Chapter II

Environmental Contamination of Food

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Maintaining an adequate, safe food supply has been a major goal of the Federal Government since 1906, when the first Federal food and drug law was signed into law. Historically, chemicals such as salt, sugar, and wood smoke have been used to preserve foods. Modern food technology relies extensively on the use of chemicals not only for preservation but also to produce appealing colors, flavors, aromas, and textures.

Most developed countries now have food laws designed to permit the use of such chemicals in food under conditions judged to be safe. These chemicals are not considered adulterants or contaminants and are classed as intentional additives. Other chemicals may enter food as a result of their use in food production, handling, or processing. Such substances maybe legally permitted if they are unavoidable under good manufacturing practices and if the amounts involved are considered safe. These chemicals are classed as incidental additives. The presence of both these classes of chemicals in food is controlled by regulation.

Environmental contaminants include substances from natural sources or from industry and agriculture. Many of the naturally occurring contaminants in food are of microbiological origin and consist of harmful bacteria, bacterial toxins, and fungal toxins. (Aflatoxin, a contaminant of peanuts and grains, is an example of a fungal toxin or mycotoxin.) The second category of environmental contaminants includes organic chemicals, metals and their complexes, and radionuclides. Only those environmental contaminants introduced into food as a result of human activities such as agriculture, mining, and industry are considered in this assessment.

The environmental contamination of food is a result of our modern, high-technology society. We produce and consume large volumes of a wide variety of substances, some of which are toxic. It is estimated that 70,000 chemicals may currently be in commercial production in the United States and that 50 of these chemicals are manufactured in quantities greater than 1.3 billion lbs per year. Seven percent of this country's gross national product (GNP), $113 billion per year, is generated by the manufacture and distribution of chemicals (l). During the production, use, and disposal of these substances, there are opportunities for losses into the environment. For example, the Environmental Protection Agency (EPA) estimates that there are more than 30,000 chemical and radioactive waste disposal sites. Of these, 1,200 to 2,000 are considered threats to human health (2).

Environmental contamination of food takes two forms: long-term, low-level contamination resulting from gradual diffusion of persistent chemicals through the environment, and relatively shorter term, higher level contamination stemming from industrial accidents and waste disposal.

An example of low-level contamination is polychlorinated biphenyls (PCBs). This group of substances was widely used in transformers and capacitors, as heat-transfer fluids, and as an additive in dyes, carbon paper, pesticides, and plastics (3). Although production was halted in 1977, PCBs remain an ubiquitous, low-level contaminant of many foods, especially freshwater fish.

An example of the second type of contamination is polybrominated biphenyls (PBBs) in dairy products and meat. PBBs, a fire retardant, were accidentally mixed into animal feed. Dairy cattle that were fed the contaminated feed produced contaminated milk. The distinctions between the two types of food contamination are not exclusive. For exampie, PBBs have now become a long-term, low-level contaminant in Michigan because they are very stable and resistant to decay. Animals raised on farms affected by the original feed contamination are now contaminated by the PBB residues remaining in the pastures and farm buildings.

HOW FOOD BECOMES CONTAMINATED

Chemicals contaminate foods through different routes depending on the chemical and its physical properties, its use, and the source or mechanism of contamination.

Organic substances that have contaminated food have been either industrial or agricultural chemicals. Pesticides are the only agricultural chemicals known to be environmental contaminants in food (see tables 1-3). A pesticide becomes an environmental contaminant when it is present in foods for which the application or use of the substance has not been approved. Livestock, poultry, and fish can be contaminated when application or manufacturing of pesticides occurs in the vicinity or when residues are transported through the environment. Improperly fumigated railroad cars, trucks, ships, or storage buildings used for transport or storage of human food and animal feed are also sources of environmental contamination. The interiors are sprayed or fumigated with pesticides, and if not sufficiently aired, contamination of the food or feed occurs.

The manufacture of organic chemicals produces sludges, gases, and liquid effluents of varying chemical complexities. The usual waste disposal methods (sewage systems, incineration, landfill) are unable to prevent organic residues from entering the environment in spite of Federal laws and corresponding regulations governing disposal. The routes include the atmosphere, soil, and surface or ground water.

Table 1.— Reported Incidents of Food Contamination, 1968-78, by State and Class of Contaminant

State	Pesticide	Mercury	PCB	PBB	Other	Total
New York . . . . • ., .	1	1	1	—	—	3
Idaho.	1	2	—			3
South Carolina.		—		—	1-biphenyl	1
Minnesota	—	1	—	—		1
Louisiana	8	5	4	—	—	17
Colorado.	1	1		—	—	2
Georgia.	15	—	—	—	—	15
Maryland.	—	1	—	—	2-petroleum	3
Texas	—	1	—	—		1
New Jersey.	2	1	—	—	1-ß-methoxy napthalene and tetraline	4
Kansas . . .	—	(l)*	—	—		(1)*
Missouri	4	—	—	—	—	4
New Mexico. . .	—	1	—	—	—	1
Alaska.	(1)*	—	—	—	—	(1)*
California .	1	3	—	—	—	4
Indiana .,	3 well-documented 5 other incidents	—	1	—	—	9
Michigan .	13	1	2	1	—	17
Virginia, ., . . .	1	—	—	—	—	1
Totals	56	19	8	1	4	88

“Several conservatively estimated as one

SOURCE Of fice of Technology Assessment

Table 2.— Reported Incidents of Food Contamination, 1968-78, by State and Food

State	Dairy	Eggs	Fruit/ Vegetable	Fish/shellfish	Grain	Game/meat/ poultry	Incidents
New York	—	—	—	3	—	—	3
Idaho	1	—	—	1	—	1	3
South Carolina	—	—	—	—	1		1
Minnesota	—	—	—	1	—		1
Louisiana	5	1	1	9	1		17
Colorado	1[a]	—	1[a]	—	—		2[a]
Georgia	—	—	15	—	—		15
Maryland	—	—	—	3	—		3
Texas	—	—	—	1	—	—	1
New Jersey	—	—	2	2	—	—	4
Kansas	—	—	—	—	1		1
Missouri	4	—	—	—		—	4
New Mexico	—	—	—	—	—	1	1
California	—	—	1	2	—	1	4
Indiana[b]	1	2	—	—	—	1	9
Michigan	7	—	2	4	—	4	17
Alaska[c]	—	—	—	—	—		1
Virginia	—	—	—	1	—		1
Totals	19	3	22	27	3	8	88

[a]Dieldrin contamination of milk and lettuce, reported as one incident
[b]Five additional incidents, but not well documented.
[c]Several pesticide incidents, but not well documented, therefore conservatively estimated as one
SOURCE Office of Technology Assessment

Table 3.— Number of Incidents of Environmental Contaminants of Food Reported by Federal Agencies, 1968-78

Agency	Pesticides	Mercury	PCB's	Other	Food affected
USDA/FSQS	39	—	—	—	Chickens, turkeys. ducks. cattle, swine, lambs
	—	1	—	—	Swine
	—	—	6	—	Poultry
	—	—	—	1 (Phenol)	Cattle
FDA	21	—	—	—	Fish. cheese, pasta
	—	84	—	—	Fish
	—	—	3	—	Fish, eggs, bakery products
Total	60	85	9	1	

SOURCE Off Ice of Technology Assessment

Metals can be released into the environment in several ways. The mining and refining processes produce dust and gases which enter the atmosphere. Metallic salts formed during recovery and refining processes can escape as waste products into surface and ground water. Sewage sludge used as fertilizer on agricultural land also poses a potential food contamination problem. Trace metals present in the sludge can be taken up by crops grown on treated soil. Cadmium is the trace metal in sludge that currently generates the greatest concern.

Radioactivity in food stems from three sources: natural radioactivity. releases from operation of nuclear reactors and processing plants, and fallout from nuclear weapons tests. The primary route by which food becomes contaminated is the deposition of airborne material on vegetation or soil. The subsequent fate of the radionuclide is determined by its chemical and physical nature and whether it is absorbed and metabolized by plants or animals. Natural radioactivity may become a concern when ores containing radioactive substances are mined and processed. The products or wastes may concentrate the radionuclides. Examples of this are uranium tailings, phosphate rock waste, or slags from phosphorus production. Radium may enter the food chain when it dissolves in ground water and is taken up through plant roots.

Nuclear reactors normally release radioactive noble gases that do not contaminate foods. Reactors do contain large inventories of fission products, transuranics, and other activation products. Accidental releases can contaminate vegetation by deposition of particles on leaves and soil, or through water. Gaseous releases would most likely involve the volatile elements such as iodine and tritium, or those with volatile precursors, such as strontium-90 and cesium-137. Aqueous releases would follow failure of the onsite ion exchange cleanup system. Any of the water-soluble elements could be involved. Table 4 summarizes the radionuclide contaminants of significance for foods.

Nuclear waste-processing plants could also have either gaseous or aqueous releases. In this case, the fission products are aged before processing, and iodine and the gaseous precursor radionuclides are not released. Tritium and carbon-14 are the major airborne products, while the waterborne radionuclides are the same as for reactors.

Atmospheric nuclear weapons tests distribute their fission products globally. Local deposition depends on the size of the weapon and the conditions of firing (high altitude, surface, or underground).

Table 4.— Radionuclide Contaminants of Significance for Foods

Element or nuclide	Source	Emission	Notes
Uranium	Natural	α	Normally present in small amounts, Significant only when enhanced
Thorium	Natural	α	Normally present in small amounts
Radium-226	Natural	α	Member of uranium series. Normally present, metabolized somewhat like calcium
Radium-224	Natural	α	As radium-226, only a member of thorium series
Polonium-210		α	Members of uranium series
Lead-210	Natural	β	Normally present
Plutonium	Transuranic activation product	α(^{238}Pu, ^{239}Pu ^{240}Pu) β(^{241}Pu)	Product of nuclear reactions
Americium	Transuranic activation product	α(^{241}Am)	Product of ^{241} Pu decay
Tritium	Natural, also from nuclear reactions	β	Low energy, usually in form of water or organic compounds
Carbon-14	Natural, also from nuclear reactions	β	Low energy, usually in form of organic compounds
Iodine-131	Fission products	β, γ	Short half-life, so important only for fresh foods, e.g., milk and leafy vegetables
Strontium-89 and -90	Fission products	β	Follows calcium somewhat in metabolism
Cesium-134	Reactor product	β, γ	Follows potassium somewhat in metabolism
Cesium-137	Fission product		
Mixed fission products	Fission products	β, γ	Most important are isotopes of zirconium, cerium, barium, rubidium, rhodium. Mostly surface contaminants
Iron-59, chromium-51, zinc-65, cobalt-60, cobalt-58, manganese-54, sodium-22, phosphorus-32	Activation products	β, γ	Follow stable elements in metabolism

SOURCE: N. H. Harley, "Analysis of Foods for Radioactivity," OTA Working Paper, 1979.

MAGNITUDE OF THE PROBLEM

There is little information available on the number of food contamination incidents, the amount and costs of food lost through regulatory actions, or the effects of consumption of contaminated food on health. To obtain information on the extent of the problem, OTA reviewed the literature and sought information from the States and Federal agencies.

Evidence of Human Illness Resulting From Consumption of Contaminated Food

In evaluating the significance of environmental contaminants in food the key question is whether consumption of contaminated foods poses a health risk. Measurable health effects depend on the toxicity of the substance, the level at which it is present in food, the quantity of food consumed, and the vulnerability of the individual or population. In Japan, foods contaminated with substances such as PCBs, mercury, and cadmium have produced human illness and death. No such mass poisonings have occurred in the United States. However, in cases such as PBBs where a large populace has been exposed, some physiological changes have been noted. But no conclusions can as yet be drawn on the ultimate health effects.

It is known from limited surveys that the U.S. population is exposed to a wide variety of chemical contaminants through food, air, and water. The long-term health effects and the implications of possible interactions among these residues are unknown. A recent literature review of over 600 published studies (4) found that nonoccupationally exposed U.S. residents carry measurable residues of 94 chemical contaminants. Twenty-six of these are organic substances, including twenty pesticides and pesticide metabolizes. The remainder are inorganic substances.

Americans also have been exposed to low levels of PCBs, PBBs, mercury, and ionizing radiation through their food. The following sections briefly summarize current knowledge and the extent of uncertainties on the health effects of these environmental contaminants.

Polychlorinated Biphenyls

PCBs occur in food as the result of environmental contamination leading to accumulation in the food chain, direct contact with food or animal feeds, or contact with food-packaging materials made from recycled paper containing PCBs (5). Several comprehensive literature reviews have been published in the last 5 years detailing the acute and chronic toxic effects of PCBs in animals and humans (5-1 1).

Human illness has been caused by exposures to PCBs at much higher levels than those that occur in the United States. In the early part of 1968 the accidental contamination of edible rice-bran oil led to a poisoning epidemic among the Japanese families who consumed the oil. The disease became known as Yusho or rice-oil disease. Its chief symptoms were chloracne (a severe form of acne) and eye discharge; other symptoms included skin discoloration, headaches, fatigue, abdominal pain, menstrual changes, and liver disturbances. Babies born to mothers who consumed the rice oil were abnormally small and had temporary skin discoloration. The first symptoms of Yusho disease were registered on June 7, 1968, and 1,291 cases had been reported as of May 1975 (9).

Since the rice oil was also contaminated with polychlorinated dibenzofuran (PCDF), it is difficult to determine from the Yusho data exactly what effect(s) exposure to PCBs alone could have on humans. It has been calculated that the PCDF made the rice oil 2 to 3.5 times more toxic than would have been expected from its PCB content alone (1 1). Careful records of the 1,291 Yusho patients have been kept to determine possible long-term effects. At least 9 of 29 deaths that occurred as of May 1975 were attributed to cancer (malignant neoplasm), but a causal relationship between PCBs and cancer cannot necessarily be inferred because of the high concentration of PCDF in the oil. The Yusho study, nevertheless, had two important results: first, the information established that PCBs can be transferred from mother to fetus and from mother to child through breast feeding, and second highly chlorinated PCB compounds are excreted more slowly from the body than less chlorinated ones (9).

More recent experiments in animals have demonstrated a variety of toxic effects. Cancers have been produced in mice and rats fed PCBs (6, 12). Monkeys fed levels of PCBs equivalent to the amounts consumed by Yusho patients developed similar reproductive disorders (13-16). Young monkeys nursing on mothers consuming feed containing PCB developed toxic effects and behavioral abnormalities (15-1 7).

Polybrominated Biphenyls

Practically every Michigan resident has been exposed to PBB-contaminated food products. It is estimated that some 2,000 farm families who consumed products from their own PBB-contaminated farms have received the heaviest exposure (18).

Fries (19) studied the kinetics of PBB absorption in dairy cattle and its elimination in milk, If intake of contaminated milk alone is considered, those Michigan residents most severely exposed consumed from 5 to 15 grams of PBB over the initial 230 days of the exposure. Those residents that coincidentally consumed contaminated meat and/or eggs may have received higher total doses of PBB, but the number of such cases is probably small,

Geographically the residents of the lower peninsula, where the original accident occurred, were found to have the greatest levels of exposure. In 1976, the Michigan Department of Public Health conducted a study on PBB concentrations in breast milk. It was found that 96 percent of the 53 women selected from the lower peninsula and 43 percent of the 42 women selected from the upper peninsula excreted PBB in their breast milk (20).

Low concentrations of PBBs also have been detected in animal feed in Indiana and Illinois. Unconfirmed surveys of food throughout the country found extremely low levels below the Food and Drug Administration (FDA) action level in the following States (21):

State	Food
Alabama	Chicken
Indiana	Turkey
Iowa	Beef
Mississippi	Chicken
New York	Chicken
Texas	Chicken
Wisconsin	Duck

Wolff, et al. (22) reported that serum PBB was higher for males than females. It was suggested that the greater proportional body fat in women may account for this difference, but exposure may also be important. Males may consume more contaminated food or have more direct contact with PBB than females.

The same study found no consistent trends with respect to age. It was observed, however, that young males had greater concentrations of serum PBB than young females. Young females had greater concentrations than older males, and older males had greater concentrations than older females. It was also found that very young children and individuals who had lived on farms less than 1 year had lower serum PBB levels than other groups (22).

Serum PBB concentration is related to the intensity of exposure. Most studies indicate that consumers and residents of nonquarantined farms had significantly lower PBB levels than residents of quarantined farms; however, families on quarantined farms stopped consuming meat and milk from their own animals (20).

In late 1974, the Michigan Department of Public Health conducted a survey to determine if any adverse effects could be correlated with PBB levels in the body, A sample of 165 exposed persons (quarantined farms) and 133 nonexposed (nonquarantined farms) was studied. Medical history interviews and physical examinations were performed on each subject and blood specimens were taken, Blood PBB levels as high as 2.26 parts per million (ppm) were found in the exposed individuals; about half exhibited levels greater than 0.02 ppm. Of the nonexposed individuals, only two showed blood PBB levels greater than 0.02 ppm; 70 percent of the adults and 97 percent of the children exhibited levels of 0.0002 to 0.019 ppm. Comparison of a list of selected conditions and complaints revealed no significant differences in the frequency of illness between the two groups. Physical examinations and clinical laboratory tests disclosed no effects attributable to "chronic" PBB exposure (24).

The effect of PBB exposure on white blood cell (lymphocyte) function of Michigan dairy farmers who consumed contaminated farm products was examined by Bekesi, et al. (25). Forty-five members of Michigan farm families who had eaten PBB-contaminated food for periods of 3 months up to 4 years after the original accident were compared for immunological function to 46 Wisconsin farmers and 79 New York residents. All of the exposed individuals showed reduced lymphocyte function, and 40 percent showed abnormal production of lymphocytes. There were also significant increases in lymphocytes with no detectable surface markers ("null" cells). However, the short- and long-term health implications of these differences are not now known.

Lillis (20) examined Michigan farmers and consumers of dairy products and found that the effect of PBB on humans was mainly neurological in nature. He found marked fatigue, hypersomnia, and decreased capacity for physical or mental work. Other symptoms included headache: dizziness: irritability; and musculoskeletal, arthritis-like complaints—swelling of the joints with deformity, pain, and limitation of movement. Less severe gastrointestinal and dermatological complaints were also encountered.

Mercury and Methylmercury

Foods are the major source of human exposure to mercury. The mercury concentration in food is dependent on the type of food, the environmental level of mercury in the area where the food is produced, and the use of mercury-containing compounds in the agricultural and industrial production of the food. All living organisms have the ability to concentrate mercury, Therefore, all animal and vegetable tissues contain at least trace amounts (26). Several recent reviews have examined the health effects associated with consumption of mercury (26-28). The results of these reviews indicate that the effects of methylmercury poisoning become detectable in the most sensitive adults at blood levels of mercury of 20 to 50 μg/100 ml, hair levels from 50 to 120 mg/kg, and body burdens between 0.5 and 0.8 mg/kg body weight (26).

Since the Minamata Bay tragedy in Japan, the effects of chronic exposure to methylmercury have been well-documented. Mercury readily accumulates within the central nervous system (29-3 1), and clearance of mercury back into the bloodstream is slow (32). Consequently, the central nervous system is considered to be the critical target in chronic mercury exposure. The clinical symptoms of central nervous system involvement include headache, vertigo, vasomotor disturbance, ataxia, and pain and numbness in the extremities (30). The most prominent structural changes of the central nervous system resulting from chronic mercury exposure are diffuse cellular degeneration (30).

In evaluating the teratogenic hazards of mercury exposure to man, the placental transfer of mercury is particularly significant. Levels that are not toxic to pregnant women are sufficient to produce birth defects in their offspring (33-35). Transfer of methylmercury across the human placenta results in slightly higher blood levels in the infant at birth than in the mother (36). Table 5 compares fetal and maternal blood concentra-

Table 5.— Methylmercury Concentrations in Normally Exposed Populations

Location	Concentration (µg Hg/g)		
	Maternal blood	Placenta	Fetal blood
Japan	0.017	0.072	0.020
Sweden	0.006	—	0.008
Tennessee	0.009	0.021	0.011
Iowa	0.001	0.002	0.001

SOURCE Adapted from B J Koos and L D Longo " Mercury Toxicity in the Pregnant Woman, Fetus, and Newborn Infant " *American Journal of Obstetrics and Gynecology* 126(3) 390, 1976

tions in normally exposed populations in Japan, Sweden, and the United States,

In humans, the most widely reported fetal risk associated with maternal exposure to mercury is brain damage. The placental transfer of mercury and its effects on the human fetus were first recognized in the **1950's** with the well-known outbreak of congenital Minamata disease in the towns of Minamata and Niigata, Japan. By 1959, 23 infants suffering from mental retardation and motor disturbances had been born to mothers exposed to methylmercury during their pregnancies. The clinical symptoms of the infants resembled those of severe cerebral palsy or cerebral dysfunction syndrome. They included disturbance of coordination, speech, and hearing; constriction of visual field; impairment of chewing and swallowing; enhanced tendon reflex; pathological reflexes; involuntary movement; primitive reflexes; superficial sensation; salivation; and forced laughing (30). Only 1 of the 23 mothers exhibited any symptoms of mercury poisoning (32).

Radioactivity

Ionizing radiation (X-rays, gamma rays, or beta particles with sufficient energy to strip electrons from molecules and produce ions) can produce birth defects, mutations, and cancers (37). These adverse health effects are usually associated with high dose levels delivered at high dose rates.

Such a combination is not ordinarily encountered in food. Previous radioactive contamination of foods has involved relatively small quantities of radioactive elements which have delivered low dose rates (38).

In these situations, the effects of the radiation exposure on health are extremely difficult to evaluate. High dose rates (100 million to 1 billion times background) are estimated to produce 2,600 ionization events per second in cells. Background radiation levels are estimated to produce less than one ionization in the cell nucleus per day (37). Because cells have the capacity to repair damage to their genetic material, repair of ionization damage may occur at low radiation exposure. Higher exposures may overwhelm the cells' repair capacity. Whether any effects are observed in such cases depends on several factors. These include the dose delivered to the tissues, the nature of the emissions, and the metabolism of the cell. The following examples illustrate these points:

- Strontium-90 in food arouses most concern not only because of its long half-life but also because it behaves in the body in a manner somewhat similar to calcium. The replacement of bone calcium with strontium-go exposes tissues and cells covering the bone to radiation, In addition, bone marrow is subject to the ionizing radiation from the strontium-go. Thus, cancer of the bone-forming and bone-covering tissue as well as leukemias of the bone marrow blood-forming cells can possibly result.
- **Iodine** is concentrated by the thyroid gland. Radioiodines produced in atmospheric nuclear detonations or released from nuclear power stations are also taken up and concentrated by the thyroid, increasing the risk of thyroid cancer.
- **Tritium,** or radioactive hydrogen, combines chemically with oxygen to form water. Tritium derived from food would be widely distributed throughout the body exposing all tissues to radiation.

The uncertainties surrounding the repair capacities of cells and the irreversible nature of the possible health effects have led to the adoption in the United States of a prudent policy toward low-level ionizing radiation. Since any amount of radiation is potentially harmful, unnecessary exposure should be avoided.

Number of Food Contamination Incidents

Questionnaires were mailed to the commissioners of health in each of the 50 States and the District of Columbia as well as to Federal agencies. For the 10-year period 1968-78, each was asked to report on the number of incidents of environmental contamination of food that resulted in regulatory action. This survey has limitations. Some States did not answer all questions. The questions were subject to interpretation and misunderstanding. The accuracy and completeness of the answers were dependent on the respondent. The results presented are therefore preliminary and do not necessarily represent complete and comprehensive information on all States responding. Nonetheless, these data are the first to be developed on the extent of environmental contamination of food.

Responses were received from 32 States. Seven of the top ten agricultural States and six of the top ten manufacturing States responded to the questionnaire, The agricultural States in the top 10 were California, Texas, Minnesota, Nebraska, Kansas, Indiana, and Missouri. The manufacturing States in the top 10 were California, New York, Michigan, New Jersey, Texas, and Indiana. Three of these States—California, Texas, and Indiana—are in the top ten for both agricultural and manufacturing production. A fairly representative distribution of States responded from each region of the United States (figure 2).

In the following discussions, an incident is defined as a case in which a Federal or State agency has taken regulatory action against contaminated food, The Michigan PBB episode is reported as one incident because the contamination stemmed from one source and was limited to one State. Mercury contamination is reported as separate incidents because the sources differed (environmental mercury v. industrial waste), the States involved are widely separated, and regulatory actions were taken at different times, Eighteen States reported at least one environmental contaminant incident since 1968 for a total of 88 incidents. All food categories were involved and a variety of substances were implicated (see tables 1-3).

The data provided by States are complemented by the Federal responses. The two Federal agencies responsible for regulating the Nation's food supply reported the number of environmental contamination incidents that they had identified since 1968. FDA had 108 reported incidents, and the Food Safety and Quality Service of the U.S. Department of Agriculture (USDA) had 47 reported incidents (see table 3). The combined Federal and State total number of incidents comes to 243.

Neither State nor Federal responses indicated any significant radionuclide contamination episodes during the 1968-78 period. Extensive Government programs for monitoring radionuclides in food exist. Thus far, radionuclide contamination of food has not been found to exceed the exposure limits recommended in the Federal Radiation Council Protective Action Guides. In most cases, the amount of food contamination in the continental United States has never even approached these limits (39), While atmospheric nuclear testing is less a threat today than before the signing of the 1963 Test Ban Treaty, radionuclide contamination of food is still a concern of both Federal and State governments.

The number of food contamination incidents reported to OTA does not represent the total number that has occurred in the United States, only those in which the Federal Government and 18 State governments have taken regulatory action. Many incidents never come to the attention of State or Federal authorities. This is because local government officials can and do handle environmental contaminant incidents by warning offenders or by condemning contaminated products without informing the appropriate State officials. Also, the farmer whose livestock or poultry has been environmentally contaminated may negotiate directly with the firm responsible for the contamination for financial

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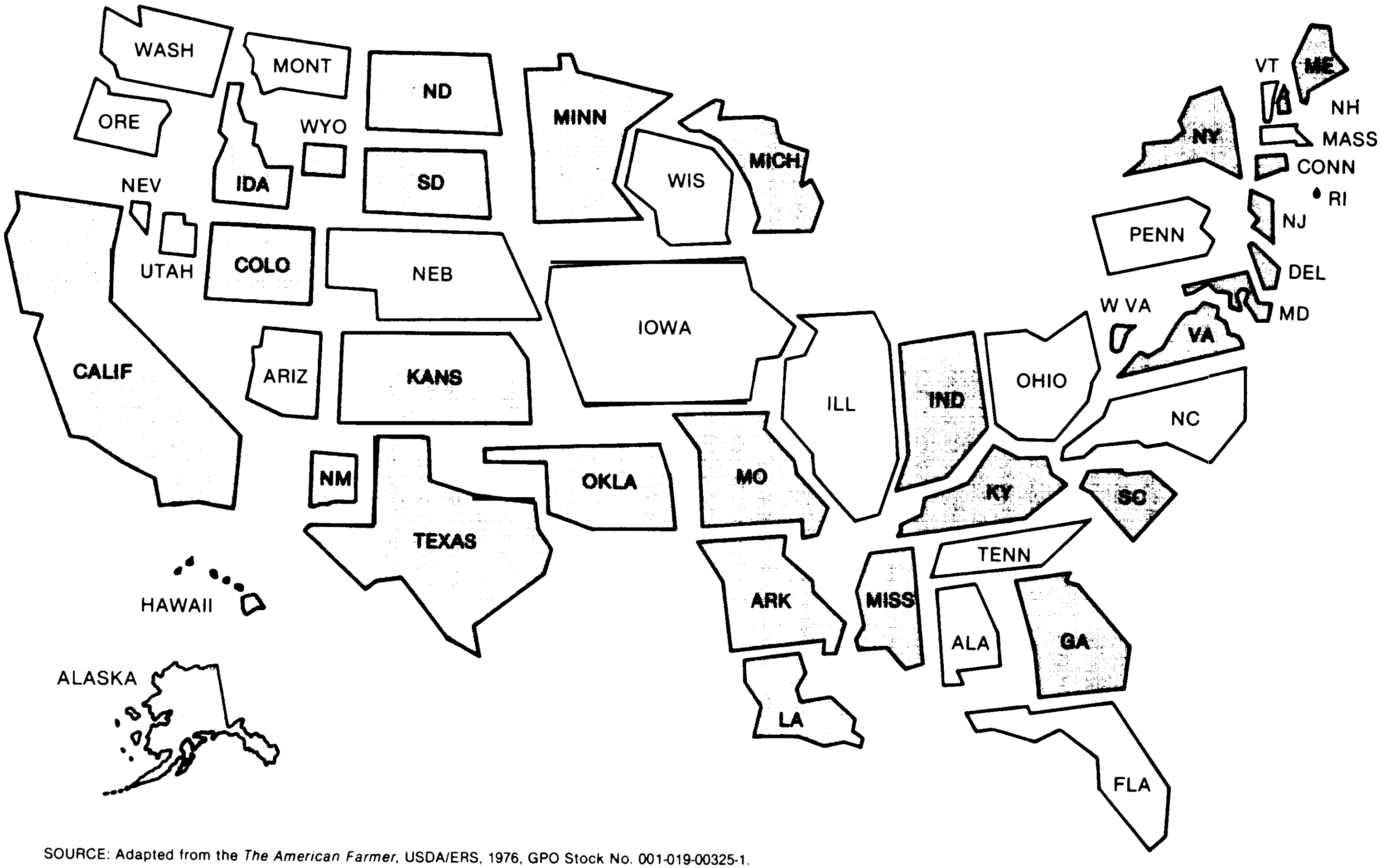
Figure 2.—Distribution of States Responding to Questionnaire

The United States would look like this if the sizes of States were proportional to their value of farm production. The shaded States responded to the questionnaire. The States are ranked by 1974 cash receipts.



SOURCE: Adapted from the *The American Farmer*, USDA/ERS, 1976, GPO Stock No. 001-019-00325-1.

reimbursement without reporting the contamination to Federal or State officials (40).

Economic Impact

The economic impact of an incident involving the environmental contamination of food includes the cost of condemned food, health costs, and the corresponding distributional effects and costs. The magnitude of the economic impact is determined by:

- the amount of food contaminated,
- the concentration of the contaminant in food,
- the chemical and toxicological characteristics of the contaminant, and
- the corresponding regulatory action taken on the contaminated food.

The initial regulatory action taken by Federal and State authorities may be the issuance of a warning or the establishment of either an action level or a tolerance. A more detailed discussion of this regulatory action is presented in chapter III. Action levels and tolerances establish a permissible level for the contaminant in food. Any food found to contain concentrations of the substances above this level is condemned and either destroyed or restricted from being marketed.

Costs of Food Condemned

In addition to the four factors listed above, the cost of condemned food is also affected by its position in the food production and marketing process at the time of condemnation, An action level or tolerance for a contaminant is the most important of the five factors. If no action level or tolerance is set, no food would be condemned and thus there would be no costs incurred. The impact of such a regulation will depend on the exact level of a substance that is allowed to be present in food,

The chemical properties of a contaminant are also important because of the potential for long-term effects on the amount of food affected. Since many contaminants biologically and chemically degrade slowly, their presence in the environment can mean food contamination above the action level or tolerance for many years after the source of the pollution has been stopped. The James River in Virginia, for example, is still closed to commercial fishing several years after kepone discharges into the river have been eliminated. The relative influence for each of these factors on the final cost will vary in each contamination incident.

Estimates of the cost of food condemned through regulatory action are most often expressed in dollars. Consequently, this cost is usually (and incorrectly) cited as representative of the total economic impact. Such costs were collected in OTA's State and Federal surveys. The data, however, only partially reflect the total economic impact for environmental contamination of food in the United States. This is because the cost of condemned food is only one component of the total economic impact of an incident. In addition, few of the incidents reported to OTA included data on the cost of food condemned. OTA estimates from the available data that the total cost of condemned food as a result of environmental contamination in the United States since 1968 is over $282 million (table 6). The only cost estimates used were those clearly stated for an incident by the reporting States or Federal agencies.

State **Estimates.**—Of the 18 States reporting contamination incidents, only 6 provided data on the economic impact in dollar terms. Of those six, Michigan represents 99 percent of the total cost ($255 million) while reporting only 19 percent of the number of incidents in the 18 States. Indeed, Michigan accounts for 90 percent of the total costs reported in the United States while reporting only 7 percent of the incidents that occurred during the 1968-78 period. It must be recognized, however, that 84 percent of Michigan's costs are attributed to the PBB incident. Many incidents reported by State and Federal agencies are considerably smaller than the PBB episode. Thus, the PBB episode is an indication of how severe a contamination incident can be.

Table 6.—Economic Impact of Food Contamination

	Reported incidents	Total estimated cost ($)
State		
Idaho. . .	Dieldrin	$ 100,000
	PCP	3,000
Colorado. . . .	Dieldrin	100
	Mercury	3,700
Maryland,	Mercury	23,000
Texas. . .	Mercury	85,000
Indiana .	Dieldrin	25,027
	Dieldrin	250,000
Michigan.	Mercury	10,000,000
	PCB	30,000,000
	PCNB	100,000
	PBB	215,000,000
	Picloram	12,000
	Chlordane	2,500
	DDT	2,000
	Toxaphene	2,000
	Parathion	328
	Diazinon	13,700
	Pentachlorophenol	28,468
	PCB	150,000
	Dieldrin	12,500
		$255,813,323--
Federal		
USDA/FSQS	Pesticides	18,900,000
	Mercury	63,000
	PCB	7,450,000
	Phenol	350
		26,413,350
Total United States		*$282,226,673*

SOURCE: Off Ice of Technology Assessment

Some States reported the amount of food destroyed without estimating the cost. Kentucky, for example, reported the destruction of **400,000** lbs of milk since 1968 because of pesticide contamination. While such information can be converted into dollars, data on market position and price of product at time of confiscation are not readily available. Many States were unable to provide any estimates on either the cost or the amount of food condemned as a result of reported contamination incidents. New York (with PCBs) and Virginia (with kepone) are two States that could not provide cost estimates for food condemned as a result of environmental contamination. Virginia, however, has initiated a study to determine the economic impact of the kepone incident.

Federal Estimates.—Of the two Federal agencies reporting information to OTA on environmental contaminant incidents, USDA's Food Safety and Quality Service (FSQS) reported food condemnation cost estimates. These estimates, however, only cover livestock and poultry—the food products over which FSQS has regulatory authority. FDA, which has regulatory authority over the remaining food commodities, did not estimate costs for reported environmental contamination incidents (70 percent of the Federal total). Thus, a significant proportion of the total costs for environmental contamination incidents requiring Federal action is unknown. Comparison of the two agency responses with the State responses reveals little duplication in the reporting of incidents.

FSQS cost estimates were determined by the number of animals or pounds destroyed multiplied by the market value at the time of confiscation. Since most of these animals were taken at the farm or wholesale level, the market value was the farm or wholesale price. Most of the losses resulting from FDA actions would be based on a wholesale or retail price because the seized products had advanced further in the marketing system. Therefore, their estimated costs would be greater than if they were seized at the production level (generally the case with FSQS seizures).

Summing up, the available data on the cost of condemned food is limited; consequently OTA's $282 million condemned-food estimate is likely to be a gross underestimation of the actual costs. The true cost would be impossible to estimate from this limited sample.

Health Costs

Health costs are also an important component of economic impact. These costs are incurred by the consumer whose health has or potentially can be affected adversely by a contaminant present in food. These adverse effects can cause illness and death, and the range of effects will vary depending on the toxicity of the contaminant, the concentration of the contaminant in food, and the amount of food consumed.

In this country, the concentration of contaminants has been at levels that have not produced immediate measurable and conclusive effects in exposed populations. Estimates are therefore made for the potential long-term effects on exposed populations from various contaminants in food.

Health costs can be estimated from such projected health effects. Costs would include health care costs for treating illness and burial expenses associated with death. Additional costs would include estimated value of productive days or years lost from work due to the projected illness or death associated with the contaminant in food. All of these health-related costs, however, do not and cannot include the emotional and psychological impacts on those afflicted and their friends and families.

Health costs are not available for previous U.S. food contamination incidents. Approaches and techniques for estimating health costs are discussed in chapter VI.

Distributional Effects and Costs

Distributional effects and costs involve the various people, groups, and organizations who are economically affected by an environmental contamination incident. Information on the extent and distribution of such effects and costs provides a clearer picture of the total economic impact on society. This information is usually couched in descriptive terms. Those who are economically affected are identified but the extent of the impact is seldom estimated in dollars. The exact distribution of costs from an incident through society is affected by the same five factors that influence the cost of condemned food.

Many of the distributional effects and costs for various types of environmental contaminant incidents are discussed in the following sections. The purpose of this discussion is not to identify all the distributional costs but rather to demonstrate the variety of effects and costs that can result from an incident.

Producers.— Food producers are affected economically in different ways by contamination episodes. But all are affected directly when the food they produce is condemned. For example, food found contaminated at the farm level is confiscated and destroyed. This was the case for over 500 Michigan farmers whose dairy herds were partially or entirely destroyed (41). In such cases, farmers either replace their livestock, plant a new crop, or go out of business.

Farmers can be faced with severe economic hardship, since they are not always reimbursed financially for the animals or commodities confiscated. While insurance programs such as the Federal Crop Insurance Corporation are available to cover natural hazards which might destroy crops or livestock, such Federal assistance is not available to farmers for losses from environmental contamination. An injured farmer can obtain a loan at commercial rates or sue the responsible firm for compensation. But the loan and the interest add to a farmer's financial difficulties, and suing for compensation can take time that the farmer may not have.

The commercial fisher is faced with a different situation. If a river, lake, or species of fish is restricted because of environmental contamination, the fisher whose source of income depends on this species or waterway may have few employment alternatives. The alternatives depend to some degree on the extent of the contamination. If the only waterway available in a section of a State or a whole State is closed to commercial fishing because of the contamination, the fisher's source of employment is eliminated until the restriction is ended. Since the restriction can last for years (depending on the chemical stability of the contaminant), the fisher either will have to move to other commercial fishing areas or seek other employment.

Food producers economically affected by the condemnation of contaminated food are likely to incur health costs. This is because many of the producers and their families regularly eat the food that they produce or harvest. Consequently they are exposed to the contaminated food at greater concentrations than the average consumer. This was the case for several farm families in Michigan.

Firms Held Accountable for Environmental Contamination.—In most instances blame for a contamination incident can be established. Those accountable are subject to fines and lawsuits. Firms admitting responsibility often try to settle with producers out of court if possible. Most of the compensation is for the economic damages stemming from the destruction of food or loss of employment. Compensation for people whose health has been impaired as a result of eating contaminated food would be sought through civil litigation. Such litigation, however, is rare in this country, since the level of contamination in food is so low that demonstrating the necessary cause and effect is difficult.

Fines or compensation paid by the firms held accountable for the contamination are, in fact, poor indicators of the true costs incurred by the producers. This is because the settlement costs which are frequently negotiated or imposed bear little relationship to the actual costs incurred.

For example, compensation has been provided by Michigan Chemical Corporation and Farm Bureau Services, Inc., to many of the farmers whose livestock and poultry were destroyed following PBB contamination. Michigan Chemical and Farm Bureau Services have together paid more than $40 million in compensation from a jointly established insurance pool (42). In another case involving PCB-contaminated fish meal sold to poultry producers, Ralston Purina Company negotiated compensation for the 400,000 chickens destroyed. The cost of the compensation has not been disclosed (43).

Governments.—Federal, State, and local governments also incur costs from an environmental contamination incident. Although the Federal Government and most State governments have agencies with programs to regulate or control food safety problems, these programs usually are not funded to handle the kind of long-term problems created by a PBB or kepone incident. The Michigan Department of Agriculture, for example, estimates it will spend $40 million to $60 million within the next 5 years to monitor and test for PBBs in animals and animal byproducts (44). This is money that could have been saved or spent for other programs if PBB contamination had not occurred. In order to recover its expenses from the PBB incident, the State of Michigan filed a lawsuit against both the Michigan Chemical Corporation and Farm Bureau Services, Inc., claiming more than $100 million in damage (45).

Federal involvement is limited unless the contaminated food is part of interstate commerce, Many of these incidents are not considered by the Federal Government to involve interstate commerce, FDA may provide technical assistance at the request of the State government when a contamination incident is regarded to be a local problem (43). These technical facilities and experts are available to all States through the Federal and regional offices. Additional expenditures by the Federal Government for contamination incidents are limited. Additional State expenditures, however, can be substantial. Federal expenditures are made when Federal regulations are developed and promulgated for particular contaminants in food such as PCB.

Consumers.—Consumers can incur costs from an environmental contaminant incident in several ways. The removal of food from commerce could increase prices for that food product or other food products being sold. Thus, the consumer could pay more for food as a result of an environmental contamination incident. In order for this price increase in food to occur, however, a significant amount of a food product or food products would have to be taken off the market. Such prices of food might vary by State or region and affect certain socioeconomic classes differently.

Health costs could increase as a result of the consumption of contaminated food. This would not affect all consumers but rather those who received the most exposure and/or those most susceptible to a contaminant, such as children or senior citizens. While these costs would already be included in estimated total health costs, the distributional effects could indicate those consumers most likely to be affected.

Indirect Costs.—Most of the costs mentioned directly stem from an environmental contamination incident. However, indirect or secondary costs can and do occur. For example, a bait and tackle store on a lake that is closed to commercial and sport fishing because of an environmental contamination is likely to suffer economic hardship, Food processors whose normal supply of food has been condemned because of environmental contamination will also suffer economically unless they find new sources of supply. These are just two examples of the many indirect costs which might occur.

POTENTIAL FOOD CONTAMINATION PROBLEMS

Because a limited number of substances posing health problems already have been identified in food, concern exists that other toxic substances are likely to contaminate food in the future. This concern arises from the number of substances presently being manufactured, used, and disposed of in the United States, and the difficulties in preventing them from entering the environment. New substances developed to meet new needs or to replace known toxic substances may create unexpected environmental problems if not properly controlled. Byproducts of new technologies such as synthetic fuels are also potential environmental contaminants. These are described in appendix A.

There are two methods of objectively assessing possible future contaminants: 1) by sampling the food supply for chemical contaminants and ranking them according to potential hazard and 2) by surveying the universe of industrial chemicals and ranking them according to their potential for entering the food supply in toxic amounts. These methods are discussed in more detail in chapter VII, "Monitoring Strategies. "

Of the three categories of environmental contaminants considered in this report, organic chemicals probably pose the greatest potential environmental and food contamination problems. This conclusion is based on the number, volume, and toxicity of the organics manufactured and used in this country (40). Both trace metals and radioactive substances continue to warrant concern, but not as great a concern as organic substances. The extent of food contamination from these substances depends on our success in preventing them from entering the environment.

CONCLUSIONS AND ISSUES

Data presented here indicate that environmental contamination of food is a nationwide problem of unknown magnitude. Long-term, low-level exposure to toxic substances in food poses health risks that are difficult to evaluate given present techniques. Incidents of high-level contamination of food that cause human illness have not occurred in the United States, However, regulatory actions have been taken to restrict consumption of contaminated food in cases where the potential health risks were considered unacceptable. These episodes have resulted in economic losses when contaminated food was removed from the market,

The following chapters analyze several issues related to the regulation of environmental contaminants in food. These are:

- Is our present regulatory system protecting the public health? (Chapters 111 and IV)

- Are methods used by the regulatory agencies for estimating health impacts the most appropriate ones? (Chapters III and V)
- Should economic impacts be an explicit part of regulatory decisionmaking? If so, how should economic impacts be evaluated? (Chapters III and VI)
- Should regulatory monitoring be capable of detecting substances as they enter the food chain? (Chapters VII and VIII)

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