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Chemistry and Modern Society

In many parts of the world the 30-year period from 1945 to 1976 saw a general improvement in the standard of living of which chemistry was perhaps the main promoter. Food became better and more plentiful; synthetic fibers made clothes available to people too poor to afford the cost of traditional materials; new drugs conquered old diseases. It is not an overstatement to say that society in the industrialized nations is based on the chemical industry.

Statistics show that in the OECD countries (Organization for Economic Cooperation and Development, whose members include, among others, the Western European nations, the United States, Japan, and Canada) chemical production in the decade 1963–1973 increased at a rate of 9.3% per year.[1,*] One important measure of the impact of chemistry's growth is given by the per capita consumption of chemical products. The average Italian, for example, consumed $77 worth of chemicals in 1963 and $247 worth in 1975. In the same period per capita consumption in the German Federal Republic rose from $130 to $424; in Switzerland, from $77 to $335. In the European OECD countries, the average increased from $77 to $334. Table 1.1 illustrates these changes.

From a more strictly industrial point of view, the value added per person employed in the chemical industry is considerable. For the year 1975 it was computed at $32,460 per year for the German Federal Republic, $28,300 for Belgium, and $21,600 for Italy. These figures, listed in table 1.2, form a basis for considering the economic aspects of the chemical industry in general and, in particular, the relative degrees of production in the individual countries. (It is worth

*Numerical superscripts indicate reference citations; alphabetical superscripts indicate notes. Notes and references are to be found at the back of the book.

Table 1.1
Estimated per capita consumption of chemicals in the OECD countries from 1963 (in dollars)

Country	1963	1970	1973	1974	1975
Austria	56[a]	121	285	402	n.a.[b]
Belgium	70	154	297	405	334
Denmark	n.a.	n.a.	248	336	329
Finland	n.a.	130	227	368	405
France	80	141	265	335	340
Italy	77[a]	115	186	254	247
Norway	73	134	208	285	325
Holland	76[a]	172	212	338	294
Portugal	14[a]	47	78	n.a.	n.a.
United Kingdom	113	165	246	347	343
German Federal Republic	130	182	306	392	424
Spain	39	96	196	258	281
Sweden	89	174	261	394	412
Switzerland	77[a]	155	271	364	335
Average OECD, Europe	77[a]	143	242	331	334
Canada	77[a]	109	185	283	285
Japan	59	141	242	294	294
United States	160	227	290	358	377

Source: *L'Industrie chimique 1974/75* for the figures up to 1973; *L'Industrie chimique 1975* for the 1974 and 1975 figures.
a. Excluding man-made fibers.
b. n.a. = not available.

noting that since 1973 the added value for employees in the United States has been *twice* that of Italy—$34,870 versus $17,980 in 1973).

As far as employment is concerned, in 1975 the Italian chemical industry provided jobs for 294,500 people, 39,000 of which were in the fiber sector. Technical and clerical employees numbered 91,800, versus 163,700 blue-collar workers. To these must be added 7,300 employees and 31,700 workers in the textile industry. In Italy white-collar workers constitute 36.4% of the chemical labor force, while in the United States and in the German Federal Republic the percentage is higher, about 42%.

Chemistry is thus a source not only of goods but of jobs, and it is a stimulus for related industries. The size of the principal chemical firms is immense; their sales volumes are enormous. Table 1.3 lists the 10 largest chemical producers in the world in order of sales volumes.

Such impressive growth was undoubtedly favored by the fact that the prices of crude oil remained practically unchanged from 1948 to

Table 1.2
Value added per person employed in the chemical industry in the OECD countries from 1963 (in dollars)

Country	1963	1970	1973	1974	1975
Austria	n.a.[a]	n.a.	n.a.	14,640	n.a.
Belgium	5,040	11,400	22,600	31,300	28,300
Denmark	n.a.	n.a.	n.a.	23,560	26,400
Finland	6,600[b]	9,180	12,850	20,120	22,390
France	7,530[b]	11,890	19,280	23,360	24,600
Italy	6,110[b]	11,020	17,980	21,730	21,610
Norway	6,860[b]	11,770	15,250	19,420	23,420
Holland	5,400[b]	9,710	22,100	n.a.	n.a.
United Kingdom	5,960	8,370	13,980	17,750	18,990
Spain	3,110	5,710	10,500	11,585	15,330
Sweden	7,350	13,400	21,950	29,400	n.a.
Average Europe	5,940	10,270	17,390	22,780	24,390
Japan	4,680	12,610	22,300	24,740	22,720
United States	18,500	23,860	34,870	42,520	n.a.

Source: *L'Industrie chimique 1974/75* for the figures up to 1973; *L'Industrie chimique 1975* for the 1974 and 1975 figures.
a. n.a. = not available.
b. Excluding man-made fibers.

1973 since oil is the main source of not only energy but the most important raw materials in industrial chemistry (with the exception of metals and cellulose). But following the increase in the price of crude oil, the rate of production took a steep downturn. Figure 1.1 shows that this downturn, already appreciable in 1974, reached in the first 6 months of 1975 a rate of 14% in the European countries and 21% in Japan; figure 1.2 illustrates the performance of the chemical industry in its various production branches in this period. These price increases affected the chemical industry more than manufacturing in general: In Italy, for example, from 1973 to 1974 chemical prices rose by about 59.4%, compared with a 31% increase in the price of manufactured products; for the United States, these figures are, respectively, 33.5% and 22%; for France, 31.7% and 27.7%; and for Great Britain, 28.5% and 24.7%. In Western Europe the consumption of chemical products amounted to \$105 billion in 1974, compared to \$81 billion in 1973; for the United States these figures are \$75 billion and \$61 billion, respectively. From 1973 to 1974, however, prices rose by an average of 30%; hence the increase in consumption is more apparent than real.

Table 1.3
The ten leading chemical producers in 1977

Company	Country	Principal products	Sales (×10^3)	Net income (×10^3)
Hoechst	German Federal Republic	Pharmaceuticals, plastics, resins, fibers, dyestuffs, inorganic chemicals, agricultural products	10,041,671	92,969
E. I. du Pont de Nemours	United States	Synthetic fibers, plastics, resins, rubbers, dyes, pigments, fluorocarbons, diesel additives, industrial and agricultural chemicals, pharmaceuticals, explosives	9,434,800	545,100
Bayer	German Federal Republic	Dyestuffs, inorganic chemicals, pharmaceuticals, agricultural products, plastics, synthetic rubber, fibers, raw materials for polyurethane foams	9,220,047	136,169
BASF	German Federal Republic	Plastics, oils and gases, dyes, organic products, fertilizers, raw materials for synthetic fibers, potassium salts	9,115,918	167,444
Imperial Chemical Industries	United Kingdom	Dyestuffs, inorganic chemicals, explosives, plastics, fibers and textiles, paints, chemicals for agriculture and fertilizers, pharmaceuticals, metals	8,139,127	394,476
Union Carbide	United States	Chemicals and plastics	7,036,100	385,100
Dow Chemical[a]	United States	Basic organic and inorganic chemicals, plastics, metals, pharmaceuticals, agricultural chemicals, packing materials	6,234,000	555,700
Montedison	Italy	Organic and inorganic chemicals, fertilizers, fibers	6,183,520	(514,686)
Rhône-Poulenc	France	Chemicals, pharmaceuticals, textiles	4,804,839	17,094
Akzo Group	Holland	Synthetic fibers, organic and inorganic chemicals, pharmaceuticals, coating materials. chemical specialties, food products	4,252,527	(67,865)

Adapted from *Fortune* 92(3):172 (1978).
a. From D. M. Kiefer, "Big chemical producers post moderate growth," *Chemical and Engineering News* 56(18):40 (1978).

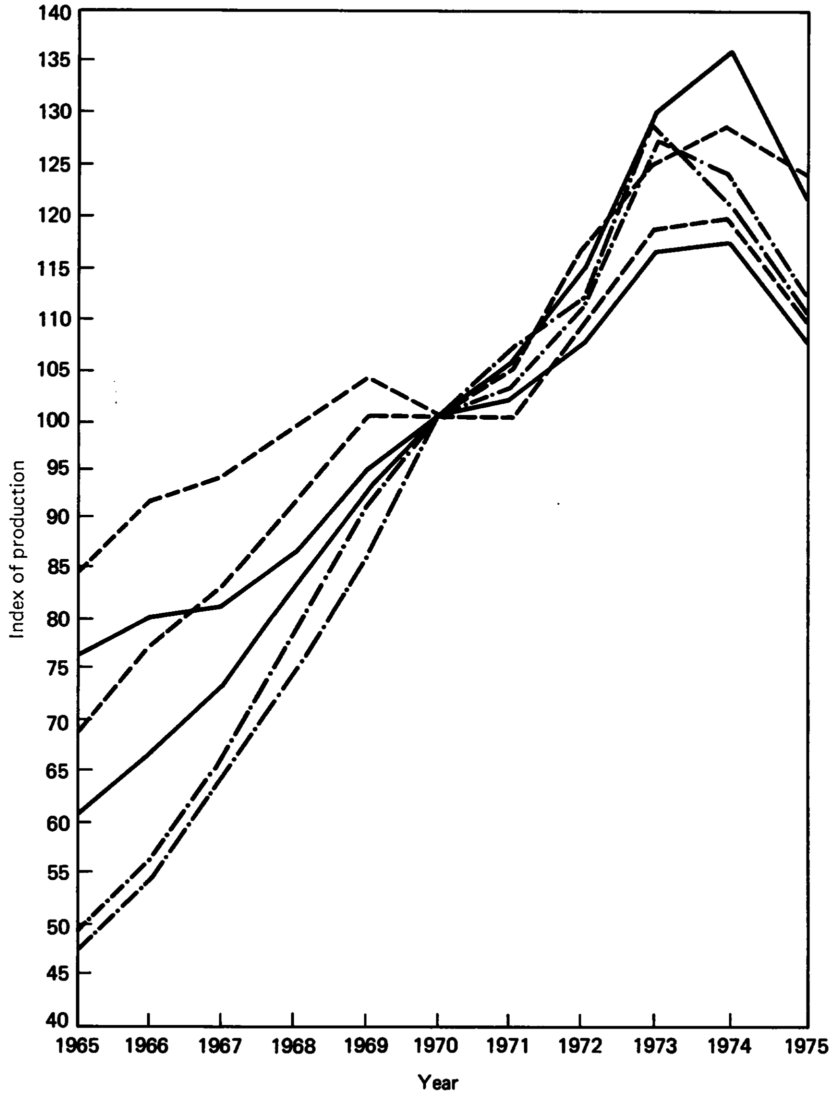

Figure 1.1
Index of production (1970 = 100) for the European OECD countries, the United States, and Japan. Key to production (chemical/total industrial) by country: ———, Europe; ———, United States; —.—.—., Japan. (From *L'industrie chimique 1974/75*, modified by data from *L'industrie chimique 1975*)

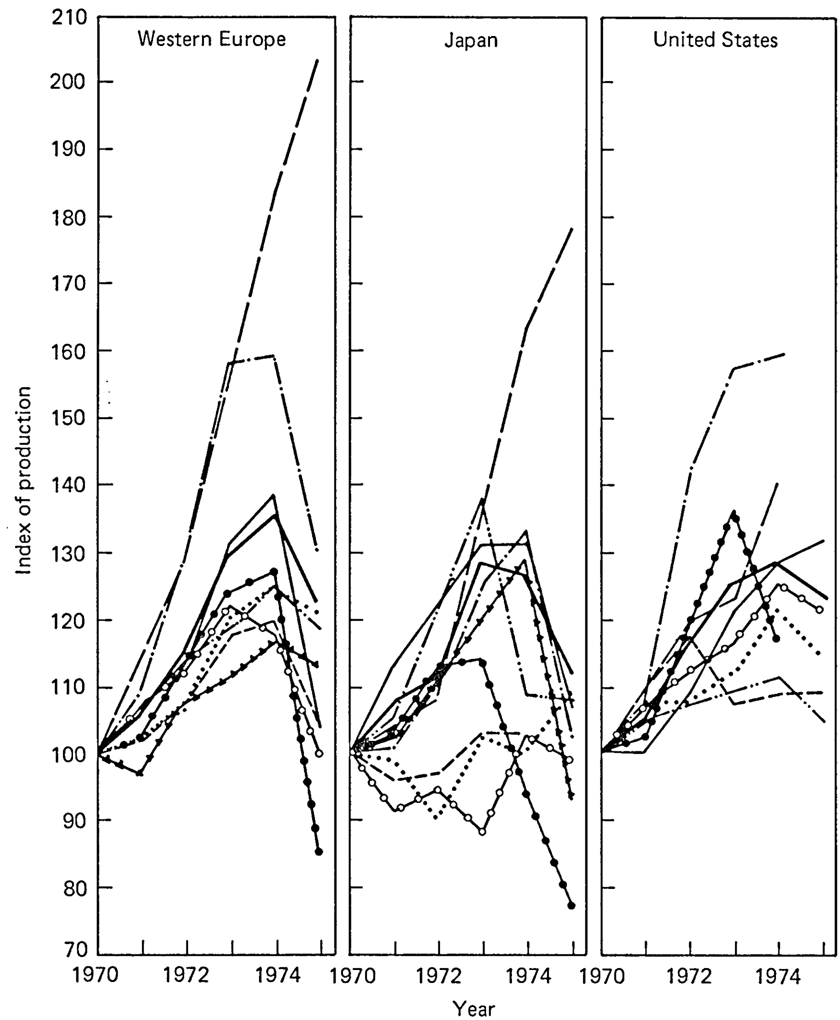

Figure 1.2
Production trends in the major branches of the chemical industry in Europe, Japan, and the United States. Key: ———, organic chemical products; ---, sulfuric acid; —·—·—·, plastics; -●-●-●-, dyestuffs; · · ·, nitrogenous fertilizers; -O-O-O-, phosphatic fertilizers; —· ·—· ·—· ·, paints and varnishes; ———, pharmaceuticals; -▲-▲-▲-, soaps and detergents; ———, total chemical industry. (From *L'industrie chimique 1975*)

Chemistry and the Environment

As these figures show, the amount of chemicals produced and sold throughout the world is truly enormous. According to studies released by the EEC (European Economic Community), world production of organic compounds alone, excluding lubricating oils, amounted to 7 million tons in 1950, 63 million in 1970, and is expected to reach 250 million by 1987. A considerable fraction of these products percolates into the environment. According to fairly reliable calculations, if we take into account the rate at which these substances break down in the environment, it can be shown that in 1975 our planet was contaminated by 60–100 million tons of synthetic organic compounds. To these already fantastic amounts we must add lubricating oils, metals, solid waste, urban refuse, fuel combustion gases, sulfur compounds, oxidants, and so forth, all of which pollute our soil, water, and air.

Despite the abatement measures adopted by urban communities and industries, part of the polluting load is not eliminated and ends up in the water we drink, and in the air we breathe. The most dangerous water pollutants are toxic metals (such as lead, selenium, arsenic, chromium, and cadmium), chloride derivatives (some industrial solvents), nitrates, and detergents. Among the numerous air contaminants the most hazardous to human health are carbon monoxide, generated by furnaces and automobile engines; sulfur oxides, produced in the combustion of sulfur-containing fuels such as diesel, oil, and coal; nitrogen oxides, generated mostly by motor vehicles; residues of unburnt hydrocarbons; soot; and industrial dusts.

Once in the atmosphere, moreover, these pollutants often react with each other or with normal atmospheric constituents. Such interactions, which may be activated by ultraviolet radiation or the ozone present at high altitudes, result in the formation of a variety of compounds that are among the most troublesome to control. The most dangerous of these secondary pollutants are peroxide compounds, which are associated with the major air pollution disasters in Pennsylvania in October 1958 (20 persons died and 6,000 became ill) and in London in December 1962 (thousands of casualties, especially among elderly people suffering from chronic bronchitis).

Toxicity of Chemicals

With the exception of pharmaceutical products, food additives, pesticides, and herbicides, only a few of the many chemicals introduced into commerce every year undergo extensive toxicological tests. Although care is taken with notoriously unsafe products such as arsenic derivatives, lead salts, and toxic gases like carbon monoxide or phosgene, most chemicals are usually marketed and used without great precautions.

Intoxication, however, can occur, and often does, from the prolonged absorption of substances that are not known to be highly toxic but nonetheless possess a degree (albeit small) of toxicity. When absorbed by the organism over long periods of time, even in small amounts, such substances may accumulate beyond the threshold level and cause intoxication symptoms. By and large, it is extremely difficult to establish a cause-and-effect relation between poisoning and the responsible toxin. People move from place to place, eat all kinds of things, drink alcoholic beverages, take medications, breathe exhaust fumes. Frequently, intoxication is caused not by a single chemical agent but by a mixture of compounds that potentiate each other (a phenomenon known as *synergism*). It is symptomatic that the deleterious effects of protracted exposure to low-toxicity agents are usually revealed—if and when they are—by epidemiological studies conducted on factory workers who are professionally exposed to certain chemicals for long periods of time. It is in this manner that the carcinogenic properties of some substances (arsenic, asbestos, some aromatic amines, and vinyl chloride) have been discovered, as well as the toxic effects of benzene (an ingredient of glues), tri-*o*-cresyl phosphate, and other compounds used in factories as raw materials or industrial aids.

It is now generally accepted that *there is no safe substance; anything, taken in sufficient quantity, is toxic.* The toxic action may be acute and immediate or it may be a slow, insidious process. In the latter case there are two main factors that determine intoxication: accumulation of the substance in the organism and reinforcement of the effects. Many substances are retained by the organism for a length of time that varies from chemical to chemical and depends to a large extent on the conditions of the organism itself (state of health, age, metabolism, and so on). When one of these substances is absorbed with a certain continuity in either large or small amounts, if the body cannot eliminate it at a high enough rate, the substance *accumulates* and may eventually reach a level such that symptoms of intoxication develop. This is the case for compounds that are soluble in fats but not in water, such as DDT and other chlorinated hydrocarbons, organic derivatives of heavy metals (e.g., methyl mercury chloride, chief cause of the collective poisoning at Minamata, Japan), and phenol derivatives.

Reinforcement of the effects is a property of some carcinogenic substances. The development of symptoms in this case depends on the total amount absorbed by the organism—regardless of the length of absorption time, the size of the individual doses, and the rate of elimination. The effect persists even if the substance is eliminated from the body. Thus, if such a substance is absorbed even in minute amounts for a sufficiently long period of time, cancer may develop. This effect is sometimes due to the absorption of more than one substance, each having a certain degree of carcinogenity. The individual effects can also potentiate each other.[2]

Chemistry and Man's Health

The multitude of chemical products to which modern man is exposed may all be toxic to some extent. Some of these health hazards arise from the voluntary absorption of chemicals, in the form of cigarette smoke, foods, alcohol, cosmetics, and other commonly used products. Others are beyond individual control. Pollution affects us in all our functions. Air contaminants with irritating effects (peroxides, ozone, and soot, for example, all of which are found in urban smog) cause eye troubles (keratitis, allergic conjunctivitis) and respiratory ailments (allergic rhinitis, laryngitis, acute and chronic bronchitis, asthma, emphysema). Two other diseases of environmental origin involving the respiratory tracts are silicosis and asbestosis, both of which, however, are associated with specific professional activities. Our skin is particularly vulnerable to radiation and atmospheric pollutants. Dyes, detergents, and even textiles can have a pathogenic effect on it. And through the skin we can absorb noxious substances such as hydrocarbons and lead compounds formed from tetraethyl lead.

In addition to specific ailments for which a cause-and-effect relation between responsible agent and pathology can be ascertained with a certain precision, man faces a very serious problem in the growing incidence of cancer. Epidemiological studies conducted in the United States, France, and Great Britain show beyond any doubt that a definite connection exists between the spread of chemical products and cancer development. According to the 1975 report of the Council on Environmental Quality,[3] from 1900 to 1970 cancer as a cause of death rose from eighth place (3.7% of the total number of deaths) to second (17% of the total); see table 1.4. (It should be noted, however, that this

Table 1.4
Leading causes of death: 1900, 1960, and 1970

Rank	Cause of death	Deaths per 100,000 population	Percent of all deaths
	1900: all causes	(1.719)	(100)
1	Pneumonia and influenza	202.2	11.8
2	Tuberculosis (all forms)	194.4	11.3
3	Gastritis, etc.	142.7	8.3
4	Diseases of the heart	137.4	8.0
5	Vascular lesions affecting the central nervous system	106.9	6.2
6	Chronic nephritis	81.0	4.7
7	All accidents[a]	72.3	4.2
8	Malignant neoplasms (cancer)	64.0	3.7
9	Certain diseases of early infancy	62.5	3.6
10	Diphtheria	40.3	2.3
	Total		64
	1960: all causes	(955)	(100)
1	Diseases of the heart	366.4	38.7
2	Malignant neoplasms (cancer)	147.4	15.6
3	Vascular lesions affecting the central nervous system	107.3	11.3
4	All accidents[b]	51.9	5.5
5	Certain diseases of early infancy	37.0	3.9
6	Pneumonia and influenza	36.0	3.5
7	General arteriosclerosis	20.3	2.1
8	Diabetes mellitus	17.1	1.8
9	Congenital malformations	12.0	1.3
10	Cirrhosis of the liver	11.2	1.2
	Total		85
	1970: all causes	**(945.3)**	**(100)**
1	Diseases of heart	**362.0**	**38.3**
2	Malignant neoplasms (cancer)	**162.8**	**17.2**
3	Cerebrovascular diseases	**101.9**	**10.8**
4	Accidents	**56.4**	**6.0**
5	**Influenza and pneumonia**	**30.9**	**3.3**
6	**Certain causes of mortality in early infancy[c]**	**21.3**	**2.2**
7	**Diabetes mellitus**	**18.9**	**2.0**
8	**Arteriosclerosis**	**15.6**	**1.6**
9	**Cirrhosis of the liver**	**15.5**	**1.6**
10	**Bronchitis, emphysema, and asthma**	**15.2**	**1.6**
	Total		**85**

Source: Council on Environmental Quality, *Environmental Quality: Report VI.*
a. Violence would add 1.4%; horse, vehicle, and railroad accidents provide 0.8%
b. Violence would add 1.5%; motor vehicle accidents provide 2.3%; railroad accidents provide less than 0.1%
c. Birth injuries, asphyxia, infections of newborn, ill-defined diseases, immaturity, etc.

increase is made more impressive by the concurrent decline of other diseases, once terminal but now curable.)

There is general agreement on the estimate that 60–90% of all cancer cases can be traced to environmental factors, both natural and man-made. Preeminent among them is smoking, followed by natural radiation and then by the absorption of natural or synthetic chemicals. With regard to environmental influence on cancer development it is interesting to read the following excerpt from an article by John N. P. Davies and his coworkers:

> A growing body of evidence suggests that the environment plays an essential role in the development of most human cancers. . . . Cancer registries have demonstrated major differences in occurrence of each anatomic type of cancer in various parts of the world. . . . This can be easily exemplified by briefly examining the situation with respect to gastrointestinal cancer. . . .
>
> Cancer of the stomach is a major site of cancer death. It is the fifth leading cause of death from cancer in the United States and the leading cause of death from cancer in Italy. The frequency of stomach cancer has been declining rapidly in many countries during recent years. In the United States, for example, the rate has fallen by more than 50% in the last thirty years, and in Scandinavian countries such as Norway, an extremely high incidence area, a smaller but significant decline has been observed in recent years.
>
> There are wide geographic variations in the occurrence of stomach cancer, it being particularly common in Japan, Iceland, Chile and several European countries. The rates in Australia, Canada and the United States are relatively low. The frequency of gastric cancer appears to be higher in Northern China than in the southern part of this country and may partially be related to the greater coarseness of food in the former. In addition, a comparison of the diets in Japan and Iceland, both areas of high incidence, demonstrated marked dietary differences. These differences both within a given country (e.g. China) and between countries (Japan and Iceland) suggest a multiplicity of environmental agents not necessarily the same.
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> Observations of migrating populations are of great interest. Persons moving to another country, and their children born in that country, tend to take on the cancer risk of the country to which they migrate. This is true for many types of cancer. Stomach cancer is more common in Poland than in the United States. Americans of Polish descent, however, have a rate similar to that of other Americans. Japanese living in Japan have a higher risk of developing stomach cancer than Japanese living in California. The opposite is true for prostate and colon cancers, diseases common in the United States.
>
> Within a particular community, people of different income levels may have different cancer risks. Stomach and cervix cancers are more

common among poor persons, while breast cancer, Hodgkin's disease, and perhaps prostate cancer and leukemia are more common in upper-income groups.[4]

Let us consider some specific cases. In June 1973 the EPA (Environmental Protection Agency) reported that asbestos microfibers had been found in the drinking water of Duluth, Minnesota. These fibers originate from the dumping of 67,000 tons a day of taconite, a low-grade iron ore processed by the Reserve Mining Company. As asbestos has marked carcinogenic properties, a number of measures have been taken to protect the local population from a danger whose magnitude is still unknown; the first symptoms of cancer from asbestos appear after a lag phase of about 20 or 30 years.

Another case of chemically induced cancer involves a synthetic compound, vinyl chloride. In January 1974 the National Institute of Occupational Safety and Health announced that the Goodrich Company had determined that the death by angiosarcoma of three workers involved in the production of PVC (polyvinyl chloride) could be related to the prolonged absorption of even small amounts of vinyl chloride during working hours.

Since then, additional cases of angiosarcoma have been found among workers in PVC plants and the carcinogenic properties of vinyl chloride are now clearly established. What is not known with any certainty is the number of workers that will be affected since the induction period for cancer is generally longer than 15 years and PVC production started just about 15 years ago.

Statistical studies conducted in England show that the death rate for lung cancer is far higher in cities and industrial areas than in the country: 64 in 100,000 in rural areas, 84 in towns with less than 50,000 people, and 112 in cities with more than 100,000 people. Similar results have been found by Dutch and Norwegian researchers in their respective countries.[4]

The prime culprit is tobacco. Some scientists estimate that cigarette smoking is responsible for 70% of all cases of lung cancer (The remaining 30% would be due to environmental factors). Furthermore, tobacco may act in synergism with other pollutants of the environment and with the carcinogens absorbed from the myriad of chemicals we are exposed to in our daily lives. In this light, the statement made in April 1974 by Benjamin F. Byrd, president of the American Cancer Society, appears entirely justified: "Wipe out smoking, and you eliminate some 15 to 20% of all cancer deaths."[5]