, operated five to six days a week. The operation used approximately 200,000 gallons of water daily and discharged wastewater with a daily BOD loading of 4,500 pounds. Even at these levels of discharge, it was not until the implementation of a new sewer-use ordinance, pretreatment limits and surcharge levels in June of 1987 that excess waste generation in the facility was recognized.

The Problem

The traditional approach to food processing was practiced by Equity. High production quality and sanitation standards translated into high water usage. Additionally, the requirements of the U.S. Department of Agriculture directing all production lines to be free of any meat accumulation while in operation were interpreted as requiring all equipment to be hosed down three times per shift. The result was a tenfold increase in water usage and waste production. Since discharge of waste materials had not presented a problem in the past, standard operating procedure was to flush waste food ingredients down the drain to the pretreatment plant. On an average, the per shift food loss to the drains was 55 pounds of chicken meat, three pounds of tempura and 15 pounds of dry batter per production line. There were 6 lines.

During this same period, Reidsville was fined for noncompliance with their wastewater discharge limits. Subsequent analysis revealed that the city's wastewater treatment plant was incapable of handling incoming wastewater at the loading levels that were being received. This resulted in a new sewer-use ordinance being adopted. The new ordinance established stringent pretreatment limits and heavy surcharge levels. Equity's BOD loadings were well above the established limits and were very costly.

Initial Response

Upon notification of the city's wastewater treatment problem, the new discharge limits and the increased surcharges for BOD, Equity took immediate action. A committee was formed and charged with the task of investigating all approaches to reducing waste loadings. The committee was chaired by the director of personnel who contacted the N.C. Pollution Prevention Program (PPP) and the Cooperative Extension Service. The director of personnel was a people-oriented person who had no preconceived ideas about what could and couldn't be done with regard to technical problems and waste treatment. His lack of preconceived ideas coupled with the employee trust proved to be very valuable assets.

Technical Assistance

In July and August of 1987, preliminary waste surveys were performed by PPP and extension specialists. At this point, the severity of the problem became apparent. A report outlining operational and cleanup procedures was submitted to Equity and a preliminary training program for selected managers and line supervisors was held.

This initial training program acquainted attendees with wastewater terminology as well as informed them of the difficulties that Equity was having with their wastewater discharge. Additionally, it pointed out that these wastewater problems were a result of hosing batter and meat into the drains and that a new policy of keeping the food off the floor and out of the drain would be implemented.

The traditional approach to waste problems taken by Equity had been pretreatment. Since waste reduction and pollution prevention was a new approach, they applied for and received a grant from PPP to establish and implement a waste reduction program.

Identification

After the preliminary survey and initial training program, managers and line supervisors were prepared when a more detailed water and waste survey was conducted. This survey consisted of observing and photographing processing and cleanup activities. Still camera shots and videos were taken. Additionally monitoring and testing was performed on water usage and waste generation by shift and during periodic points through the day.

This detailed survey revealed that solid waste such as fat, raw chicken bits, dry batter and processed nuggets were being washed down the drain. Liquid wastes included chicken blood and tempura batter. Additionally, the survey showed that over half of the waste load resulted from the cleanup.

Closer examination of the problem revealed that solid waste was being washed down the drain because there was no alternate disposal option and because there were no containment (catch pans) facilities to capture crumbs, flour, oil and other products lost during product transfer. It also became apparent that waste was being generated because of worn-out equipment, missing gaskets, misaligned conveyors, leaking valves and lines, and a general lack of routine maintenance.

The most serious problem was the lack of communication between management, the line workers, maintenance staff and the cleanup crew. The line workers were unaware that their actions could have a direct affect on wastewater problems. They had not been trained in dry cleanup practices. The maintenance approach was "if it ain't broke don't fix it." Cleanup functioned under the misconception that more water used in cleanup translated into a better job done.

Dry Cleanup

The dry cleanup approach took on two phases. The first portion was to provide containers for the collection and separation of solid and liquid waste. These containers included catch pans under equipment where product was lost during transfer as well as containers into which employees place dry waste that accumulated on their equipment or was on the floor. Catch pans were also emptied into these containers. With containers in place, supervisors instructed their employees as to proper dry cleanup methods. These involved removing ALL dry ingredients from the floor and equipment prior to cleaning with water. Any wet ingredients were collected separately from dry wastes. By 1988, this basic training had resulted in a 50 percent reduction of the BOD loading in the wastewater.

The effectiveness of dry cleanup was not only demonstrated in the BOD reduction but in the amount of solid waste that was being accumulated. The collected solid waste is mostly carbohydrate and protein based and is marketable. More than 5 million pounds per year are being sent off site for use as animal feed with the remaining being sent to be rendered. This resulted in approximately 30 ton/week of solid waste being removed from the landfill in 1988.

The quantity of solid waste generated, which was previously hidden in the wastewater, resulted in the evaluation of the processes. This evaluation focused on how chicken blending took place, the quantities of batter formulated and the way ingredients were being used. This approach was used to reduce the actual generation of the waste.

The Program Continues

Even though the grant from PPP ended in 1988, Equity's commitment to waste reduction continues. This is evident by their more recent efforts.

In October 1989 each and every employee at Equity was involved in an in-depth training program. Each shift was broken into half or thirds so that production could continue and group size be limited. Training was audience specific so that workers were intimidated or confused. Separate presentations were made to production line workers, cleanup crew, supervisors and management. A member of management attended each presentation to emphasize corporate commitment.

Employee training took place in the conference room using slides of actual plant activities. Employees were trained as to what a waste was, where it came from, how it affected the environment and how the increased sewer charges were affecting profitability and their jobs. All training was positive. Employees were not condemned for previously acceptable practices. Instead, the change in standards was explained. They also received training in dry cleanup and water-saving procedures. Employees were also asked what could be done to make their jobs easier and less wasteful, if there was any special equipment that would help or if they had any ideas on the subject.

Employees became enthusiastic participants in the waste reduction program. The effectiveness of this low cost, low technology approach is apparent by the reduction of wastewater pollutant loadings realized. In October 1989, total suspended solids and BOD loadings in the wastewater were in the 2,500 mg/l range. Following the training they dropped to the 300 mg/l range. This translated to a $10,000 per month sewer surcharge savings.

With enthusiasm about the environment high and employee concern at a peak, Equity decided to start an environmental employee involvement group. Thus the Waste Awareness Program (WAP) was begun in October 1989. The WAP committee is composed of workers from company departments and shifts. Employees are rotated on and off the committee periodically to ensure total employee involvement and maintain fresh approaches to the complex waste issues. Committee members receive patches to wear on their uniforms. The committee and its input has been effective as waste loadings have continued to decline.

Recently, Equity noticed that water usage had begun to increase slightly. Management was determined to nip this in the bud and implemented a water reduction program as part of the WAP. Additionally, new approaches to solid waste management have been tested utilizing equipment that had been removed from service. Initial results indicated that batter is a marketable commodity without the current handling requirements.

The Last Step

Even with a waste reduction program that is as active as the Equity WAP, most food processing plants need some form of pretreatment. The nature of their waste, totally organic, makes this a necessity. Equity is no different. They have invested money in upgrading their wastewater pretreatment facility which consists of an aeration basin, an air scrubber, a hydro-float system and a belt press. The solids residue produced by the pretreatment process is being sold to renderers.

The waste reduction approaches within the plant reduced loading to the pretreatment facility which has resulted in less energy required for aeration and reduced pretreatment costs.

SUMMARY

The director of personnel for Equity, Jim Waynick, was the key ingredient in the initial and ongoing success of their waste reduction program. His people management skills coupled with his lack of preconceived ideas made him a champion of the cause. Waynick recently compared waste reduction to alcoholism. He referred to it as "wasteaholism". As he so aptly put it "waste reduction is very much like alcoholism. First there is denial: 'No, I don't have a problem.' Then comes admitting there might be a problem: 'Well, maybe I have a problem, but it is not that bad. It would be easy to fix. The comes acceptance: 'Well yes, I do have a problem, and it is going to take some real effort to fix.'" Waynick continued the analogy by saying that like alcoholism you are never cured of wasteaholism. It is always an ongoing process. If you let you guard down wasteful practices will reoccur and will ruin any progress made.

Low technology approaches to waste reduction are very effective, but they do require a champion that believes it can work, corporate commitment, a change in attitude, and employee involvement. Each of these ingredients is critical to the success of a program. As Equity proved, it is not a one shot program; it must be an active, living program.

Remember start small, start simple, look for the basics. Low technology approaches to waste reduction are understood and accepted by the employee. Low technology approaches to waste reduction can be implemented by the employee. Since the first line of defense against waste is the employee, low technology approaches are the logical choice.

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