Health Issues 11

Over the past several years, concerns have been raised about the potential health risks of portable cellular telephones and emissions from radio antennas. These concerns are rapidly becoming one of the most controversial issues surrounding the widespread use of wireless technologies. Although some research on possible adverse health effects has been conducted, it has not been conclusive—government, industry, and academic researchers agree that it is not yet possible to say with certainty whether the devices or the antennas do or do not pose a risk to human health or how serious any risk may be. As a result, the long-term issues surrounding the health and safety effects of cellular telephones and other wireless devices remain unresolved. In the face of this uncertainty, the debate over the safety of wireless devices and systems is likely to become an important public policy problem as concerned citizens take their concerns to state and federal policymakers and regulators.

OTA did not conduct an indepth assessment of the possible health effects associated with radio communication devices and systems. Nor did it exhaustively review and critique the health effects research conducted to date. Such an endeavor is properly the focus of an additional, more narrowly focused study. Rather, this chapter presents only a general overview of the research performed to date, and discusses the controversy that surrounds these issues.

FINDINGS

The debate over the safety of wireless systems is characterized by high emotion and heated rhetoric—on all sides. Picking through the rhetoric and separating fact from fiction will be extremely difficult for lawmakers and regulators as the controversy continues.

The findings presented below are based on the general state of research as it exists in early 1995. As more studies are completed, issues may become clearer; although evidence gathered to date and the experiences of other public health-related issues—including the controversies over electric power lines and tobacco—indicate that resolution of these issues could be years or even decades away.

- **Scientific research to date has found no conclusive evidence that low power microwave radio communication signals adversely affect human health. However, currently available scientific information is insufficient to conclude that there are no long-term adverse health effects—either from handheld wireless communication devices or from towers**.[1] Because of the paucity of data on biological and health effects, and the ambiguity in the results of research conducted so far, neither public interest advocates nor industry have made a clear and convincing argument sufficient to prove their case. All parties agree that more research is needed to determine whether there could be any health effects from long-term exposure to radio frequency (RF) radiation at the power levels used by wireless communications devices, what they might be, and how serious a risk they could pose. Specifically, additional research will be required as new technologies are developed that use different frequencies, power levels, and transmission formats.
- Public concern persists over many forms of radiation, including nonionizing electromagnetic radiation.[2] The willingness of the public to give credence to anecdotal reports of radiation-induced human health risks is an enduring phenomenon. Maintaining the public's trust and confidence in technologies associated with radio waves demands extraordinarily high levels of responsible scientific work and policy development. Given the character of public concern over many types of hazards in the environment, the technical complexity of new wireless systems, the difficulty the public has in understanding the complex results of scientific research, and the likelihood of many more radio devices working at new frequencies and with new technologies, it may be prudent for the federal government, including Congress, to continue to monitor technology and industry developments and the ongoing research into wireless health issues.

  Industry has taken some steps to address public concerns, and is making substantial funds available for research. However, especially in health-related areas, it may be difficult for the public or policymakers to trust that industry-funded research will always be conducted in an objective manner. **Some continuing federal role—as an overseer of**

[1] U.S. Food and Drug Administration, "Talk Paper" on cellular telephone safety, 1993; U.S. Federal Communications Commission, Office of Engineering and Technology, "Information on Human Exposure to RF Fields from Cellular Radio Transmitters," 1994; Institute of Electrical and Electronics Engineers, "Position Statement on RF from Portable and Mobile Phones and Other Devices," 1992; U.S. Congress, General Accounting Office, *Status of Research on the Safety of Cellular Telephones*, GAO/RCED-95-32 (Washington, DC: November 1994), pp. 3-4, 15; Mark Fischetti, "The Cellular Phone Scare," *IEEE Spectrum*, vol. 30, No. 6, June 1993, pp. 43-47; "Cellular Phone Industry Research Group Sees Need for 'Basic Information in All Areas'; Proposals Under Review," *Microwave News*, September/October 1994, pp. 9-10; Scientific Advisory Group on Cellular Telephone Research, *Interim Status Report: Potential Public Health Risks from Wireless Technology: The Development of Data for Science-based Risk Management Decisionmaking*, Nov. 29, 1994, p. 4; "SAG Chairman Comments on Significance of Research Agenda; Proud of Group's Track Record," *Cellular Telephone Update*, vol. 2, No. 1, Fall 1994, p. 2.

[2] Although "radiation" is the preferred technical term when discussing radio wave emissions from wireless transmitters, radio communication radiation should be clearly differentiated from the harmful ionizing and particulate ("hard") radiation associated with nuclear energy. These two types of radiation are not the same. Public concern about all forms of electromagnetic radiation may be fueled by a misunderstanding of the technical terms involved.

industry-funded work, as a participant in the research and testing process, or in mounting its own research program—may be desirable to assure research integrity and to maintain high levels of public trust and confidence in these technologies.

A vigorous federal government role is particularly important given the difficulties in evaluating technologies that have not yet reached large-scale deployments. As wireless technologies become more ubiquitous, unanticipated interactions or consequences may appear. What appears to be a negligible or unknown problem in the lab or at reduced scale may turn out to have significant effects when widely deployed, as was the case with lead paint and asbestos.[3] **Long-term monitoring of the effects of radio frequency exposure on humans may be necessary to avoid surprises and persistent public uncertainty.**

THE CONTROVERSY SURROUNDING HEALTH EFFECTS

The debate over the possible health effects from the radio waves used by cellular telephone and other mobile communications systems is intensely polarized. On one side, some citizens and a few researchers are firmly convinced that such radio waves pose a substantial health risk to public health. They believe that cellular phones should be redesigned or banned and that construction of new radio transmitters and antennas, especially those needed for cellular and future personal communications services (PCS) systems, should be restricted and perhaps even stopped. (Radio interference with medical devices such as pacemakers is addressed in chapter 12.) On the other side, equipment manufacturers and service providers maintain that there is no credible evidence that their products and services threaten human health. Without clear and definitive proof of harm, they argue that the development of new systems (and expansion of existing systems) should continue. Both sides have evidence—scientific studies, statistical records, and anecdotal reports—they believe supports their case. The result is a confusing and often conflicting body of scientific and medical literature.

In disputes like this, identifying and evaluating risk to the public is often difficult. Many elements contribute to understanding risk, and often these are confused, misinterpreted, or misrepresented. In many cases, the elements become divisive public policy issues as different groups with different perspectives battle over what is legitimate, acceptable, and "true," and what is not. In situations where individuals cannot avoid exposure—as in the case of radio waves—it is the role of government through the regulatory and policy process to decide what level of risk is acceptable and to enact the necessary provisions to protect public health. To focus government resources and policy efforts most effectively, it is important for policymakers and regulators to understand the different stages involved in evaluating this risk.

The first step in assessing this type of risk is establishing *causality*—what effects are due to what causes, and how certain is the relationship between them. Disputes can arise between different parties claiming that effects are or are not associated with particular causes, and disagreements frequently center on the adequacy of the science that supports a particular position. This is true with radio wave radiation and its effects on animal tissues. High-power microwave radiation, for example, is known to produce thermal effects (heating), but the possible nonthermal effects of radio waves, which include changes in cell membrane permeability, cell metabolism, or on genetic material, are more contentious. A few researchers have found some such effects, but results are still considered tentative, and the mechanisms causing them are not well understood.

[3] George Brandon, "Pulling Together an Electromagnetic Field Defense: Defendants Need a Coordinated Strategy for the Mass Tort Some Call the 'Asbestos of the '90s,'" *The National Law Journal,* Aug. 1, 1994, p. B19.

The second element in assessing risk is demonstrating *harm* from the effects. Even if a cause and an effect can be positively linked, this does not necessarily mean that harm results. Making this connection is at the heart of current debates over the safety of radio communication systems. In the case of radio waves' effects on animal tissues, this means that any observed *biological* effects need to be clearly linked to observed *health* problems. Heating effects have been shown to cause adverse health reactions, but *not* at the low power levels used by today's cellular telephones. Determining harm is more difficult with nonthermal effects—which might affect basic cell functions that are only now beginning to be understood—and will be the subject of long debate.

In any case, some people will view any biological effects as harmful, whether or not there are any actual impacts on health. Fundamentally, an assessment of risk and one's reaction to it is quite subjective and personal. For example, many people are afraid to fly, although airline fatalities are rare. On the other hand, automobile safety receives far less public scrutiny, even though tens of thousands die annually from highway accidents.

In trying to evaluate the possible harm from radio communication systems, different groups disagree over what *standards of proof* should be used to determine safety or harm—that is, what proof is adequate to prove or disprove potential adverse health effects. One view requires *proof of no harm* before a technology is deployed. This approach is generally taken, for example, by the pharmaceutical industry and the U.S. Food and Drug Administration: firms must show, through extensive self-funded testing, that a new drug has few significant known adverse effects when used as prescribed.

An alternative approach is to permit a technology to be deployed, under certain guidelines, until it can be shown convincingly that negative effects result, or *no proof of harm* (note word order difference from above). In this case, experimentation is not limited to test groups in experimental settings, but also takes place among the public where a technology can be fully and vigorously evaluated in real-world conditions. For example, software producers expect bugs in early releases of their products because they know they cannot completely test programs and applications on their own beforehand.[4]

Most technologies fall somewhere between these two positions: initial experimentation is extremely limited in scale and scope, often confined solely to the laboratory. Next, the technology or product is subjected to more rigorous evaluation to see if hazards exist. After a period of controlled testing and evaluation, standards may be issued by the relevant technical body, such as the Institute of Electric and Electronics Engineers (IEEE). These standards may be accepted by government regulators, and become enshrined as substantial benchmarks guiding general and large-scale use and deployment of the technology or product.

If new information about hazards or other negative effects later comes to light, the standard may be changed with the agreement of the standards bodies and regulators. Changes at this stage may be difficult due to the institutional interests surrounding the status quo and the changing standard of proof required to attend to problems. With technologies or products such as asbestos, lead paint, or tobacco that come to be seen as hazardous, the firms that manufacture them have, in many cases, successfully resisted efforts to label them as bad for health, despite steadily mounting evidence to the contrary.

Another issue in determining harm is the *integrity* of the process by which research is conducted, including that of the people performing the work. If research is conducted in a way that raises questions of bias or poor quality, then such work will fail to settle questions about cause and effect, as well as potential hazards. Charges of bias, ignoring contrary evidence, or slipshod research meth-

[4] This difficulty in testing before full-scale release poses particularly acute problems for systems that operate highly reliably the first time, but cannot easily be subjected to real-world tests, such as antiballistic missile system software.

ods may be unfounded, but nevertheless must be taken seriously. Failure to demonstrate good faith or adherence to good scientific practice in the process by which information is gathered and evaluated may lead to continuing controversy. The makeup of research teams, lack of financial or other ties to firms with a stake in the outcome, fair and open evaluation of research proposals and research results, open publication of results or other public reporting requirements, participation by all interested parties, regardless of their affiliation—all these contribute to the integrity of the research process. These factors are also essential to reducing public concerns about research bias, and to increasing public trust and confidence in the technologies or products in question.

In the face of inconclusive and ambiguous evidence, different groups have different reactions. Opponents of widespread deployment of cellular and PCS facilities, and those claiming that cellular telephones promote cancer, argue that the industry should be held to the "proof of no harm" test. Without convincing proof of their safety, some people believe that antennas and towers should be restricted or moved and phones should be redesigned or prohibited altogether, even those that conform to current safety guidelines. The wireless industry, on the other hand, argues that there has been no proof of harm to date, and that changes in standards and use of the technologies should occur only when substantial and persuasive proof of harm is demonstrated. The industry also argues that it is funding research into biological and health effects, and that this research will help settle disputes about the safety of microwave radio frequency technologies. Compromise between these two groups will be very difficult, because their reactions to uncertainty are based on diametrically opposed philosophies—stop until safety is guaranteed or keep going until harm is proven—and both hold up different standards of proof.

Faced with a technical and policy controversy such as this, policymakers have difficult choices to make. If a technology is already being widely used, as is the case with many wireless technologies, using a "proof of no harm" standard is unrealistic. Television broadcasting towers, public safety radios, cellular towers and antennas, and hand-held cellular telephones have been deployed for years, and are used by tens of millions of people. Stopping these systems until definitive testing can be done is not realistic in today's political climate. However, finding out about possible harm through monitoring and active research is a viable option. Identifying early indications of effects or harm is in the public interest, even if short-term costs are high. Research to determine cause-and-effect relationships, and to ascertain the extent to which and under what circumstances harm may ensue, is essential. Some researchers also suggest that those concerned about possible hazards from electromagnetic radiation practice "prudent avoidance," which is avoidance of emissions where it is economically, operationally or physically easy to do so.[5]

BIOLOGICAL AND HEALTH EFFECTS OF WIRELESS TELECOMMUNICATIONS

Cellular and other radio communications devices should be distinguished from low frequency electromagnetic fields found around electric power lines. Electric power systems in the United States operate at a low frequency of 60 cycles or hertz (Hz) and at high power, while cellular telephones operate at much higher frequencies, 800 to 900 megahertz (MHz), and at extremely low power levels. New PCS systems will operate at even higher frequencies, 2 gigahertz (GHz) and still lower power levels. Researchers have established that the effects of electromagnetic radiation vary greatly with frequency and power levels, and empirical work over the last several decades has been

[5] See U.S. Congress, Office of Technology Assessment, *Biological Effects of Power Frequency Electric and Magnetic Fields*, OTA-BP-E-53 (Washington, DC: U.S. Government Printing Office, May 1989), pp. 77-80 for a discussion of prudent avoidance in the context of electric power line electromagnetic radiation and potential human health effects.

conducted to determine safe levels at various combinations.[6] Because of this variability, however, effects found at one level are not generalizable to other frequency/power combinations—independent research must be conducted.

Research Is Inconclusive

While considerable research has been conducted on the effects of electromagnetic fields generally, very little work has yet been done on the possible health effects of exposures in the specific frequency and intensity ranges generated by wireless communications devices and systems. A particular weakness in the existing literature is the lack of research on the impact of long-term exposures.

The data that does exist paints an ambiguous picture. Some—but not all—research conducted on cells and animals suggests that exposures to fields with characteristics similar to those generated by cellular phones may cause behavioral and biological effects, including abnormal cell growth and increased incidence of malignancies.[7] The results of other studies involving claimed links between radio waves and cancer are inconsistent and difficult to interpret.

> [GAO] has concluded that [no] research has been completed on long-term human exposure to low levels of radiation specifically from portable cellular telephones. Research findings on exposure to other sources of low-level radio-frequency radiation are inconclusive. Some laboratory studies show that biological effects can occur when animals and cells have undergone extended exposure to low-level radio-frequency radiation; others do not. Scientists at FDA and EPA said that existing research does not provide enough evidence to determine whether portable cellular telephones pose a risk to human health.[8]

There are two fundamental issues concerning radio-frequency electromagnetic radiation and human exposure. The most obvious is the thermal or heating effect of such radiation on tissue. It is well known that high-power radio waves will generate heat in exposed tissues. Microwave ovens, high-powered radars, and other high-power microwave devices, for example, radiate energy—a small portion of which is absorbed by body tissues. The rate at which this energy is absorbed is called the specific absorption rate (SAR). Absorbed energy raises the temperature of the tissues through the excitation of water molecules (the typical microwave oven operates at about 600 watts at 2450 MHz). The higher the power level the more heat is generated at a given distance for a given sample, and the higher the frequency, the more of the incident energy is superficially absorbed.

The thermal effects of radio communication devices are generally not considered harmful. Wireless devices are required to comply with well-established standards governing human exposure to electromagnetic radiation. These standards incorporates a substantial safety factor as a cushion against unanticipated effects or exposure in unusual situations. As a result, researchers have been unable to measure heating of tissue at the low power levels used by hand-held cellular telephones. Microwaves do not penetrate metal, so shielding against them is fairly straightforward. In addition, power densities decline rapidly with distance from the source, so exposure can be reduced by lowering the power level and maintaining proper distances from operating antennas.

The second, and more controversial, issue is the possibility that RF radiation may cause nonthermal effects, including changes in genetic

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[6] For recent reporting on low-frequency power effects, see Tekla S. Perry, "Today's View of Magnetic Fields," *IEEE Spectrum*, vol. 31, No. 12, December 1994, pp. 14-23. High frequency standards are dealt with in Institute of Electrical and Electronics Engineers, *IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz*, IEEE C95.1 1991, approved by IEEE Sept. 26, 1991, approved by the American National Stardards Institute Nov. 18, 1992, (New York: Institute of Electrical and Electronics Engineers, November 1994).

[7] See U.S. Congress, General Accounting Office, op. cit., footnote 1, pp. 29-31, for a brief review of this literature.

[8] Ibid, p. 3.

BOX 11-1: Origins of Recent Concern About Brain Cancer and Cellular Telephones

Public concern about low-power, high-frequency radio devices such as cellular telephones has its origins in a wrongful death lawsuit filed in April 1992, by David Reynard against his cellular telephone company, alleging that his wife's frequent and prolonged use of her cellular telephone contributed to her death by brain cancer. The story was first reported in the Ft. Lauderdale *Sun-Sentinel,* and received widespread attention following an interview with Reynard by Larry King on the CNN television network in January 1993.

News of the suit led to a significant drop in the stock prices of cellular companies and led to efforts by the companies to assure the public that cellular telephones are safe. While there was broad public concern at the time about the safety of the devices, committed users apparently were unwilling to forego use of the phones: cellular telephone subscription rates and usage did not significantly drop during this time. The case was dismissed on May 17, 1995, for lack of evidence meeting Florida's standards for admissibility. [1] There are currently seven other cases pending on the safety of cellular telephone use.

[1] *H. David Reynard, et al., v. NEC Corp., et al.,* "Order," in United States District Court, Middle District of Florida, Tampa Div., case no. 94-825-CIV-T-21 E. See also John Schwartz, "Court Call Favors Cellular: Judge Throws Out Claim of Link to Brain Cancer, " *The Washington Post,* May 20, 1995, p. A2.

SOURCE: Office of Technology Assessment, 1995.

structure, the changes in the permeability of cell membrances, and disturbances in cell metabolism. These nonthermal effects theoretically could occur at lower power levels and under different modulation schemes than would be necessary to generate thermal effects. Much research in this area remains to be done, as government, industry and the academic communities agree. While there is no evidence that low-power, high-frequency radio signals ***cause*** cancer in cells, the possibility has been raised that such low-power radio waves could ***stimulate*** the growth of cancerous or precancerous cells, although early evidence is very weak (see box 1 l-l). Some preliminary evidence of microwave effects on DNA has also been reported, but not yet confirmed.[9]

▮ Exposure Standards Are Still Being Debated

To protect people from harmful exposure to high levels of electromagnetic energy, the Institute of Electric and Electronics Engineers (IEEE) developed standard IEEE C95.1, which was revised and adopted by IEEE in September 1991 and approved by the American National Standards Institute (ANSI) in November 1992.[10] Essentially, the standard says that devices operating between 100

[9] Henry Lai and Narenda Singh, "Acute Low-Intensity Microwave Exposure Increases DNA Strand Breaks in Rat Brain Cells,'' *Bioelectromagnetics,* vol. 16, spring 1995, forthcoming. See report in "Microwaves Break DNA in Brain; Cellular Industry Skeptical," *Microwave News,* vol. 14, No. 6, November/December 1994, pp. 1, 11-13.

[10] Institute of Electrical and Electronics Engineers, *IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to300GHz,* IEEE C95.1 1991, approved by IEEE Sept. 26,1991, approved by the American National Standards Institute Nov. 18, 1992 (New York: Institute of Electrical and Electronics Engineers, November 1994). These standards are based on several decades of biological and radiological work, particularly on the question of electromagnetic radiation and cancer. For the most recent version of the standard, promulgated in 1991 and 1992, the standards committee had 14 biological evaluation working groups, with 125 scientists, physicians, and engineers drawn from academia, the private sector, and government. Similar standards have been adopted by other organizations as well.

MHz and 450 MHz are within permissible limits if they radiate less than 1.4 watts, and the radiating structure is at least one inch from the body.[11] At higher frequencies, the permitted power levels drop: for example, at 1500 MHz, the limit is 0.4 watts. Most hand-held telephones used in the United States operate at no more than 0.6 watts. Mobile telephones (installed in cars) are permitted to emit up to 3 watts because car phone antennas are installed outside vehicles away from close human contact. These levels are considerably below the 4 watt per kilogram energy absorption threshold identified in the scientific literature as the lowest level at which adverse effects due to heating had been noted and replicated. In a December 1992 report, IEEE concluded that "prolonged exposure at or below the levels recommended in these guidelines is considered safe for human health."

The exposure limits in the standard were derived from work done by the U.S. Navy and the IEEE before 1960, and reviewed and revised every five years, according to ANSI policy. Because of this historical foundation, the standard principally addresses concerns about the thermal effects of microwave radiation. Nonthermal effects, while reportedly discussed in the standards committee deliberations, are not directly addressed by the ANSI/IEEE standard, in part because little research on them had been done when the standard was last revised.[12] Too little is known about the mechanism(s) by which nonthermal effects operate to set standards for exposure, presuming harmful nonthermal effects exist. As the IEEE standard document notes:

> Biological effects data that are applicable to humans for all possible combinations of frequency and modulation do not exist. Therefore, this standard has been based on the best available interpretations of the extant literature and is intended to prevent adverse effects on the functioning of the human body[13]. . . .
>
> Research on the effects of chronic exposure and speculations on the biological significance of nonthermal interactions have not yet resulted in any meaningful basis for alteration of the standard. It remains to be seen what future research may produce for consideration at the time of the next revision of this standard.[14]

Disputes over biological and health effects revolve around the continued acceptability of this standard as new research is performed.[15] As of spring 1995, the FCC was still considering whether to adopt the C95.1-1992 standard for *all* devices operating at microwave radio frequencies. Analog cellular telephones are presently exempt from testing under FCC rules because of their low power levels. However, the FCC indicated in 1994 that PCS phones would be subject to testing and SAR level limitations unless their maximum power

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[11] This is a conventional way of stating the levels permitted under the standard, expressed in terms of what levels the emitting devices may have. The standard actually says nothing about emitting devices, but specifies exposure levels for humans, and is considerably more complex and detailed: it covers a wide range of frequencies (from 3 kHz to 300 Ghz), and power levels, measured as electric field or magnetic field strength or power density, depending on the frequency range. Compliance with the IEEE/ANSI standard also requires that, at cellular phone frequencies, actual exposure for the general public (measured by the specific absorption rate) not exceed 0.08 watts per kilogram whole-body average or 1.6 milliwatts per kilogram peak exposure in any one gram of tissue over 30 minutes. The maximum power density level is 0.57 milliwatt per square centimeter of tissue for over the whole body. These levels are somewhat different for other radio devices, such as ESMR, PCS or police radios. See Mark Fischetti, "The Cellular Phone Scare," *IEEE Spectrum*, vol. 30, No. 6, June 1993, pp. 44, 46.

[12] IEEE notes that most reports of biological effects have dealt with acute exposures at relatively few frequencies rather than with chronic exposures, and its work reflects this data base. The cutoff date for the literature review on which the standard depends was December 1985, with some carefully selected exceptions. See Institute of Electrical and Electronics Engineers, op. cit., footnote 6, p. 26-27.

[13] Institute of Electrical and Electronics Engineers, op. cit., footnote 6, p. 21.

[14] Ibid., p. 24.

[15] Louis Slesin, publisher of *Microwave News*, is a careful exponent of those advocating increased attention to biological effects of high-frequency, low-power electromagnetic radiation on humans. See for example, "Cellular Phones: Why the Health Risk Can't Be Dismissed," *Microwave News*, vol. 13, No. 1, January/February 1993, pp. 1, 11-12.

BOX 11-2: Statistics and large numbers

In 1991, there were approximately 17,600 deaths caused by brain cancer in the United States and about 514,300 cancer deaths overall. The cancer rate, between five and six deaths per 100,000, has not changed significantly over the past decade.[1] In a population of 180 million adults 20 years old and above, there are about 20 million cellular telephone users, or about 11 percent of the adult population. Mathematically, one would expect about 1,956 cellular telephone users to get brain cancer, independent of any specific cause. The National Cancer Institute, a part of the National Institutes of Health, estimated that there would be 350 new cases of brain cancer among cellular telephone users in 1993.[2] It is unknown how many actual cases occurred, since data on cancer and cellular telephone use is not yet available.

The lesson in these numbers is that, just because someone uses a cellular telephone and gets cancer, there is no reason to assume it is the phone that *caused* it. Because the numbers are so small, it would be difficult to distinguish cancer due to cellular telephones from other possible causes. If it were scientifically proven that cellular telephone users contract cancer at rates above the average, all other things being equal, it might be concluded that cellular telephones had a role to play. But even this is difficult to say with certainty because so many factors contribute to the incidence and growth of cancer.

[1] Letter from Dr. F. Kristian Storm, Professor, Departments of Surgery and Human Oncology, University of Wisconsin, Comprehensive Cancer Center, to Rep. Edward Markey, Feb. 2, 1993.

[2] Mark Fischetti, "The Cellular Phone Scare," *IEEE Spectrum,* vol. 30, No. **6,** June, 1993, pp. 43-47.

SOURCE: Office of Technology Assessment, 1995.

output was less than 0.1 watt and a 2.5 centimeter separation was maintained between the user and any radiating structures.[16] The standard has been endorsed by the cellular industry and the FDA's Center for Devices and Radiological Health, but EPA, the National Institute for Occupational Safety and Health and others have objections.[17]

■ Research Activities

Research into the possible health effects of radio communication devices and systems is underway in a variety of institutions, including work sponsored by the cellular telephone industry. Questions have been raised about the potential bias of such work,[18] but these concerns appear to have been addressed.[19] Planned research may provide some answers to recently raised questions about the health effects of wireless telecommunications.

Research is concentrated in epidemiology, dosimetry, toxicology, and clinical studies. Through statistical studies of large populations, epidemiological studies seek to determine whether the occurrence of a disease can be associated with characteristics of people or their environments (see box 11-2). Dosimetry studies attempt to develop appropriate models of exposure relevant to human use of cellular and other wireless telephone use. Laboratory studies use controlled experi-

[16] *Microwave News,* vol. 14, No. 5, September/October 1994, p. 8.

[17] *Microwave News,* vol. 14, No. 3, May/June, 1994, p. 13.

[18] U.S. Congress, General Accounting Office, *Status of Research on the Safety of Cellular Telephones,* GAO/RCED-95-32 (Washington, DC: November 1994).

[19] Letter from Dr. George Carlo, Chairman, Wireless Technology Research, to Mr. Keith O. Fultz, Assistant Comptroller General, Resources, Community and Economic Development Division, U.S. General Accounting Office, Apr. 10, 1995.

ments with cell tissues or animals to ascertain the biological effects of particular radio-frequency emissions. These types of studies, epidemiological and laboratory, are necessary to assess whether there is a health risk to the population.

Two major research programs are being conducted in the United States. In the first, Motorola, a major manufacturer of cellular telephones and switching equipment, is funding a number of studies, some of which are published in the peer-reviewed literature. The other major research program is a three-to-five year effort, estimated to cost upward of $25 million, funded by the cellular telephone industry using an unrestricted deposit-only escrow fund that may be increased as research questions are refined.[20] This effort is overseen by Wireless Technology Research (WTR) (formerly the Scientific Advisory Group (SAG)),[21] and will support a number of multidisciplinary studies in epidemiology, cell cultures, test models, and genetics.[22] Both analog and digital transmission formats will be examined at power levels and frequencies used by current cellular systems, as well as those of proposed PCS. The resulting scientific work is subjected to review through an independent peer-review board coordinated by the Harvard University School of Public Health's Center for Risk Analysis.[23] Results will be submitted for publication in the scientific literature.

Research on cellular telephone health effects is also being conducted in Europe, although differences in transmission frequencies, power levels, and waveforms make it difficult to know the applicability of research findings in the United States. In the United Kingdom, the National Radiological Protection Board is developing computer models to characterize the fields induced in the human head by hand-held devices. Both German Telkom and the Research Association for Radio Applications—a consortium of manufacturers and cellular providers—are sponsoring behavioral and health effects research in Germany. The European Commission commissioned a study of thermal and nonthermal health effects from wireless device emissions in late 1994. The study is being conducted at the Center for Personkommunikation at Aalborg University, Denmark.

The credibility of industry-funded research depends on an open process, extensive peer and government review, adherence to accounting and auditing standards, no-strings-attached funding, appropriate research questions and methods, and timely disclosure of research results. For the CTIA-sponsored effort, the peer-review panels and the research itself are funded through an escrow account to provide for strict independence. GAO (see below) questioned whether the research efforts conducted under the cellular industry program could be considered truly objective and credible; the WTR established a new nonprofit administrative structure to manage the research funds and altered its funding and supervisory structures to respond to GAO's concerns.[24] Government funds might be contributed to the effort,

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[20] Interview with Scientific Advisory Group (now Wireless Technology Research) staff members, March 29, 1995.

[21] Membership of the Scientific Advisory Group consists of Dr. George L. Carlo, of the Health & Environmental Sciences Group, Ltd., and George Washington University; Dr. Ian Munro, of CanTox, Inc.; and Dr. Arthur W. Guy, University of Washington, Seattle. On Mar. 31, 1995, the SAG became Wireless Technology Research, LLC.

[22] Scientific Advisory Group on Cellular Telephone Research, "Potential Public Health Risks From Wireless Technology: Research Agenda for the Development of Data for Science-Based Decisionmaking," (Washington, DC: Scientific Advisory Group on Cellular Telephone Research, Aug. 25, 1994).

[23] Details of Wireless Technology Research and associated activities can be found in *Wireless Technology Update*, its organization newsletter published in Washington, DC.

[24] Letter from Dr. George Carlo, Chairman, Wireless Technology Research, to Mr. Keith O. Fultz, Assistant Comptroller General, Resources, Community and Economic Development Division, U.S. General Accounting Office, Apr. 10, 1995.

but the WTR believes that bureaucratic and budget constraints make this unlikely.

Government Initiatives

The General Accounting Office (GAO) completed a short study of research performed on the safety of analog cellular telephones in November, 1994. The report notes that no one federal regulatory agency in the United States has responsibility for wireless communications device emissions; EPA has overall responsibility for advising the government on EMF exposures, the FDA establishes standards for devices that emit radiation, and the FCC approves wireless communications devices for use and assures that their emission levels meet safety standards.

The study also concluded that little research on the health effects of wireless telecommunications devices on humans is planned by the federal government, with the exception of an epidemiological study by the National Cancer Institute to be completed in 1997 or 1998. In 1984, the Environmental Protection Agency convened an interagency working group on electromagnetic frequency radiation, composed of scientific specialists. The Food and Drug Administration is establishing an oversight group that includes policy specialists as well.[25]

[25] Members include the U.S. Food and Drug Administration, the U.S. Environmental Protection Agency, the National Telecommunications and Information Administration, the National Institutes of Occupational Safety and Health, and the Occupational Safety and Health Administration.