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Overview of the Environmental Control Measures and Problems in the Food Processing Industries

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OVERVIEW OF THE ENVIRONMENTAL CONTROL MEASURES AND PROBLEMS IN THE FOOD PROCESSING INDUSTRIES

by

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In some food processing industries, associated wasted products may be usable as boiler fuel. The most notable instance is the use of bagasse as fuel in the cane sugar industry. The potential ash and cinder emissions from bagasse-fired boilers are high enough to require appropriate dust collection equipment.

Direct firing of process vessels is practiced primarily for the roasting or drying of various commodities. In such cases, the combustion products come into direct contact with the materials being processed, and the effluent gases may carry contaminants derived from both the fuel burned and the process material. Where the material being processed is intended for human consumption, at least, a "clean" fuel must be used in direct firing, and the fuel most often used is natural gas. In such cases, the contaminants in the gas stream are derived almost entirely from the process material. In any process involving direct firing, the gaseous and particulate effluents are specific to the process and material involved.

PROCESS SOURCE OF AIR POLLUTANTS

The "noncombustion" air pollution problems that may arise from processing in the food industry are associated with the following types of processes:

Process	Pollution Problem
Mechanical Handling (size reduction, conveying)	Particulates Odors from volatiles
Thermal Processing (roasting, blanching, concentrating, drying, frying and other cooking operations)	Particulates Odors
Preserving and Flavoring (sulfuring, smoking)	Particulates SO_x Odors PAH (toxic)
Extracting and Refining	Hydrocarbons Odors Chlorinated organics
Peeling	Chlorinated organics

Some major process sources of particulate emissions in the food processing industries are summarized in Table 4. Particulate emission factors for these sources are presented, where available, in Table 5. For comparison, the emissions from grain milling operations are shown in Table 6 along with the emissions from Portland cement manufacturing plants and coal-fired power plants.

Particulate control problems in the food industry result mainly from solids handling, solids size reduction, drying, roasting and cooking. Some of the particulates are dusts, but others (particularly those from thermal processing operations) are produced by condensation of vapors and may be in the low-micrometer or submicrometer particle-size range. Particulate collection for numerous sources, such as fish meal driers, deep fat frying, smokehouses, and coffee roasters have been discussed by Danielson.[2-6] With proper equipment selection and installation, all the problems can be adequately handled. Problems with particulate control in the grain milling industry, malting and liquor industry, and the citrus industry are also amenable to solution using currently available particulate collection devices.

The grain milling industry is one of the largest, if not the largest, source of actual or potential dust emissions in the food processing industries. This is particularly true if the category is taken to include the premanufacturing phases of grain handling: grain cleaning and drying, storage and handling at elevators, and custom grinding of feed. These phases are technically not part of the food processing industry as defined in this report (SIC 20, Food and Kindred Products), but fall into the major groups SIC 07, Agricultural Services: SIC 42, Motor Freight Transportation and Warehousing; and SIC 51, Wholesale Trade--Nondurable Goods.

The problem of SO_2 emissions from the sulfuring of fruit is discussed in Appendix A. Our conclusion is that the sulfuring of fruit is not a significant source of SO_2 emissions, relative to other point sources. However, the release of the SO_2 at or near ground level may produce problems near installations.

The potential toxic problems identified fall into four classifications:

(1) Polynuclear aromatic hydrocarbons (PAH) from smokehouses.

used – (2) Chlorinated organics from extraction and peeling operations.

— see Appendix D except

TABLE 4. MAJOR PROCESS SOURCES OF PARTICULATES IN THE FOOD PROCESSING INDUSTRIES

Industry	Transport	Size reduction	Cleaning and classifying	Roasting	Drying	Cooking	Examples
Meat processing						X	Smoke houses
Vegetable oil processing	X						
Grain milling (dry processes)	X	X	X				Flour mills
Grain milling (wet corn processing)	X	X	X		X		
Livestock food					X		Alfalfa dehydrating and grinding (baghouses)
Livestock fishmeal ind.					X		Fish meal dryers
Malted beverage	X				X		Grain handling, spent grains drying
Distilled liquor							Grain handling, spent grains drying
Roasted coffee			X	X	X		Coffee roasting, stoner and cooler, instant coffee spray dryer
Sugar cane							Bagasse-fired boilers
Canned and preserved fruits and vegetables					X		Citrus peel dryers

Source: SRI International.

*TABLE 5. PARTICULATE EMISSION FACTORS[*]

Industry	Emission factor
Meat processing (smokehouses)	0.3 lb/ton Uncontrolled (D) 0.1 lb/ton Controlled (D)
Vegetable oil processing (soy beans)	7 lb/ton (B)
Grain milling	
Rice	0.69 ∼ 5.7 lb/ton[†]
Wheat flour	3.4 ∼ 4.2 lb/ton[†]
Wet corn	2.2 lb/ton[†]
Livestock food (meal) (alfalfa dehydration)	60 lb/ton Uncontrolled (E) 3 lb/ton Controlled (E)
Livestock fishmeal	0.1 lb/ton Driers (C)
Malted beverage (spent grains)	8 lb/ton Handling and drying (E)
Distilled liquor (spent grains)	8 lb/ton Handling and drying (E)
Roasted coffee	7.6 lb/ton Direct-fired (B) 4.2 lb/ton Indirect-fired (B)
Sugar cane (bagasse)	22 lb/ton bagasse fiber (D)

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[*] The accuracy of the emission factors is ranked as "A," "B", "C", "D", or "E". "A" is considered excellent, "B" above average, "C" average, "D" below average, and "E" poor.

[†] SRI-estimated values.

Sources: EPA Compilation of Emission Factors, Second Edition, AP-42; SRI International.

Note: To convert pounds to kilograms, divide by 2.2.

TABLE 6. COMPARISON OF PARTICULATE EMISSIONS FROM GRAIN MILLING AND OTHER LARGE INDUSTRIAL SOURCES OF PARTICULATES

Type of plant	Emission factor	Typical plant size	Particulate emission rate (lb/hr)
Rice milling	0.69 ~ 5.7 lb/ton*	600 cwt/hr	21 ~ 171
Wheat flour milling	3.4 ~ 4.2 lb/ton*	200 cwt/hr	34 ~ 42
Wet corn milling	2.2 lb/ton*	1400 cwt/hr	154
Power plant‡ (coal-fired)	0.1 lb/10^6 Btu†	500 MW	315
Portland cement	0.3 lb/ton of feed	70 tons of feed/hr	21

*SRI-estimated values.

†Federal New Sources Performance Standards.

‡Assume power plant capacity factor of 0.7.

Source: EPA; SRI International.

(3) Pesticides and other possible toxic compounds emitted from roasting or drying operations.

(4) Allergenic materials in grain dust.

Problems 1, 2, and 3 above are discussed in Appendices B, C, and D, respectively.

Estimates of the maximum potential emission of PAH from smokehouses, presented in Appendix B, show that the gross emissions from these industrial sources are extremely small relative to other point sources. Although smokehouses could be the source of airborne particulates and sludges contaminated with PAH, it would be difficult to quantify the actual impact of such discharges. Localized effects from such discharges could be more important.

In Appendix C, all major known and proposed uses for chlorinated solvents in the food industry have been identified. Less than 3% of the total industrial consumption in 1974 of trichloroethylene (TCE) was for food processing and this percentage likely has dropped as methylene chloride has been introduced as a substitute. The food industry is a very minor source of the other previously mentioned toxic pollutants, but their localized effects might be important. Such compounds may be released from plants in both the gas phase and the liquid phase. Air stripping in biological treatment systems is likely to remove the compounds from water rapidly.[2-7,-8]

Estimating the quantities of pesticides emitted from food processing operations requires determining which pesticides are actually used and in what quantity they are present on the commodity as it reaches the processing plant. Little detailed information on either subject appears to be available. Some rough estimates of possible pesticides emissions from peanut roasting (Appendix D) were made in an effort to assess whether such emissions might actually be significant. The indicated pesticide concentrations in the roaster waste gas exceed slightly or moderately the allowable occupational standards for worker exposure, but the resulting concentrations in ambient air after dispersion and dilution of the stack gas would be much lower. It is questionable whether the indicated emissions would be significant even if they proved to be real.

Dusts from grain handling and milling are generally in the nuisance category, but they are also known to produce allergic reactions in sensitive individuals. Emissions of such dusts to the atmosphere may affect sensitive individuals in the general population as well as workers in the grain mills. In a study at the University of Minnesota, Cowan et al[2-9] concluded that there was a possible association between air pollutants from the grain industry nearby and the incidence of acute allergenic asthma among university students. Weill et al[2-10] demonstrated an association between local episodic asthma in New Orleans and allergenic air pollutants emitted from grain elevators in the area.

Although rice hulls contain a significant amount of silica and the soil picked up with the grain during harvesting may contain some free silica, the chance that dust from these sources might present a silica inhalation hazard is so remote as to be negligible. To be dangerous, the material must be crystalline-free silica (not silicates or other such compounds) and must be in the respirable particle-size range (i.e., ≤ about 2 μm). The actual quantities of material of this description are likely to be very small. The free silica in rice hulls is amorphous (noncrystalline), and hence not dangerous.

In cotton growing the plants are commonly sprayed with a defoliant before harvesting. Defoliation of the cotton plants makes machine picking of the cotton easier. The defoliants used have generally been organic arsenic compounds. Consequently, the trash (e.g., leaves, stems) collected along with the seed cotton is contaminated with arsenic residues. The outer tips of the cotton fibers will also carry some residual arsenic, but the seeds should be generally well protected from contact with the defoliant. At the cotton gin, the trash is separated from the cotton and is normally burned. During combustion of the trash, at least part of the arsenic enters the offgases and is emitted to the atmosphere.[2-11]

If the arsenic-bearing material did reach the cotton seed, it would present primarily a potential hazard in a food product. Apparently, the existence of any actual hazard has not been reported. The emissions from trash burning are not within the category of food processing industries. Cotton ginning (SIC 0724) falls under Agricultural Services.

ODOR EMISSION AND CONTROL

Odor emissions may occur at almost any stage of food processing, but the most serious ones usually are associated with the thermal processing steps such as cooking, roasting, drying, and evaporative concentration. The waste gases from these operations will usually contain particulate matter and perhaps condensable vapors as well as the malodorous substances. Such particulates and condensable materials complicate the problem of collecting or destroying the malodors. The condensable materials themselves may be malodorous to some degree.

For some particularly malodorous operations (e.g., slaughtering, rendering), the exhaust air from building ventilation may be so contaminated as to be a major source of odor.[2-6] Wastewater treatment ponds are another frequent source of odors, even from processing of materials that are not otherwise particularly objectionable.[2-12,-13] Anaerobic digestion of wastes is a frequent source of hydrogen sulfide emissions,[2-14,-15] although such problems can frequently be alleviated or eliminated by proper design of the treatment system. Aerobic treatment of wastewater may also produce odors.[2-12,-16] Some hydrogen sulfide can be formed and emitted, particularly under conditions of system overload.[2-17] In addition, various organic compounds (some of them malodorous) can be stripped out of solution by the air stream used in aeration.[2-7,-8,-17]

Table 7 lists food industries and processes that are major sources of nuisance odors. These are sources that are well known or cited with some frequency in the literature. The list is not exhaustive; as noted previously, most of the food industries can be sources of odors under

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Appendix C

PAH are formed under high-temperature pyrolysis of organic matter. The amount of benzo(a)pyrene (BaP) formed, for example, depends on how reducing the combustion atmosphere is. With increasing air-to-fuel ratios, BaP decreases in concentration. PAH formation also seems to be associated with higher plants that contain more complex phenolic compounds (e.g., lignin), but other types of organics can also produce PAH.[B-6] Pyrolysis of lignins and terpines during forest fires has been identified as a likely source of PAH in relatively high yields.

Listed below are typical values for concentration of PAH on particulate matter from open burning that could be comparable to values for a smokehouse.

	Mg/kg of particulate matter		
PAH	Municipal	Commercial	Open
Benz(a)anthracene	0.09-0.26	5-210	25-560
Benzo(a)pyrene	0.02-3.3	58-180	11-1100

PROBABLE SOURCES OF PAH IN THE FOOD INDUSTRIES

Of the more than 1300 meat processors in the United States, the vast majority use smoking for flavoring. In 1970, 3 million tons of meat products and approximately 17,000 tons of fish were smoked.

Within the past few years, technology has made possible the manufacture of an artificial liquid smoke flavoring product containing chemical components simulating the color, aroma, and flavor characteristics of smoke. When used in meat or poultry products, their names are modified with the term "Artificial Smoke Flavor Added."

In addition to the synthesized liquid, a natural liquid smoke product is also produced. It is prepared by burning wood and trapping and condensing the smoke into a liquid. The liquid is then filtered to remove many of the undesirable components, such as tars and solid particles. Meat and poultry products containing such a substance are required to be labeled with the terms "Smoke Flavored" or "Smoke Flavoring Added."

According to Mr. L. G. Broidy of the Western Regional Office MID, perhaps as much as 50% of the smoke processed meat is prepared with natural liquid smoke, and this proportion is increasing rapidly.[B-2]

The application of liquid smoke has at least two advantages: (1) sanitation of the smoking facilities, due to the absence of many tars from the liquid smoke; (2) environmental considerations, since there is less evacuation of pollutants into the atmosphere from liquid smoke than with the natural wood burning process. This latter advantage has gained particular attention in municipalities having strict ordinances on air pollution.[B-3]

Although PAH have not been identified as emissions from smokehouses, literature mentions the relatively high PAH content of smoked fish and meats.[B-4] The source of these PAH in the meat is probably the smoke, because the temperature of the meat itself would not be high enough to form these compounds.

The smoking of meat gives the finished product a characteristic and desirable flavor, some protection against oxidation, and an inhibiting effect on bacterial growth. Smoke is most commonly generated from hardwood sawdust or small-size wood chips outside the oven and is carried to the oven and introduced through duct work. A small stream of water is used to quench the burned hardwood sawdust before dumping the sawdust to waste. The most common operation is to overflow the water from this quenching section and to waste the water into the sewer. One plant slurried the char from the smoke generator, piped it to a static screen for separation of the char from the water, and then wasted the water.

In total quantity, the waste load and wastewater generated in this cleanup is not particularly significant. However, there is a noticeable coloration of the wastewater during cleanup and, depending on the extent of the use of caustic, an increase in the pH of the wastewater.

QUANTIFICATION OF THE PAH PROBLEM IN THE FOOD INDUSTRIES

Smokehouse Exhaust Products

Smokehouse exhaust products include organic gases, liquids, and solids, all of which must be considered air contaminants. Many of the gaseous compounds are irritating to the eyes and reasonably odorous. A large portion of the particulates is in the submicrometer size range where light scattering is maximum. These air contaminants are attributable to smoke, that is, to smoke generated from hardwood, rather than from the cooked product itself.[B-5]

Exhaust gases from both atmospheric and recirculating smokehouses can be periodically expected to exceed 40% opacity, the maximum allowable under many local air pollution control regulations. With the possible exception of public nuisance, smokehouse exhaust gases are not likely to exceed other local air quality standards.[B-5]

Hooding and Ventilation Requirements

Atmospheric smokehouses are designed with exhaust volumes of about 2.74 cubic meters per square meter of floor area. Somewhat higher volumes are used with atmospheric houses of two or more stories.[B-5]

Recirculation smokehouses have a considerably wider range of exhaust rates. During smoking and cooking cycles, volumes of 0.914 to 3.66 cubic meter per square meter of floor area are exhausted.[B-5]

The highest reported values for particulate matter in smokehouse exhaust are about 0.535 grams per normal cubic meter, with the emission factors varying from 0.136 to 0.068 kg/ton of meat for the uncontrolled and controlled cases, respectively.[B-5,6]

If one assumes a PAH concentration of 1000 ppm on the particulate matter and 3×10^6 tons of meat smoked per year (assuming no controls), then the maximum PAH release to the atmosphere would be as follows:

$$\left(\frac{3.0 \times 10^6 \text{ tons meat}}{\text{yr}}\right)\left(\frac{0.136 \text{ kg particulate}}{\text{ton}}\right)\left(\frac{455 \text{ kg PAH}}{455 \times 10^3 \text{ kg particulate}}\right) =$$

$$\frac{0.455 \text{ kg PAH}}{\text{yr}}$$

Approximately 9.09 kilograms of wood is burned per ton of meat smoked.[B-6] By assuming a char production of 0.227 kg/kg wood and a concentration of PAH of 1000 ppm on the char, the possible quantity of PAH that is washed out of the smokehouses can be estimated:

$$\left(\frac{3.0 \times 10^6 \text{ tons meat}}{\text{yr}}\right)\left(\frac{9.09 \text{ kg wood}}{\text{ton meat}}\right)\left(\frac{0.227 \text{ kg char}}{\text{kg wood}}\right)\left(\frac{455 \text{ kg PAH}}{455 \times 10^3 \text{ kg char}}\right) =$$

$$\frac{13{,}600 \text{ kg PAH}}{\text{yr}}$$

As shown in Table B-1, the total estimated amount of PAH emissions (listed as POM for polycyclic organic matter) is 4.8 million tons. The estimated releases from smokehouses are insignificant compared to other sources.

TABLE B-1. HAZARDOUS POLLUTANT SOURCES

Source	Amount of POM[*] Tons/year	%
Iron and steel		
Metallurgical coke	43,380	0.90
Asphalt industry		
Paving material preparation	2,800	0.06
Roofing material preparation	23,230	0.48
Petroleum refining	2,170	0.05
Incineration		
Industrial	2,228	0.05
Domestic	730	0.02
Auto body	14,602	0.30
Conical burner	212,211	4.42
M Open burning	M 526,843	10.98
X Agricultural burning	X 2,161,142	✓45.05
Natural fires, forest	1,433,712	29.89
Natural fires, urban	6,060	0.13
Municipal	682	0.01
Coal refuse	193,500	4.03
Power plant boilers		
Pulverized coal	8,980	0.19
Stoker coal	1,032	0.02
Cyclone coal	310	0.01
All oil	7,675	0.16
All gas	6,151	0.13
Industrial boilers		
Pulverized coal	1,896	0.04
Stoker coal	6,635	0.14
Cyclone coal	948	0.02
All oil	10,001	0.21
All gas	20,220	0.42
Residential/commercial		
Coal	66,796	1.39
Oil	33,105	0.69
Gas	10,065	0.21
Total	4,797,104	100.00

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[*] POM is polycyclic organic matter.

Source: Reference B-7.

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Appendix C

CHLORINATED HYDROCARBONS

BACKGROUND

Chlorinated hydrocarbons have been used for hops extraction, extraction of caffeine from coffee, extraction of cocoa butter, extraction of soya beans, and in the peeling of some fruits and vegetables. No data are available on the actual past usage of trichloroethylene (TCE), but it has been estimated that about 10% of the 1974 production of 157 million kilograms went to miscellaneous or nonmetal cleaning uses. The majority (two-thirds) of this miscellaneous use was probably in the production of polyvinl chloride where TCE is used as a chain terminator. Other non-food industry uses are as a solvent for textile cleaning and dyeing and as a raw material for fungicide production.[C-1] Available data show that the probable consumption of TCE by the food industries was well below 4.55 million kilograms in 1974. Coffee processing probably represented the largest single use.

COFFEE PROCESSING

Because of the "memorandum of alert" issued by the National Cancer Institute in April 1975 concerning potential carcinogenic hazards of TCE, all coffee extraction in the United States is now carried out with methylene chloride and this solvent will probably be substituted for almost all other chlorinated hydrocarbon uses in the food processing industries.

The estimated volume of discharge in 1975 of TCE from extraction of coffee from one plant was estimated at an average concentration of less than 150 mg/liter in an average raw wastewater flow of 100,000 gal/day (378.5 m^3/day), or about 55 kg/day.

A representative of Hills Bros. Coffee[C-3] reported that producers of decaffeinated coffee are now considering an aqueous extraction process. The reason is that many people consider the current substitute for TCE, methylene chloride, also to be highly suspect as a chemical carcinogen. In the new process, "saturated water" is prepared by extracting the green coffee beans. This saturated solution can be recycled and will remove

Decaf Coffee

essentially only caffeine. The process is used in Germany and may be adopted here.

General Foods and Nestle are currently the two largest decaffeinated coffee producers. Most small coffee companies usually contract out the decaffeination production because of the high investment cost for the production units.

HOPS EXTRACTION

From contacts with representatives of Dow Chemical[C-4] and the Joseph Schlitz Brewing Co.,[C-5] it was learned that Pabst and Schlitz have definitely discontinued the use of hop extracts. It is also believed that all other brewers have discontinued this practice.[C-5] The impetus for this move was an FDA ruling requiring that labels give information that the beer contains hop extracts (and any other material used for the extraction that may remain).

OIL SEED EXTRACTION

Dow Chemical Company is now working on a process to use methylene chloride for oil seed processing. At present, the industry (without exception, according to Dow) uses hexane. The estimated loss of hexane is approximately 1 gallon per ton of seed processes, and there is apparently no real incentive to change the process solvent. Dow does not anticipate any rapid changes in the future by this industry in use of chlorinated solvents.

FRUITS AND VEGETABLES PEELING

Although a great deal of research and development work has been done on using chlorinated solvents for peeling, no processes have reached the commercial stages. The main problem with the process for commodities such as tomatoes has been migration of the solvent into the interior through the stem. According to representatives of the National Canners Association Laboratory in Berkeley, no plants are currently using chlorinated solvents for peeling, nor do they intend to do so.[C-6]

MISCELLANEOUS USES

Trichloroethylene was used as a solvent for extraction of annatto food coloring from botanical material. This food coloring is widely used in the dairy industry. It is not known if methylene chloride is now used for this extraction.

Methylene chloride is a component of inks used for marking fruits and vegetables.

Neither of these uses should represent a significant source of chlorinated solvents relative to other industrial sources.

REFERENCES

C-1 SRI International Chemical Economics Handbook.

C-2 Camisa, A. G., "Analysis and Characteristics of Trichloroethylene Wastes," JWPCF 47 (5): 1021-31 (1975).