AP-42 Section 9.13.1
Reference 1
Report Sect.
Reference

Air Pollution Engineering Manual

AIR & WASTE MANAGEMENT
ASSOCIATION
SINCE 1907

Edited by
Anthony J. Buonicore
Wayne T. Davis

VNR VAN NOSTRAND REINHOLD
New York

This project has been funded in part by the United States Environmental Protection Agency under assistance agreement T901763 to the Air and Waste Management Association. The contents of this document do not necessarily reflect the views and policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

Library of Congress Catalog Card Number 91-46007
ISBN 0-442-00843-0

Manufactured in the United States of America

Published by Van Nostrand Reinhold
115 Fifth Avenue
New York, New York 10003

Chapman and Hall
2-6 Boundary Row
London, SE1 8HN, England

Thomas Nelson Australia
102 Dodds Street
South Melbourne 3205
Victoria, Australia

Nelson Canada
1120 Birchmount Road
Scarborough, Ontario M1K 5G4, Canada

16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1

Library of Congress Cataloging-in-Publication Data

Air pollution engineering manual / Air & Waste Management Association
; edited by Anthony J. Buonicore, Wayne Davis.
p. cm.
Includes bibliographical references and index.
ISBN 0-442-00843-0
1. Air—Pollution—Equipment and supplies. 2. Gases, Asphyxiating and poisonous—Environmental aspects. 3. Particles—Environmental aspects. I. Buonicore, Anthony J. II. Davis, Wayne T. III. Air & Waste Management Association.
TD889.A39 1992
628.5′3—dc20 91-46007
CIP

FISH PROCESSING

William H. Prokop, P.E.

The processing of fish is divided into two main categories. Freshly caught fish such as salmon and tuna are either frozen or canned for human consumption. The by-product material from these operations is processed by "fish meal plants," which are similar to the rendering plants for meat and poultry processing. The products from these plants are used for pet food and animal feed supplements.

At fish freezing plants, the fresh fish is filleted and the pieces trimmed to size and packaged for freezing, either in the raw state or after cooking. Fish canneries use one of the two basic processes: wet-fish and precooked fish.[1]

The wet-fish method is used to preserve salmon, mackerel, sardines, and similar species that are collected locally and are brought to the cannery quickly. The distinctive feature of the wet-fish process is the complete removal of heads, tails, and offal before cooking. The raw, trimmed fish are cooked directly in unsealed cans. These cans are drained of any liquid, and then sealed and pressure cooked before shipment.

The precooked process is used for larger species of fish such as tuna. Whole eviscerated fish are cooked in live-steam–heated chambers operated at about 5 psig pressure. After cooking, the flesh is cooled so that it becomes firm before further handling. Only about one third of the raw tuna weight is canned for humans and pets. The remaining skin, bone, offal, and other waste parts are processed in fish meal plants.

Since the odor emissions from plants that process fresh fish for human consumption and pet food are considerably less than those associated with fish meal plants, the remaining discussion is devoted to the fish meal process and associated odor problems.

PROCESS DESCRIPTION

The raw material for fish meal processing consists of the by-product waste material from fresh fish processing and also whole fish, such as menhaden, that are specifically caught for conversion to fish meal. In the fish meal process, three main product streams result from the raw material: fish solids known as fish meal, marine oil, and stickwater solubles concentrate. It requires slightly over 3 pounds of raw fish to produce 1 pound of product, including the meal, oil, and stickwater solubles.

Table 1 illustrates the production of fish meal, marine oil, and stickwater solubles in the United States.[2] The predominant fish being processed is menhaden, which accounts for nearly 80% of the total. Shellfish account for less than 5%.

Figure 1 provides a flow diagram of the wet reduction (rendering) process for a fish meal plant. As shown, the total operation includes the unloading of whole fish from fishing vessels into storage tanks or silos for a short time before the various processing stages of cooking and pressing take place.

Unloading of whole fish from boats is divided into dry and wet methods. Dry unloading methods include the use of a bucket elevator and conveyor, an air suction method that moves fish in a current of air, and a vacuum method employing a vacuum pump and a rotary valve to maintain a proper seal. Direct pumping without water is also possible to convey fish in a sealed pipeline. The wet unloading method uses a vacuum pump and water as the transporting medium to convey the fish from the boat to the plant. The water is separated at the plant and recycled back to the vessel for reuse.

The fish meal process typically is a continuous operating system. The following description is divided into two process phases, solids flow and liquid flow.[3,4]

TABLE 1. U.S. Production[a] of Fish Meal

Year	Fish Meal	Marine Oil	Stickwater Solubles
1986	680	267	219
1987	666	249	174
1988	644	225	224
1989	618	225	233
1990	577	282	186

[a]In million pounds.

Source: Reference 2.

Solids Flow

Cooking

Raw fish enter the cookers, which are horizontal cylindrical vessels equipped with steam-heated jackets and steam-heated screws with hollow flights. The cooking step coagulates the fish protein so that liquids and solids can be separated mechanically. Fat cells are also ruptured, releasing the oil into the liquid phase. A typical cooking process heats the fish for 10 to 15 minutes at 90°C.

Pressing

The cooked fish are conveyed to the press by an inclined screw conveyor with perforations for dewatering the cooked material. The purpose of pressing is to separate the liquid phase from the remaining solids in the cooked fish. Both continuous single- and twin-screw presses are used in the fish meal industry. The single-screw press is designed with a taper and exerts an increasing pressure on the cooked fish by reducing its volume as it passes through the press. A problem may be experienced with a single-screw press on soft fish, which can slip through the press without being

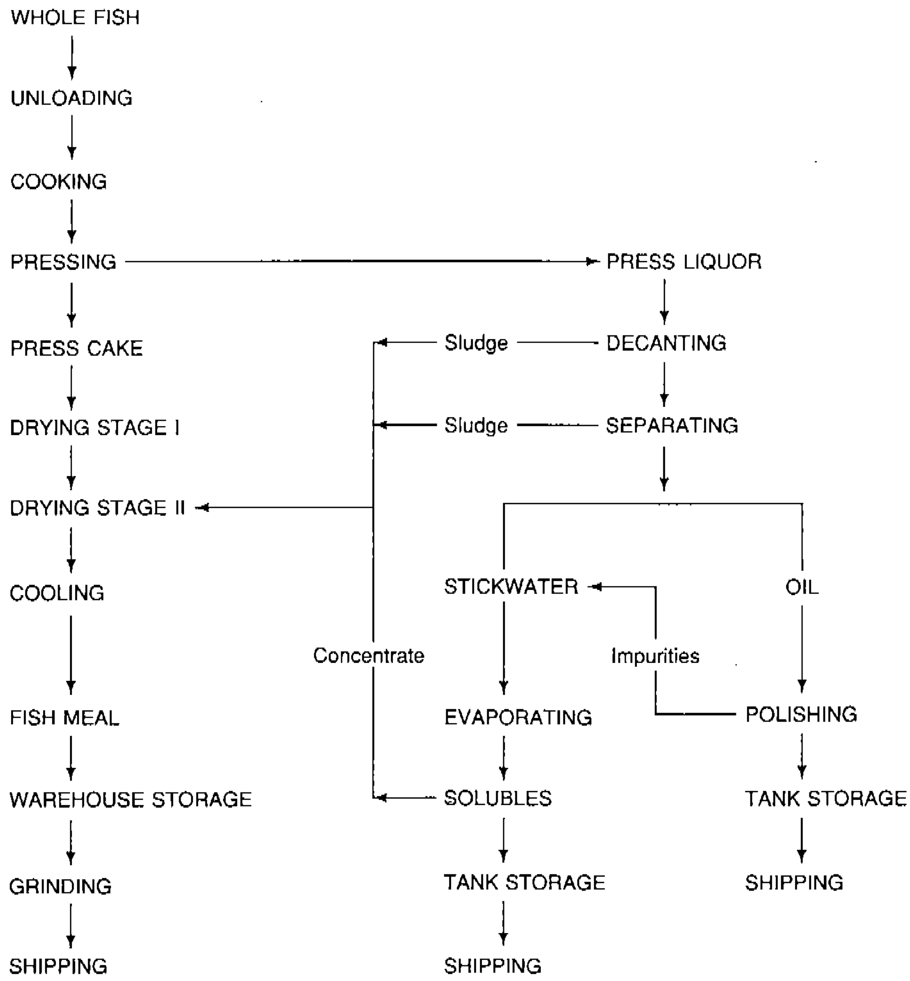

FIGURE 1. Typical Fish Meal Process

processed. This difficulty may be minimized by the use of a twin-screw press.

Drying

The pressed fish solids are then dried to produce fish meal. Drying reduces the moisture content in order to prevent microbial decomposition. The press cake fed to the dryer normally averages about 50% moisture, and the dried fish meal has a moisture content varying from 5% to 10%. Two main types of dryers are used: direct-fired rotary units and indirect rotary dryers.

The conventional direct-fired or flame-contact rotary dryer mixes the hot gases of combustion from the dryer firebox with a larger volume of fresh air before contact with the wet meal inside the rotating section. The exhaust air from this dryer usually passes through a cyclone to recover the entrained fish meal product. In this drying process, known as convection drying, the drying air and moisture-laden solids flow cocurrently, coming into direct contact with each other. The drying air inlet temperature is maintained below 600°C. The residence time of the solids in the dryer is about 15 minutes. This type of dryer is shown in Figure 2.

The indirect rotary dryer relies on heated surfaces that provide conduction drying for moisture removal. These heated surfaces consist of a series of parallel hollow disks or coils mounted vertically on a rotating hollow shaft through which passes either hot air or steam under 75–100 psig pressure. A small volume of fresh air passes countercurrent to the solids flow for moisture removal. The steam temperature generally ranges from 160°C to 170°C and the temperature of the exiting product is usually 85°C to 95°C. The retention time in this dryer is about 30 minutes. It is shown in Figure 3.

Another type of indirectly heated dryer combines certain features of both the direct-fired and the indirect rotary dryers. In the dryer, the combustion gases from the furnace pass through a heat exchanger to heat another stream of air that subsequently enters the rotary dryer, coming into direct contact with the solid particles, and removes moisture by convection. This type of indirect dryer can be referred to as an indirect rotary convection dryer to differentiate it from

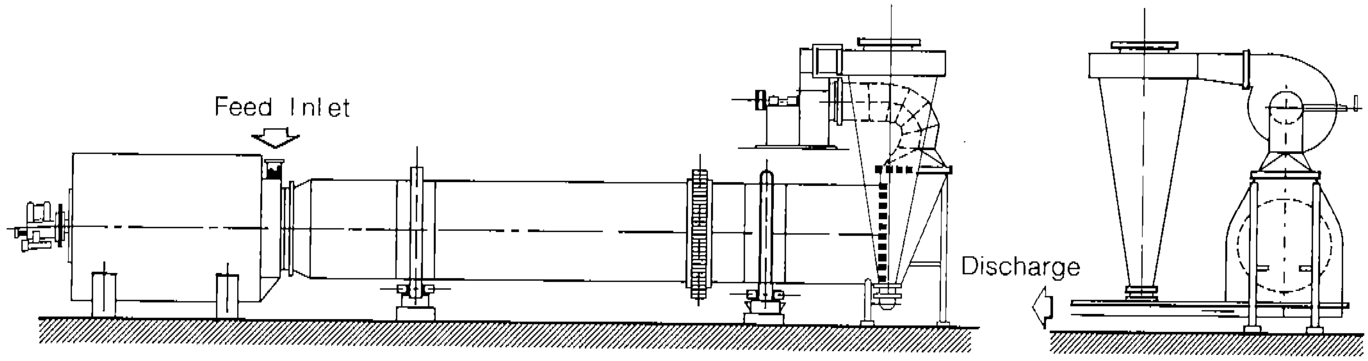

FIGURE 2. Direct-Fired Rotary Dryer (Reprinted with permission from the International Association of Fish Meal Manufacturers.)

the indirect rotary conduction dryer previously described.

Low-temperature, gentle drying systems have become more prevalent in the fish meal industry during the past five years. These improved drying methods include the increased use of indirect hot-air, vacuum, and fluid-bed dryers.[5] For example, the vacuum dryer, which is steam heated, is operated under a reduced pressure, resulting in correspondingly lower product temperatures of 50°C to 60°C.

Sand and Burt[5] compare the direct-fired dryer with various types of indirect dryers (steam, hot air, and vacuum) regarding certain criteria, including product quality, capital investment and operating costs, odor control, energy consumption, process control, maintenance, and space requirements. Wiedswang[6] compares the theoretical drying requirements for various types of dryers: direct-fired rotary, indirect rotary conduction, indirect rotary convection, and indirect vacuum.

Two stages of drying (I and II) are shown in Figure 1. A current trend exists to utilize both the direct-fired and the indirect hot-air rotary dryer in two stages. The direct-fired unit is used in the first stage to reduce the moisture in the press cake to 20–25% moisture. The indirect hot-air unit in the second stage completes the moisture removal. The stickwater concentrate and the sludge removed by the decanter centrifuges (in the liquid-flow part of the process) are added to the feed inlet to the second-stage dryer, since this additional moisture load is better assimilated at this point than in the feed inlet to the first-stage dryer.

Cooling, Storage, and Shipping

The dried meal is normally cooled in a rotary unit through which ambient air is passed countercurrent to the meal flow. The meal is then ground to pass 100% through a U.S. No. 7 Standard Screen. Fish meal must be stored in weatherproof, well-ventilated areas. Currently, the meal is being stored in bulk in sheds of single- or multi-unit construction with concrete floors and walls. Besides bulk storage, fish meal may be stored and shipped in multiwall paper, burlap, or woven plastic bags. A new type of bulk bag is capable of holding about 1 ton of product.

Liquid Flow

During the pressing operation, two intermediate products result: press cake and press liquor. As described under "Solids Flow," the press cake is dried to produce fish meal. The press liquor squeezed from the cooked fish contains coarse particles of fish and bone that must be removed before the liquor is centrifuged. These solids are removed by passing the liquor over a vibrating screen with 5–6-mm perforations. The recovered solids are sent back with the press cake to be dried.

Separation of the oil–water mixture is normally carried

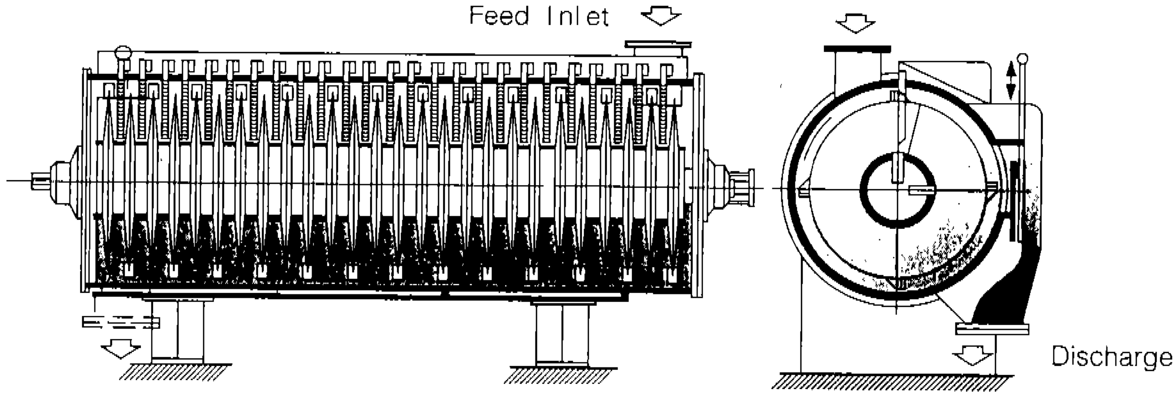

FIGURE 3. Rotary Disk Dryer (Reprinted with permission from the International Association of Fish Meal Manufacturers.)

out in three separate stages, or types of centrifuges: (1) a decanter to remove suspended solids; (2) a separator to recover oil from the press liquid, which becomes the stickwater; and (3) a polisher to remove water and other impurities from the oil concentrate. The stickwater is evaporated in a multiple-effect evaporator to produce a stickwater concentrate containing 50% dry substance. This concentrate is recycled back to the dryer for further moisture removal or is sold as a high-protein concentrate for animal feed.

Decanting (Solids Removal)

The decanter centrifuge consists of a horizontal cylindrical bowl that rotates and contains a rotating screw conveyor or scroll. The press liquor is fed into the bowl and the solids are forced to the outer wall. They are scraped off and conveyed out of the centrifuge by the scroll, which rotates at a slower speed than the bowl. Before discharge, the solids pass through a dewatering zone that tends to thicken or concentrate the solids. This sludge is returned to the dryers.

Separation

The liquid discharge from the decanter passes through a heat exchanger that raises its temperature to about 95°C before it enters the separator centrifuge. The separator is a three-phase centrifuge in which the feed liquor is separated into oil, stickwater, and a solids phase. The centrifuge consists of a series of cone-shaped disks rotating about a vertical axis and enclosed in a circular bowl. The feed liquor enters at the top center of the bowl and a sensor in the bowl is able to control the separation cycle by automatically discharging the accumulated solids. Since the main purpose of the separator is to maximize the recovery of oil, its operation is adjusted accordingly.

Polishing

The design of the polisher centrifuge is similar to that of the separator. However, its purpose is to polish or purify (ensure maximum removal of impurities from oil). As a result, the operation of the polisher is different from that of the separator. In order to obtain the desired purity, hot water equal to 10% of the oil volume is added to the feed liquor. The water and solids removed by polishing are added to the stickwater.

Evaporation of Stickwater

The water phase from the separator centrifuge is known as stickwater and usually contains 6–12% dry substance consisting of soluble proteins, fat, minerals, and vitamins. These stickwater solubles are concentrated by means of a multiple-effect evaporator that may consist of two, three, or four stages.

For a three-stage evaporator, the dilute stickwater enters the first stage, with a more concentrated solution passing on to the second stage and a final stickwater solubles concentrate of 50% dry substance discharging from the third stage. Steam under pressure is injected into the jacket at the first stage. The vapor from evaporation in the first stage passes on to the second-stage jacket and the vapor from the second stage passes on to the third-stage jacket. The vapor from the third stage is condensed and a vacuum is applied to the third-stage evaporator, which reduces the boiling points of evaporation in stages 2 and 3.

Most recent multiple-effect evaporators operate according to the falling film principle. Because the inside of the vertical evaporator tubes becomes gradually fouled due to deposits of proteins and calcium phosphate, it is necessary to circulate a caustic soda solution through the evaporator periodically in order to maintain production.

Since the raw material processed in fish meal plants contains 70–80% moisture, considerable fuel energy is required to evaporate this water. The recent trend in European and many U.S. fish meal plants has been to provide systems that require less energy.[7,8] This is accomplished by utilizing the exhaust vapors at atmospheric pressure from the indirect steam-heated or hot-air-heated dryers for moisture removal in the multiple-effect evaporator, which is operated under vacuum.

Fish meal has been used traditionally as a nutritious, high-protein feed ingredient in the diets of poultry and pigs. Currently, more fish meal is produced under improved drying methods and process control. This type of product is used to feed salmon, trout, shrimp, and mink. Fish oil is a normal constituent of many animal feeds. It is used as an industrial drying oil, such as linseed oil and tall oil, and also in margarine, shortening, and bakery fats.

AIR EMISSIONS CHARACTERIZATION

The largest odor emission source in fish meal plants normally is at the dryer, especially direct-fired dryers that require significant volumes of air for moisture removal. Lesser emissions occur at the cookers, evaporators, and other parts of the process. Table 2 provides an estimate of the odor emissions from various stages of the fish meal process.[9]

An extremely important consideration in the handling and storage of raw fish aboard a vessel concerns its temperature. The deterioration of raw fish begins rather quickly after the catch because of the bacteria and enzymes in the

TABLE 2. Odor Emissions from the Fish Meal Process

Stage of Process	Total Emission, %
Dryer	60–80
Cookers	10–20
Raw-material conveying	10–20
Pneumatic meal conveying	2–5

Source: Reference 9.

digestive tract. It has been determined for raw fish that the formation of volatile amines doubles with an increase in temperature of 6°C, and the odor unit profile increases tenfold.[7] It is essential to keep the raw fish at a low enough temperature to prevent this deterioration. As a result, fishing vessels are equipped with ice to be mixed with the fish or with refrigerated seawater circulated through their holds to maintain the temperature of the fish as low as is possible.

The storage of the raw material before processing is a definite source of odor and can vary from 1,000 to 100,000 odor units per cubic foot ASTM syringe method in the head space above the material, depending on its degree of deterioration.[10] These odor emissions from open areas, unless they are enclosed, are virtually impossible to control.

Where fugitive odor emissions from fish plants may affect the surrounding community more severely, a plant ventilating air system with subsequent odor control equipment may be necessary. Other potential sources of fugitive emissions include the leakage from certain process equipment, such as presses and open screens, and at the transfer point from one stage of the process to the next.

The odor emissions from the cookers may vary from 5,000 to 100,000 odor units per cubic foot (ASTM syringe method), depending on the state of decomposition of the raw material. The cooker is normally vented to odor control equipment at a volumetric emission rate varying from 100 to 1,000 ft^3/min.[1] Although the multiple-effect evaporator system may remove as much as 50% of the water evaporated from the total process, its operation normally is under vacuum and the odor emission is slight.

Table 3 illustrates the odor emissions from several rotary direct-fired dryers without odor control measures being applied.[11] It should be noted for dryer B that the odor units per standard cubic foot increased from 1500 to 4000 when the dryer discharge temperature increased from 240°F to 300°F. This illustrates the importance of controlling process conditions adequately in order to minimize odor generation. The exhaust from direct-fired dryers normally averages about 200°F and its moisture content ranges between 15% and 25% by volume.

Exhaust from indirect steam dryers is 30–45% lower in volume than from comparable direct-fired units. Steam dryers typically have a 25% moisture content in their exhaust, compared with about 15% moisture from a direct-fired unit processing the same material. Odor concentrations from steam dryers are generally in the same range as those from direct-fired units when fresh fish waste material is processed under proper operating conditions. Steam dryers are less likely to overheat the meal and result in excessive odor concentrations.

In many European countries, direct-fired dryers that use relatively large volumes of air and higher temperatures have been replaced by indirect steam-heated dryers because a lesser volume of fresh air is circulated through this type of dryer.[10] As a result, the operation of drying equipment that reduces odor volumetric emissions from the process allows the odor control systems to be more effective.

The composition of the odorous compounds present in the fish meal process is variable due to the various species of fish to be considered, as well as the degree of spoilage that has occurred and the actual process operating conditions being used. The concentration of gases in the head space above the storage of raw materials has been found to be quite high.[12] For example, inorganic gases such as hydrogen sulfide and ammonia were reported at levels up to 2000 ppm and 1000 ppm, respectively. The threshold limiting values (TLVs) for H_2S and NH_3 are specified at 10 ppm and 50 ppm, whereas their odor detection thresholds are reported at 0.00021 ppm and 21.4 ppm, respectively.[13] Also present were organic amines such as trimethyl amine, with an odor detection threshold of 0.00021 ppm.[13] Because of these low thresholds, even small volumes of these gases escaping to the surrounding atmosphere are capable of causing complaints.

With regard to dryer exhaust emissions, the use of gas chromatography and mass spectrometry[14] indicated the presence of sulfur compounds, such as hydrogen sulfide, carbon disulfide, carbonyl sulfide, and methyl and *n*-propyl mercaptans. In addition to ammonia, the only amine present was trimethyl amine. Analyses of the cooker exhaust in-

TABLE 3. Typical Odor Emissions from Rotary Fish Meal Dryers

Dryer	Feed Rate, tons/hour	Type of Fish	Temperature at Dryer Discharge, °F	Exhaust Gas Volume, scf/min[a]	Odor Units[b] per scf
A	10	Tuna	220	18,500	1500
A	15	Mackerel	220	18,500	1500
B	70	Tuna	220	9,000	700
B	10	Tuna	240	10,000	1500
B	14	Tuna	300	8,000	4000
C	9	Tuna	200	17,000	2500

[a]Standard cubic feet per minute.
[b]Odor units per standard cubic foot (70°F and 14.7 psia). ASTM syringe method.
Source: Reference 11.

TABLE 4. Odor-Removal Ability of Direct Condensers

System	Odor Units/scf[a]		Percent Removal	Air Temperature, °C	
	Inlet	Outlet		Inlet	Outlet
1	138,000	19,000	86		
	18,000	3,600	80	92	35
2	52,000	18,000	65	79	28

[a]Odor units per standard cubic foot, ASTM syringe method.

Source: Reference 10.

dicated that a number of sulfur compounds were present, but only one amine, trimethyl amine.

Dust emissions from the fish meal process are usually limited to the direct-fired dryers and to the grinding and pneumatic conveying of the dried fish meal. There are relatively few fines in ground fish meal. A sample of the dried product was collected from a pneumatic conveyor transporting ground fish meal. Only 0.6% by weight of the sample was less than 5 μm in diameter and 1.4% was less than 10 μm in diameter.[1] The cyclone collecting the pneumatically conveyed fish meal was found to be better than 99.9% efficient with an exhaust dust concentration of less than 0.01 gr/scf.

AIR POLLUTION CONTROL MEASURES

Since the process emissions from the cookers and dryers contain considerable moisture at temperatures of about 200°F (94°C), the necessary means should be provided to remove most of this moisture and to cool the process exhaust air before further odor control treatment. Also, there may be dust particles in the dryer cyclone exhaust that should removed before effective odor control measures can be applied. This is normally accomplished by either direct-contact or indirect water-cooled condensers. The indirect type includes the shell and tube condenser. The direct contact type includes cocurrent-flow venturi scrubbers and countercurrent flow spray-type scrubbers. They are often used where large volumes of seawater are available.

In addition to condensing water vapor and cooling the gas, a specific degree of odor reduction is obtained with direct-contact condensers since certain odorous compounds, such as NH_3, H_2S and $N(CH_3)_3$, are quite water soluble. Table 4 shows the ability of direct-contact condensers to reduce the inlet odor level.[10]

Two basic methods of odor control have been applied to the process emissions from cookers and dryers after condensing the water vapor: boiler incineration by direct-flame oxidation and wet scrubbing by chemical oxidation or the use of other scrubbing agents.

Thermal oxidation of the odorous process air is readily achieved in a boiler firebox operated at a temperature ranging from 650°C to 800°C (1200°F to 1475°F). However, the amount of odorous air to be treated must be compatible with the combustion air required for the boiler.

Where indirect steam-heated dryers are used, it may be feasible to use the dryer exhaust as combustion air after condensing the water vapor. However, if a direct-fired dryer is used, it normally is more feasible to use wet scrubbing. The fish meal industry in Europe uses the process air as a source of secondary combustion air in the boiler.[10] Table 5 illustrates the odor reduction obtained by boiler incineration.

As fuel costs have increased significantly, particularly in Europe, wet scrubbing systems have become more prevalent. Also, if fugitive odor emissions from the raw material storage area and the processing area are significant and cannot be captured by the exhaust duct system, a plant ventilating air system with adequate wet scrubbing equipment is required. Two wet scrubbing systems located in Norway and Denmark are described by Hansen.[15]

Depending upon the type of dryer (steam-heated disk units versus direct-fired units), the wet scrubbing system treats 500–1500 m^3 of dry air at standard conditions per ton of raw material processed. If plant ventilating air is required, the capacity of the scrubber system may increase to 3000–4000 m^3 of dry air at standard conditions per metric ton of raw material processed.

Seawater scrubbers are used to condense water vapor and cool the incoming gas stream. These may be venturi, packed-tower, or spray-type scrubbers and are normally

TABLE 5. Odor-Removal Ability of Boiler Incineration

System	Odor Units/scf[a]		Percent Removal
	Inlet	Outlet	
1	144,000	5,600	96
	18,000	840	95
2	4,750	850	82
	3,600	600	83
3	18,000	1,200	93
	9,000	1,000	89

[a]Odor units per standard cubic foot, ASTM syringe method.

Source: Reference 10.

TABLE 6. Odor Removal with Two Stages of Wet Scrubbing

Category of Scrubber	D/T[a]
Seawater Scrubber Inlet	200,000
Seawater Scrubber Outlet	20,000
Chemical Scrubber Outlet	1,000

[a]Odor dilution to threshold by IITRI dynamic olfactometer.
Source: Reference 15.

used as the first stage of a two-stage wet scrubbing system. The exhaust air from this first-stage scrubber passes on to the second-stage chemical oxidation scrubber, which normally contains packing. In the past, the packing consisted of 1-inch or 2-inch Rasching rings. Currently, more efficient types of packing are available. The use of sodium hypochlorite solution as a wet scrubbing agent in the second stage is preferred over potassium permanganate and hydrogen peroxide. Table 6 illustrates the odor reduction results obtained with two stages of scrubbing.[15]

Another fish meal plant in Norway is described by Onarheim and Utvik.[16] It uses two separate odor control systems—one exclusively for the dryer exhaust and the other for treating the remaining process odor emissions and the plant ventilating air. This plant processes 700 tons of raw fish (mackerel, herring, fish waste, etc.) every 24 hours.

The exhaust air from three Rotadisc driers passes to a packed tower scrubber operating at a linear velocity of 2 m/s (6½ fps) with 6 m^3/min (1600 U.S. gpm) of seawater. The scrubber outlet passes through an indirect heat exchanger, which uses the steam vapors from the dryers as a heating medium to preheat the scrubber exhaust. Most of this air is recirculated back through the dryers and the remainder is incinerated in the boiler firebox.

The second odor control system, which treats the remaining process emissions and plant ventilating air, consists of two stages of scrubbers. A packed-tower scrubber through which seawater is circulated precedes a second packed tower through which sodium hypochlorite solution is recirculated. The first-stage scrubber consumption of seawater is 2½ m^3/min (660 U.S. gpm). In the second stage, the consumption of NaOCl is estimated at 13 to 19 pounds per 1000 metric tons of raw material. Amines and ammonia could not be detected analytically in the second-stage exhaust.

In summary, fish meal plants in Europe and the United States have developed an odor control capability to treat their emissions and avoid becoming local nuisances. Process emissions are controlled by a combination of wet scrubbing with seawater and boiler incineration. Plant ventilating air is treated by wet scrubbing.

Biofilter technology developed during the past 10 years in Europe and elsewhere has been applied to the treatment of odor emissions from fish meal plants.[17] Biofilters consist of large beds of porous media that are capable of adsorbing odorous gaseous compounds and reducing these by aerobic microbial action to nonodorous components. This technology is now being applied to fish meal plants in the United States.

The Torry Research Station[18] in Scotland has developed a set of recommended practices to be used to reduce odor emissions during the production of fish meal. These practices include the delivery and handling of raw material, processing, handling and storage of fish meal, plant and equipment design, plant management, and maintenance.

Acknowledgment

This section was reviewed and comments were furnished by Anthony P. Bimbo, Director of Applied Development for Zapata Haynie Corp., Reedville, Va.

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LIVESTOCK FEEDLOTS

John M. Sweeten, Ph.D., P.E.

The purposes of this discussion are to identify and assess (1) the relationship of livestock production to air pollution emissions and (2) technology and management practices to reduce potential for air contamination from livestock and poultry operations.

MANURE PRODUCTION AND DISTRIBUTION IN THE UNITED STATES

Total U.S. manure production (dry basis) for all livestock and poultry species were calculated by Van Dyne and Gilbertson.[1] They found that total annual manure production was 112 million dry tons and the manure contained 8.2 billion pounds of nitrogen, 2.1 billion pounds of phosphorus, and 4.8 billion pounds of potassium. Volatilization, leaching, and runoff losses reduced the dry weight by 10%, total nitrogen by 36%, phosphorus by 5%, and potassium by 4%. Recoverable (collectable) manure and nutrients were estimated by subtracting the portion of materials voided on pasture areas. Collectable (economically recoverable) dry manure was estimated at 52 million tons, and the fractions from various animal species were dairy cattle, 39%; feeder cattle, 31%; hogs, 11%; laying hens, 6%; broilers, 5%; sheep, 3%; and turkeys, 2%.

The estimates[1] were based on an engineering standard adopted by the American Society of Agricultural Engineers[2] based on constituent production per unit weight of live animal. These standard values were recently updated to reflect current research data.[3] In most cases, average values of dry manure and nutrients (pounds per day per 1000 pounds live weight) were revised upward, and standard deviations were calculated to reflect the degree of variability.

PROCESS DESCRIPTION

Intensive Animal Production Systems

Major types of livestock and poultry production facilities, design information, and associated manure management systems have been described in other reports.[4–7] Roofed or total confinement facilities are common for poultry and swine and, to a lesser extent, dairy and beef production.[8] Open feedlots (nonroofed) are the type of intensive confinement facilities most commonly used for beef cattle. They are also widely used for dairy, swine, and sheep production in the southwestern United States.

Intensive livestock production systems are regarded as "animal feeding operations," which are defined (for purposes of water pollution control) in U.S. Environmental Protection Agency (EPA) regulations for the feedlots point source category as areas where animals are "stabled or confined and fed or maintained for a total of 45 days or more in any 12 month period, and . . . crops, vegetation, forage growth or post-harvest residues are not sustained in the normal growing season over any portion of the lot or facility."[9] The EPA definition is not specific as to animal species, type of confinement facility, or animal density, but essentially integrates these factors (along with climate and soils) into a single, visually determined criterion—absence of vegetation—which develops where manure production and/or animal traffic are sufficient to prevent germination or growth of forages.

Cattle Feedlots

The United States has 9.4 million beef cattle in feedlots and ranging in live weight from 450 to 1200 pounds per head, typically averaging 850 pounds. Each animal fed in a normal 130- to 150-day fattening period results in approximately 1 dry ton of collectable manure solids, or about 2 dry tons collected manure per year per head of feedlot capacity. The animal spacing per head varies according to rainfall and temperature, slope, and other factors from typically 100 to 125 ft^2 per head in the desert southwest (less than 10 inches annual rainfall) to 175–200 ft^2 per head in the southern central Great Plains (15 to 25 inches per year), which contains the largest cattle feeding states, and to 300 to 400 ft^2 per head in the eastern and northern Great Plains (25 to 35 inches per year).

Most of the manure deposited on the feedlot surface is compacted by cattle into a relatively moist manure pack of 35–50% moisture content (wet basis). At higher moisture contents, odors can develop, especially in warm weather.