Proc. Natl. Acad. Sci. USA
Vol. 89, pp. 3508–3510, April 1992
Medical Sciences

Are the stray 60-Hz electromagnetic fields associated with the distribution and use of electric power a significant cause of cancer?

(leukemia/nonionizing radiation)

J. D. JACKSON

Lawrence Berkeley Laboratory and University of California at Berkeley, Berkeley, CA 94720

Contributed by J. D. Jackson, January 15, 1992

ABSTRACT **The putative causal relation between ambient low-frequency (50 or 60 Hz) electromagnetic fields (necessarily present in living and working environments because of our ever increasing use of electrical devices) and cancer, especially leukemia, can be tested on the large scale by examining historical data on the growth of the generation and consumption of electric power since 1900 and corresponding data on cancer death and incidence rates. The United States per capita generation and residential consumption of electric power have grown roughly exponentially since 1900; total per capita generation has increased by a factor of 10 since 1940, and per capita residential consumption has increased by a factor of 20 in the same period. The ubiquitous stray fields from power distribution lines and internal and external wiring in buildings have grown in the same proportions. In contrast to the explosive increase in the generation and use of electricity, the age-adjusted cancer death rate for the population as a whole shows only a slight rise since 1900. When respiratory cancers (largely caused by tobacco use) are subtracted, the remaining death rate has actually fallen since 1940. That the death rate may have fallen because of better diagnosis and treatment, despite a rising incidence rate, is not substantiated, especially for leukemia, including childhood leukemia, where the incidence rate has been constant or declining slightly for the past 25 yr. The absence of any appreciable change in the national cancer incidence rates during a period in which residential use of electric power has increased dramatically shows that the associated stray 50- or 60-Hz electromagnetic fields pose no significant hazard to the average individual.**

An issue of recent concern is the possibility that overhead electric transmission lines, transformers, local distribution systems, and even household wiring and appliances produce stray low-frequency (50 or 60 Hz) electromagnetic fields that are harmful to humans and may induce cancer, especially leukemia. Research on the subject has been inconclusive. United States national advisory bodies are at present determining the appropriate course of action to address the issue productively. This note is intended to look at the problem pragmatically, to establish whether there is any appreciable threat to most people from the stray fields inevitably present in our increasing reliance on electrical devices for work and play. It is assumed that, in the use of electrical appliances, people are aware of the possible hazards from improper or careless operation of the devices. The question at issue is the danger or lack of danger to the general population from unavoidable exposure to the ever present, low-intensity, 50- or 60-Hz stray fields associated with the use of electric appliances or proximity to normal electric distribution lines and internal wiring in buildings.

The publication costs of this article were defrayed in part by page charge payment. This article must therefore be hereby marked "*advertisement*" in accordance with 18 U.S.C. §1734 solely to indicate this fact.

The overall statistical evidence presented here cannot address the question of whether some numerically insignificant populations are or are not at risk from stray electromagnetic fields. No reliable data exist to imply such risks, but those issues, while interesting and worthy of study, are not relevant in assessing the risk to the general population.

Since 1900 (until the 1980s) the use of electricity in the United States has grown nearly exponentially. In 1882, Edison started with 59 customers using direct current, but in the early 1900s alternating current was adopted, and by 1920 long-distance transmission lines (over 200 miles) at high voltage came into operation. The delivery system for electric power to users has changed in quantity but not in kind over the years. Long-distance transmission is at voltages of 230–350 kV on lines mounted on high towers; local distribution from substation to transformer is typically at 11–15 kV. In large metropolitan areas, local distribution is underground, but for much of the nation the power comes along the streets on lines mounted 20–30 feet above the ground on wooden poles to the neighborhood transformer, where the voltage is stepped down to single-phase 110/240-V residential service or three-phase 208Y/120-V commercial service. Within buildings the power is routed by conduits in the walls to outlets for lights, equipment, and appliances.

In going about our business of living and working we have been exposed constantly to whatever stray fields are associated with this delivery system of electric power, in more or less the same way for three quarters of a century. A good measure of the presence of stray electromagnetic fields possibly capable of adversely affecting biological processes in each person is, therefore, the total electric power generation per capita or the per capita residential power consumption. If some correlation exists, though small, between the prevalence of stray electromagnetic fields in the environment and certain types of cancer, there should be a marked historical increase in the incidence of cancer with the years since 1900.

Growth of the per capita generation of electric power by utilities and per capita residential consumption in the United States from 1900 to 1990 is shown in Fig. 1. Overlapping data exist from 1900 to 1970 and from 1949 to 1990 (1, 2). (Data from table S36 of ref. 1 from the overlap period 1949–1970 agree exactly with those of table 89 of ref. 2. Similarly, data from table S121 of ref. 1 agree within a few percent with those of table 94 of ref. 2. In both refs. 1 and 2, Alaska and Hawaii are included in the figures beginning in 1959.) Power generation, rather than overall consumption, is used because it includes the losses in transmission, a component of the distribution system brought into question by those who suspect some cause and effect. The data on residential use are of interest because they show an even steeper rise than the total generation. The national figures were converted to per capita data by using historical data on the U.S. population (3). (Table 2 of ref. 3 includes the populations of Alaska and Hawaii starting in 1940. The figures from 1940 to 1959 have been corrected to eliminate these states to be consistent with

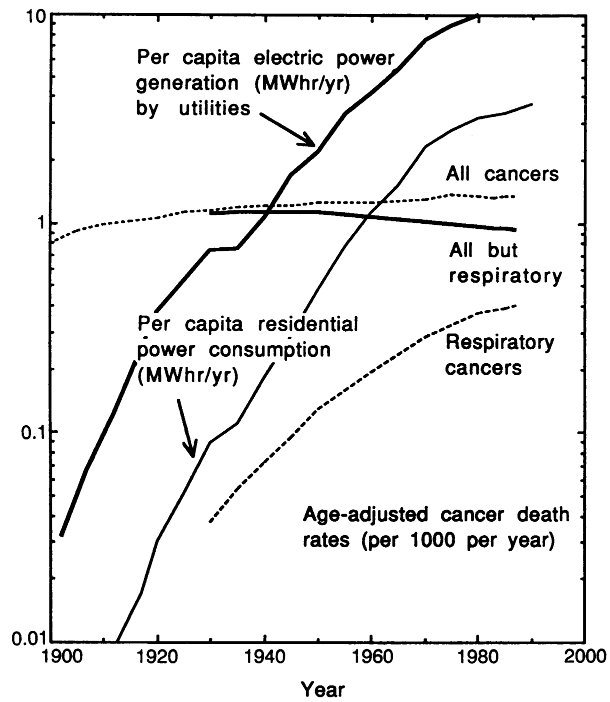

FIG. 1. United States per capita electric power generation by utilities and per capita residential consumption (MWhr per yr per capita) from 1900 to 1990 and death rates (per 1000 per yr, age-adjusted to the 1940 census population) from all cancers, respiratory cancers, and all except respiratory. (Power generation data for 1900–1949 are from ref. 1; data for 1949–1990 are from ref. 2. Cancer death rates for all cancers, 1900–1945, are from ref. 4, table 3, no. 1; cancer death rates for all cancers and respiratory cancers for 1950–1987 are from ref. 5; cancer death rates for respiratory cancers for 1930–1945 are from ref. 4, table 2, no. 3.) The power data displayed are for power generated by utilities, both public and private [additional power (≈20% in 1950, 7% in 1970) is generated independently by industry for its private use].

the electric power data of refs. 1 and 2. The corrections amount to <0.5% for those years.) The United States per capita electric power generation by utilities has increased by a factor of >300, from 32 kW·hr/yr in 1902 to 11.2 MW·hr/yr in 1990, with a factor of >10 in the past 50 yr. Per capita residential consumption was only 8% of power generation in 1920, rose to 17% in 1940, and is now at 33% of generated power. The increase in the past 50 yr has been a factor of 20. Because the basic designs of the delivery systems have not changed significantly over the years, the unavoidable low-intensity, low-frequency, stray electromagnetic fields associated with the distribution systems, not to speak of the myriad lights and appliances in homes and offices, have increased by roughly the same factors. The average individual at home is exposed to 20 times as much in the way of stray electromagnetic fields as he or she would have been 50 yr ago.

The cancer data available over the full period, 1900 to the present, are those on age-adjusted death rates* from all cancers [ref. 4, table 3, no. 1 (data are age-adjusted to the 1940 census population); ref. 5 (mortality data are age-adjusted to the 1940 census population)] and, since 1930, from respiratory cancers [refs. 4 and 5; ref. 4, no. 3, table 2 contains death rates from specific causes for the death registration states (10 northeastern and midwestern states plus the District of Columbia). The percentage of respiratory cancer deaths was

*Data for different years are adjusted for differences in the age distribution of the population to the distribution for some standard year. For the data in Fig. 1, the age adjustment is to the 1940 Census population. For Fig. 2, it is to the 1970 Census population.

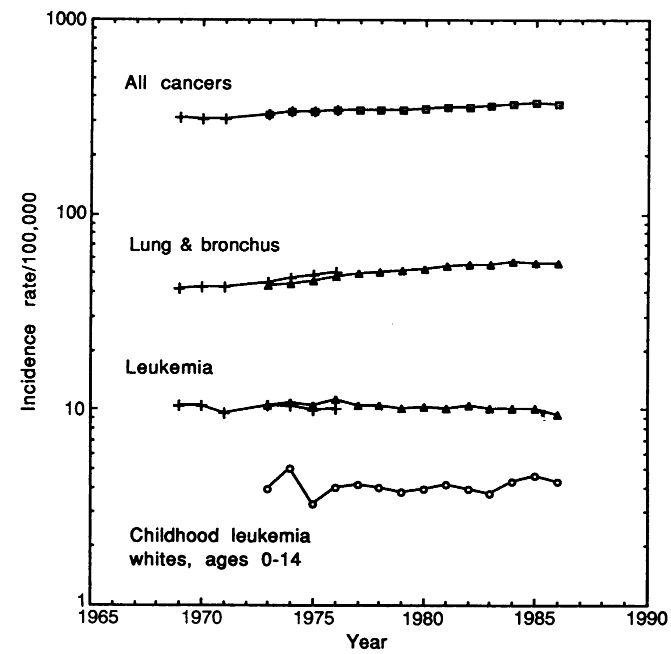

FIG. 2. United States age-adjusted incidence rates (per 100,000 per yr) of all types of cancer, cancers of the lung and bronchus, leukemia, and childhood leukemia (whites, ages 0–14) for the period 1969–1986. The age adjustment for these data is to the 1970 Census population. (Data for 1969–1976 are from ref. 6; data for 1973–1986 are from ref. 7, tables III-9 and VI-35.)

scaled to age-adjusted total rate of table 1, ref. 4, no. 1]. These rates (per 1000 per yr, not the usual per 100,000) are plotted in Fig. 1, along with the difference between the two. The last is the relevant rate because a large portion of respiratory cancers are caused by smoking.† One sees that the cancer death rate has increased relatively little, from 0.8 deaths per 1000 per yr in 1900 to 1.3 deaths per 1000 per yr in 1970 and has been essentially constant since then. Some increase in the early years is surely attributable to more complete reporting of the cause of death, as well as other factors associated with societal changes. Since 1940 the death rate from all cancers except respiratory has been slowly declining (from 1.12 per 1000 per yr in 1940 to 0.93 per 1000 per yr in 1987). These minor increases and decreases have occurred during a period of extremely rapid growth of the generation and use of electric power by society. The national data shown in Fig. 1 are *prima facie* evidence that the stray low-frequency electromagnetic fields associated with the generation, distribution, and use of electricity in the home and office are no significant cause of cancer deaths.

One should note, however, that the data on cancer in Fig. 1 are death rates, not incidence rates—that is, rates of newly diagnosed cancers. Conceivably, the more or less constant cancer death rate could be a combination of a rapidly increasing incidence of cancer (caused by stray electromagnetic fields, among other causes) and a sharply increased rate of cures as a result of improvements in medical diagnosis and treatment. Such an explanation is not supported by the facts, despite the extensive research on cancer and undoubtedly dramatic successes in the treatment of some forms. Reliable

†In the spirit of Fig. 1, one can compare national figures for cigarette production (1) with the incidence of respiratory cancers (ref. 5, table 48) some years later. For example, average daily per capita cigarette production rose from 3.9 in 1940 to 7.7 in 1960, a factor of two. In the same time interval, delayed 20 yr, incidence of respiratory cancers rose from ≈33 per 100,000 in 1960 to 58 per 100,000 in 1980, a factor of 1.7. Such correlations do not prove, but certainly support, a connection between smoking and respiratory cancers.

national data, treated in a consistent fashion, on trends in cancer incidence have only been available in the past 20–25 yr. In particular, detailed data on the United States national age-adjusted incidence rates of various cancers exist from 1969 to 1986 (refs. 6 and 7; table III-9 of ref. 7 for cancer incidence, all sites, lung and bronchus, and leukemia; table VI-35 for childhood leukemia, whites, ages 0–14). These data are shown in Fig. 2 for all cancers, lung and bronchial cancers, leukemia, and childhood leukemia. In the 18 yr there has been a 19% increase in the total incidence rate, a 35% rise in the incidence rate of respiratory cancers, and a decrease, if anything, in the total incidence of leukemia. The incidence rate of childhood leukemia, of particular concern, is essentially constant at 4.1 ± 0.4 cases per 100,000 for the 14-yr period 1973–1986. Cancer-incidence rates evidently have not risen significantly with the rapidly increasing generation and consumption of electric power per capita (roughly a factor of two in the period covered in Fig. 2). Furthermore, the data in table III-9 of ref. 7 show that the slow increase in total incidence rate of $\approx$0.93% per yr over the period 1969–1986 is caused largely by increases in the incidence rates for four sites accounting (in 1980) for 53% of the total—lung and bronchus (15%), colon and rectum (14.4%), breast (14.3%), and prostate (9.2%). The remaining 47% of cancer incidences show an average rate of increase of only 0.24% per yr. Cancers at the four sites mentioned (and those of some of the less common sites within the 47%) each have established or inferred causes that do not include 60-Hz electromagnetic fields. Thus, only a very modest fraction, at most, of the 0.93% per yr increase in the total incidence rate could conceivably be attributed to these fields.

Leukemia, in particular, shows absolutely no sign of increasing incidence; for the period 1950 to the present, the absence of an increase in the incidence of leukemia in the state of Connecticut with increasing power consumption has been noted elsewhere (8). One might argue that the reason one sees no rise in the incidence rate is that there may be a very long latency for cancers induced by weak 60 Hz electromagnetic fields. Such an argument cannot be disproved, but it makes the concerns more or less moot at present. This way out runs counter to the claim that such fields cause leukemia in children.

Conclusions from the data of Figs. 1 and 2 and ref. 7 are that (*i*) there cannot be any *significant* cause of cancer from the use of electricity in society; (*ii*) there is no evidence to support the claim that stray 50- or 60-Hz electric and magnetic fields cause leukemia—the 20-fold increase (2000 %!) in per capita residential use of electric power in the last 50 yr (with the same increase in ambient stray fields), with no appreciable change in the incidence of leukemia is strong contrary evidence.‡ These conclusions will not come as a surprise to scientists concerned with the issue. There is broad agreement that the hazards to the average person are insignificant; any disagreements are confined to questions of possible risk to very small segments of the population particularly susceptible for one reason or another.

The average person has nothing to fear about sleeping next to an electric radio/alarm, using household appliances, or walking under high-tension power lines. He or she should, however, think twice about lighting up and look both ways before crossing the street.

‡Coherent studies of the incidence of site-specific cancers, such as leukemia, earlier than 1969 are not common. Devesa and Silverman (9) report results of the Second (1947–48) and Third (1969–1971) National Cancer Surveys. For the periods 1947–1949 and 1969–1971, they give the leukemia incidence rates per 100,000 (age-adjusted to the 1950 population) as 7.6 and 8.4, respectively, corresponding to a 10% change over 20 yr. The rates in ref. 6 (for 1969–1971) and 7 (for 1973) are 10.2 and 10.5, respectively. The 18% discrepancy between the two values for 1969–1970 far exceeds the correction for the different age-adjustment dates and indicates the uncertainties associated with attempts to combine different data sets. Nevertheless, we may conclude that the overall leukemia rate has increased 10–15% at most in 40 yr and probably much less.

This work was supported in part by the Director, Office of Energy Research, Office of High Energy Physics and Nuclear Physics, Division of High Energy Physics of the United States Department of Energy under Contract DE-AC03-76SF00098.

1. Bureau of the Census (1975) *Historical Statistics of the United States, Colonial Times to 1970*, Bicentennial Edition (U.S. Dept. Commerce, Washington), Part 2, Table S36, p. 820; Table S121, p. 828.
2. Energy Information Administration (1991) *Annual Energy Review 1990* (U.S. Dept. Energy, Washington), DOE/EIA - 0384(90), Table 89, p. 205; Table 94, p. 215.
3. Bureau of the Census (1990) *Statistical Abstract of the United States: 1990* (U.S. Dept. Commerce, Washington), 110th Ed., p. 7.
4. Federal Security Agency (1951) *Vital Statistics—Special Reports, Trend of Cancer Mortality in the United States, 1900–1945* (U.S. Public Health Serv., Natl. Office Vital Stat., Washington), Vol. 32, Nos. 1–9.
5. National Center for Health Statistics (1990) *Health, United States 1989* (U.S. Public Health Serv., Hyattsville, MD), Table 23, p. 121.
6. Office of Technology Assessment (1982) *Cancer Risk* (Westview, Boulder, CO).
7. National Cancer Institute (1990) *Cancer Statistics Review, 1973–1986* (Natl. Inst. Health, Bethesda, MD), NIH Publ. 90-2789.
8. Adair, R. K. (1991) *Health Phys. Newslett.* **19** (10), 18–20.
9. Devesa, S. S. & Silverman, D. T. (1978) *J. Natl. Cancer Inst.* **60**, 545–571.