Control Number: 38230

Item Number: 1212

Addendum StartPage: 0

SOAH DOCKET NO. 473-10-4398
DOCKET NO. 38230

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APPLICATION OF LONE STAR TRANSMISSION, LLC FOR A CERTIFICATE OF CONVENIENCE AND NECESSITY FOR THE CENTRAL A TO CENTRAL C TO SAM SWITCH/NAVARRO PROPOSED 345 kV CREZ TRANSMISSION LINE	§ § § § § § § §	BEFORE THE STATE OFFICE OF ADMINISTRATIVE HEARINGS

RESPONSE OF DARRELL N. UECKERT, PH.D.
TO
LONE STAR TRANSMISSION, LLC'S FIRST REQUEST FOR INFORMATION TO DARRELL N. UECKERT, PH.D.

This request was received on August 17, 2010 and my response is being sent to Chris Reeder at creeder@brownmccarroll.com on August 22, 2010, which is within 10 days of receipt of the request, as per Order No. 1 in this PUC Docket No. 38230.

In compliance with the Commission's Procedural Rules, Darrell N. Ueckert is the witness in this cause who will sponsor the answer to the question at the hearing and can vouch for the truth of the answer.

I, Darrell N. Ueckert, hereby certify that my answers to the following questions may be treated as being under oath.

LONE STAR TRANSMISSION, LLC'S FIRST REQUEST FOR INFORMATION TO DARRELL N. UECKERT, PH.D.

Request No. 1. For all direct testimony you file in this proceeding, please provide a copy, in their native and original format, of all attachments, exhibits, photographs, maps and other documents that are attached to your direct testimony. Copies of color photographs, maps, or other documents should be provided in color or in an electronic file if that is its original format.

Answer to Request No. 1. I am providing copies of Attachment DNU-1 (my resume) and Attachment DNU-2 (Link H Soils: Wind Erodibility Index). The wind erodibility materials were obtained via the United States Department of Agriculture, Natural Resources Conservation Service's Web Soil Survey at http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm

1212

Request No. 2. If your testimony relies on or references any studies, articles or other documentation (that was not prepared by Lone Star or its consultants or attorneys), and if you have not included those in your direct testimony, please provide a copy of those materials.

Answer to Request No. 2. I am providing copies of pertinent pages of the Jones County Soil Survey (front cover, first page, and page no. 12) that gives the description of Nobscot fine sand soils and Nobscot soils and Blow-out land. The only other document that I referenced or referred to in my testimony was the June 2002 publication entitled <u>EMF Electric and Magnetic Fields Associated with the Use of Electric Power</u> prepared by the National Institute of Environmental Health Sciences, National Institute of Health. Lone Star Transmission, LLC graciously provided a complimentary copy of this publication to me, at my request. Therefore, I consider the preparers of this publication to be consultants of Lone Star Transmission, LLC, and thereby assume Lone Star Transmission, LLC has a large supply of this publication on hand for their use during the hearing and for the use by the Texas Public Utility Commission. If not, the publication can be downloaded at <u>http://www.niehs.nih.gov/health/docs/emf-02.pdf</u>

This concludes my response.

An original and five copies of my answers will be mailed to the Filing Clerk, Public Utility Commission of Texas, 1701 N. Congress Avenue, Suite 8-110D, Austin, Texas 78701 per instructions in the Lone Star Transmission, LLC's request.

<u>Certificate of Service</u>

It is hereby certified that notice of the filing of the foregoing has been sent to <u>dkt38230@soah.state.tx.us</u> on this 22nd day of August, 2010, and served upon the party to whom the pleading is directed by first class mail, electronic mail, or facsimile, consistent with Order No. 5.

Darrell N. Ueckert

Darrell N. Ueckert

ATTACHMENT DNU-1
RESUME
Dr. Darrell N. Ueckert, Ph.D.

I have a BS degree in Range Management (Texas Tech University – 1966), a MS degree in Range Science (Colorado State University – 1968), and a PhD degree in Range Science (Colorado State University – 1969).

I worked as a Range Conservationist (GS-7) with the USDA Soil Conservation Service in 1966 prior to entering Graduate School at Colorado State University. I worked as an Assistant Professor and Associate Professor at Texas Tech University during late 1969 through late 1976 in a 75% research/25% teaching position. My research was in rangeland plant and animal ecology. In late 1976, I was employed as a rangeland ecologist (Associate Professor) with the Texas Agricultural Experiment Station (Texas A&M University System) at San Angelo, being promoted to Professor rank in 1980. I was awarded the title Regents Fellow & Professor in 2000. My research program was in the areas of rangeland plant ecology, rangeland vegetation management, restoration of disturbed and degraded rangelands, and technology transfer to clientele. I retired from the Texas Agricultural Experiment Station (now Texas AgriLife Research) in December 2005. My wife and I live on and operate 2 ranch properties and a wheat farm in southwestern Jones County, Texas. In addition to ranching, I operate a rangeland consulting business. I am currently President of the Noodle-Horn Community Center, on the Board of the Jones County Farm Bureau, and on the Advisory Committee of the Rolling Plains Quail Research Ranch.

I have published 70 articles in scientific journals, 4 Experiment Station bulletins, 1 Experiment Station monograph, 12 books or chapters therein, 40 conference or symposium proceedings, and over 130 other papers, reports and leaflets. I have served as a Director and President of the Texas Section – Society for Range Management. For the international Society for Range Management, I have served on the Editorial Board, as an Associate Editor, Chair of the Advisory Council, and member of the Budget Committee, Executive Committee, and Public Affairs Committee.

Major awards and recognitions

Texas Sheep & Goat Raisers Association - Special Achievement Award – 2006
Society for Range Management - Outstanding Achievement Award – 2001
Texas A&M University System – Regents Service Fellow Award – 2000
Texas Natural Resource Conservation Commission – Texas Environmental Excellence Award – 2000
Progressive Farmer Magazine (SW Ed.)– Leader of the Year in Texas Agriculture – 2000
Texas Tech Univ. Coll. of Agric. Sci. & Nat. Resources – Distinguished Alumnus – 1999
Texas Agricultural Extension Service – Superior Service Award – 1999
Texas A&M Univ. System Deputy Chancellor's Award for Partnership Efforts - 1997
Society for Range Management – Chapline Research Award – 1995
Texas Section Society for Range Management – Outstanding Contribution to Range Management Award - 1995

Texas A&M Univ. System Deputy Chancellor's Award for Research Off-Campus – 1988

Darrell N. Ueckert

SELECTED PUBLICATION RELEVANT TO RANGELAND PLANT ECOLOGY AND MANAGEMENT

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Ueckert, D.N., P.W. Jacoby, Jr., and S. Hartmann. 1982. Tarbush and forage response to selected pelleted herbicides in the western Edwards Plateau. Texas Agr. Exp. Sta. Bull. B-1393. 6 p.

Ueckert, D.N. 1982. Manipulating herbaceous vegetation with prescribed fire. p. 19-31. In: T.G. Welch (ed.) Proc. Symposium on Prescribed Range Burning in Central Texas. Oct. 28, 1982. Goldthwaite, Texas. Texas Agr. Ext. Service, College Station.

Ueckert, D.N., S.G. Whisenant, and G.W. Sultemeier. 1983. Control of rayless goldenrod (*Isocoma wrightii*) with soil-applied herbicides. Weed Sci. 31:143-147.

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Whisenant, S.G., C.J. Scifres, and D.N. Ueckert. 1984. Soil water and temperature response to prescribed burning. Great Basin Nat. 44:558-562.

Potter, R.L., J.L. Petersen, and D.N. Ueckert. 1986. Honey mesquite control with pelleted hexazinone in western Texas. J. Range Manage. 39:132-135.

Potter, R.L., J.L. Petersen, and D.N. Ueckert. 1986. Seasonal trends of total nonstructural carbohydrates in Lindheimer pricklypear (*Opuntia lindheimeri*). Weed Sci. 34:361-365.

Petersen, J.L., D.N. Ueckert, and R.L. Potter. 1988. Herbicidal control of pricklypear cactus in western Texas. J. Range Manage. 41:313-316.

Ueckert, D.N., J.L. Petersen, R.L. Potter, J.D. Whipple, and M.W. Wagner. 1988. Managing pricklypear with herbicides and fire. Texas Agr. Exp. Sta. PR-4570.

Scifres, C.J., B.H. Koerth, R.A. Crane, R.C. Flinn, W.T. Hamilton, T.G. Welch, D.N. Ueckert, C.W. Hanselka, and L.D. White. 1989. Management of South Texas mixed brush with herbicides. Texas Agr. Exp. Sta. Bull. B-1623. 66 p.

Ueckert, D.N. 1991. Pricklypear and juniper management. p. 51-57. In: T.G. Welch (ed.) Proc. Brush Management Symposium. May 7-8, 1991. Abilene, Texas. Texas Agr. Ext. Service, College Station.

Dye, K.L. II, D.N. Ueckert, and S.G. Whisenant. 1995. Redberry juniper-herbaceous understory interactions. J. Range Manage. 48:100-107.

McGinty, A. and D. Ueckert. 1996. Brush Busters - How to Master Cedar. Three safe and effective ways to control small cedar (juniper). Texas Agric. Ext. Serv. & Texas Agric. Exp. Sta. Leaflet L-5160.

Ueckert, D.N. 1997. Biology and ecology of redberry juniper, p. 3-3 to 3-10. In: Proceedings 1997 Juniper Symposium. Jan. 9-10, 1997. San Angelo, Texas. Texas A&M Univ. Agric. Res.& Ext. Center, San Angelo. Tech. Rept. 97-1.

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Ueckert, D.N. 1997. Pricklypear ecology, p. 33-42. In: Brush Sculptors Symposium Proceedings. Aug. 21-22, 1997 - Uvalde, Texas; Sept. 17-18, 1997 - Abilene, Texas. Texas A&M Univ. Agric. Res. & Ext. Center, San Angelo.

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Ueckert, D.N., R.A. Phillips, J.L. Petersen, and X.B. Wu. 2001. Redberry juniper canopy cover dynamics on western Texas rangelands. J. Range Mange. 54:603-610.

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Wiedemann, H.T., D.N. Ueckert, and W.A. McGinty. 2003. Spray boom for sensing and selectively spraying small mesquite on highway rights-of-way. Applied Engineering in Agriculture 18(6):661-666.

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Hamilton, W.T., A. McGinty, D.N. Ueckert, C.W. Hanselka, and M.R. Lee (eds.). 2004. Brush Management - Past, Present, Future. Texas A&M University Press. College Station, Texas. 282 p.

Hamilton, W.T. and D.N. Ueckert. 2004. Introduction - Rangeland woody plant and weed management - past, present, and future. Ch. 1 (p. 3-13). In: Hamilton, W.T., A. McGinty, D.N. Ueckert, C.W. Hanselka, and M.R. Lee (eds.). 2004. Brush Management - Past, Present, Future. Texas A&M University Press. College Station, Texas.

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Krueter, U.P., H.E. Amestoy, M.M. Kothmann, D.N. Ueckert, W.A. McGinty, and S.R. Cummings. 2005. The use of brush management methods: a Texas landowner survey. Rangeland Ecology and Management 58:284-291.

Wilcox, B.P., M.K. Owens, W.A. Dugas, D.N. Ueckert, and C.R. Hart. 2006. Shrubs, streamflow, and the paradox of scale. Hydrological Processes 20:3245-3259.

Recent Consulting and Expert Witness Activities

2007-2008: The Bailey Law Firm –San Angelo, TX and The Burris Law Firm – Eagle Pass, TX. Developed comprehensive plan for restoration of surface damages to a ranch caused by oil & gas exploration & production activities.

2008-2009: Jones, Galligan, Key and Lozano, LLP – Weslaco, TX. Expert witness on effects of fire on rangeland vegetation and wildlife habitat.

2009:_ Hay, Wittenburg, Davis, Caldwell & Bale, LLP – San Angelo, TX. Expert witness on rangeland vegetation and brush management - ranch real estate transaction dispute.

2009: Walter Noelke – San Angelo, TX. Developed noxious weed management plan for rangeland being leased for oil & gas exploration & production.

2009-2010: Shafer, Davis, O'Leary & Stoker — Odessa, TX. Expert witness on effects of fire on rangeland vegetation and wildlife habitat.

2010: Jackson Walker L.L.P. – San Antonio, TX. Expert witness on alleged herbicide damage to trees and shrubs at a homesite.

ATTACHMENT DNU-2
LINK H SOILS· WIND ERODIBILITY INDEX

Wind Erodibility Index—Jones County, Texas
(Link H Soils - Wind Erodibility Index)

USDA Natural Resources Conservation Service

Web Soil Survey
National Cooperative Soil Survey

ATTACHMENT DNU-2
LINK H SOILS: WIND ERODIBILITY INDEX

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils
- Soil Map Units

Soil Ratings
- 0
- 38
- 48
- 56
- 86
- 134
- 160
- 180
- 220
- 250
- 310
- Not rated or not available

Political Features
- Cities

Water Features
- Oceans
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads

MAP INFORMATION

Map Scale: 1:52,200 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:20,000.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: UTM Zone 14N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Jones County, Texas
Survey Area Data: Version 5, Oct 27, 2009

Date(s) aerial images were photographed: 2/16/1997; 1/14/1996

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Wind Erodibility Index

ATTACHMENT DNU-2
LINK H SOILS: WIND ERODIBILITY INDEX

Wind Erodibility Index— Summary by Map Unit — Jones County, Texas				
Map unit symbol	**Map unit name**	**Rating (tons per acre per year)**	**Acres in AOI**	**Percent of AOI**
AbA	Abilene clay loam, 0 to 1 percent slopes	48	27.0	0.9%
MmB	Miles loamy fine sand, 0 to 3 percent slopes	134	110.3	3.7%
MnB	Miles fine sandy loam, 1 to 3 percent slopes	86	47.8	1.6%
MnC	Miles fine sandy loam, 3 to 5 percent slopes	86	0.2	0.0%
No	Nobscot fine sand	220	2,509.8	84.8%
Ns	Nobscot soils and blown-out land	220	166.3	5.6%
Sp	Spur loam	48	92.5	3.1%
WnB	Winters fine sandy loam, 1 to 3 percent slopes	86	4.5	0.2%
Totals for Area of Interest			**2,958.1**	**100.0%**

Description

The wind erodibility index is a numerical value indicating the susceptibility of soil to wind erosion, or the tons per acre per year that can be expected to be lost to wind erosion. There is a close correlation between wind erosion and the texture of the surface layer, the size and durability of surface clods, rock fragments, organic matter, and a calcareous reaction. Soil moisture and frozen soil layers also influence wind erosion.

Rating Options

Units of Measure: tons per acre per year

Aggregation Method: Dominant Condition

Component Percent Cutoff: *None Specified*

Tie-break Rule: Higher

SOIL SURVEY OF

Jones County, Texas

United States Department of Agriculture
Soil Conservation Service
In cooperation with
Texas Agricultural Experiment Station

Issued June 1972

Major fieldwork for this soil survey was done in the period 1960–65. Soil names and descriptions were approved in 1966. Unless otherwise indicated, statements in this publication refer to conditions in the county in 1966. This survey was made cooperatively by the Soil Conservation Service and the Texas Agricultural Experiment Station. It is part of the technical assistance furnished to the Middle Clear Fork and California Creek Soil and Water Conservation Districts.

Either enlarged or reduced copies of the soil map in this publication can be made by commercial photographers, or they can be purchased on individual order from the Cartographic Division, Soil Conservation Service, United States Department of Agriculture, Washington, D.C. 20250.

HOW TO USE THIS SOIL SURVEY

THIS SOIL SURVEY contains information that can be applied in managing farms, ranches, and woodlands; in selecting sites for roads, ponds, buildings, and other structures; and in judging the suitability of tracts of land for farming, industry, and recreation.

Locating Soils

All the soils of Jones County are shown on the detailed map at the back of this publication. This map consists of many sheets made from aerial photographs. Each sheet is numbered to correspond with a number on the Index to Map Sheets.

On each sheet of the detailed map, soil areas are outlined and are identified by symbols. All areas marked with the same symbol are the same kind of soil. The soil symbol is inside the area if there is enough room; otherwise, it is outside and a pointer shows where the symbol belongs.

Finding and Using Information

The "Guide to Mapping Units" can be used to find information. This guide lists all the soils of the county in alphabetic order by map symbol and gives the capability classification of each. It also shows the page where each soil is described and the page for the capability unit and the range site in which the soil has been placed.

Individual colored maps showing the relative suitability or degree of limitation of soils for many specific purposes can be developed by using the soil map and the information in the text. Translucent material can be used as an overlay over the soil map and colored to show soils that have the same limitation or suitability. For example, soils that have a slight limitation for a given use can be colored green, those with a moderate limitation can be colored yellow, and those with a severe limitation can be colored red.

Farmers and those who work with farmers can learn about use and management of the soils from the soil descriptions and from the discussions of the capability units and range sites.

Game managers, sportsmen, and others concerned with wildlife can find information about soils and wildlife in the section "Wildlife."

Ranchers and others interested in range can find, under "Range Management," groupings of the soils according to their suitability for range, and also the names of many of the plants that grow on each range site.

Engineers and builders can find, under "Engineering Uses of the Soils," tables that contain estimates of soil properties, and information about soil features that affect engineering practices.

Soil scientists and others can read about how the soils were formed and how they are classified in the section "Formation and Classification of Soils."

Newcomers in Jones County will be especially interested in the section "General Soil Map," where broad patterns of soils are described. They will also be interested in the information about the county given at the beginning of the publication.

Cover: Planting cotton in a dryfarmed area of nearly level Rowena clay loam.

U S GOVERNMENT PRINTING OFFICE 1972

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402

Soil blowing is the principal hazard on these soils. Most of the acreage consists of fields that formerly were cultivated, but a few areas are seeded to native grasses. Capability unit VIe-5; Sandyland Savannah range site.

Nobscot Series

The Nobscot series consists of deep, well-drained, nearly level to undulating soils that are moderately rapidly permeable. These soils are slightly acid and have low available water capacity.

In a representative profile the surface layer is brown, slightly acid fine sand about 5 inches thick. Next is very pale-brown, loose fine sand about 31 inches thick, and then reddish-brown, friable fine sandy loam about 16 inches thick. The underlying material, to a depth of 70 inches, is reddish-yellow, loose, slightly acid loamy fine sand.

Representative profile of Nobscot fine sand (50 feet north of ranch road and 3 miles northeast of ranch headquarters, 1 mile north of Farm Road 1812 and 0.2 mile east of Fisher County line):

A1—0 to 5 inches, brown (10YR 5/3) fine sand, dark brown (10YR 4/3) moist; single grain (structureless); loose; slightly acid; gradual, smooth boundary.

A2—5 to 36 inches, very pale brown (10YR 7/4) fine sand, light yellowish brown (10YR 6/4) moist; single grain (structureless); loose; slightly acid; gradual, wavy boundary.

B2t—36 to 52 inches, reddish-brown (5YR 5/4) fine sandy loam, reddish brown (5YR 4/4) moist; weak, fine, subangular blocky structure; hard, friable; slightly acid; gradual, smooth boundary.

C—52 to 70 inches +, reddish-yellow (5YR 7/6) loamy fine sand, reddish yellow (5YR 6/6) moist; single grain (structureless); loose; slightly acid.

The A1 horizon ranges from 4 to 6 inches in thickness. Reaction ranges from slightly acid to neutral.

The A2 horizon ranges from 15 to 32 inches in thickness and from light brown to very pale brown in color. Reaction ranges from slightly acid to neutral.

The B2t horizon ranges from 8 to 18 inches in thickness and from yellowish red to reddish brown in color. Reaction ranges from slightly acid to neutral.

The C horizon ranges from fine sand to loamy fine sand in texture. It ranges from neutral to slightly acid in reaction.

Nobscot fine sand (No).—This soil has the profile described as representative of the series. It occurs in an area of about 11,000 acres. Slopes are dominantly 1 to 3 percent, but they range from 0 to 5 percent.

Included with this soil in mapping are small areas of Nimrod fine sand and of Nobscot soils and Blown-out land.

Soil blowing is a hazard on Nobscot fine sand. Most of the acreage is used as range. Capability unit VIe-5; Deep Sand range site.

Nobscot soils and Blown-out land (Ns).—Areas of this mapping unit occur within larger areas of Nobscot fine sand. The areas range from 20 to 300 acres. Slopes are dominantly 1 to 3 percent, but they range from 0 to 5 percent.

Nobscot fine sand makes up 40 to 50 percent of this unit. It has a surface layer of brown fine sand about 5 inches thick. Below is very pale brown fine sand about 31 inches thick, and then reddish-brown fine sandy loam about 16 inches thick. The underlying material is reddish-yellow loamy fine sand.

A soil that has a surface layer of reddish-yellow, neutral to slightly acid fine sand, 20 to 40 inches thick, makes up 10 to 20 percent of this unit. Below, to a depth of 50 inches, is reddish-brown, slightly acid clay loam that has coarse, prismatic structure that parts to coarse, medium, blocky. Patchy clay films are on the faces of the peds.

A soil that has a surface layer of brown fine sand, about 20 inches thick, makes up 15 to 20 percent of this unit. Below the surface layer, to a depth of 50 inches, is reddish-brown sandy clay loam.

A soil that occurs in areas that are 5 to 15 feet above surrounding soils makes up about 10 to 20 percent of this unit. It has a reddish-yellow, slightly acid surface layer of fine sand that is 60 to 80 inches thick over red sandy clay loam.

Blown-out land makes up 10 to 20 percent of this unit. Most of the surface layer of this land type has been blown away, and reddish-brown sandy clay loam about 30 inches thick is exposed. The underlying material is reddish-yellow fine sand and loamy fine sand.

Soil blowing is the principal hazard on these soils. Most of the acreage is used as range. Capability unit VIe-5; Deep Sand range site.

Oil-Waste Land

Oil-waste land (Os) consists of areas that range from 5 to 55 acres. Slopes are generally 1 to 3 percent. Liquid oily waste and salt water have contaminated these areas to a depth of 2 feet or more. Gravity flow and lateral seepag from slush pits and wells have added to the contamination

Plants on areas of Oil-waste land are sparse, and revegetating the areas is difficult. Capability unit VIIIs-1; not used as range.

Olton Series

The Olton series consists of deep, well-drained, nearly level to gently sloping soils that are moderately slowly permeable. These soils have high available water capacity

In a representative profile the surface layer is reddish brown, noncalcareous clay loam about 12 inches thick. Th next layer is reddish-brown, firm sandy clay, about 1 inches thick, that is calcareous in the lower 9 inches. It i underlain by red, calcareous sandy clay, about 10 inche thick, and light-red, friable clay loam that is about 1 inches thick and is 20 to 30 percent calcium carbonat Below, to a depth of 64 inches, is red, friable, calcareou sandy clay loam.

Representative profile of an Olton clay loam (90 fe south and 0.1 mile west of intersection of county roads, miles north and 1 mile east of Funston):

Ap—0 to 8 inches, reddish-brown (5YR 4/3) clay loam, da reddish brown (5YR 3/3) moist; moderate, very fin subangular blocky structure to granular; hard, friabl sticky; mildly alkaline; gradual, smooth boundary.

A12—8 to 12 inches, reddish-brown (5YR 4/3) clay loam, da reddish brown (5YR 3/3) moist; medium, subangul blocky structure to granular; hard, friable, stick common worm casts and a few fine pores; mildly alk line; abrupt, smooth boundary.

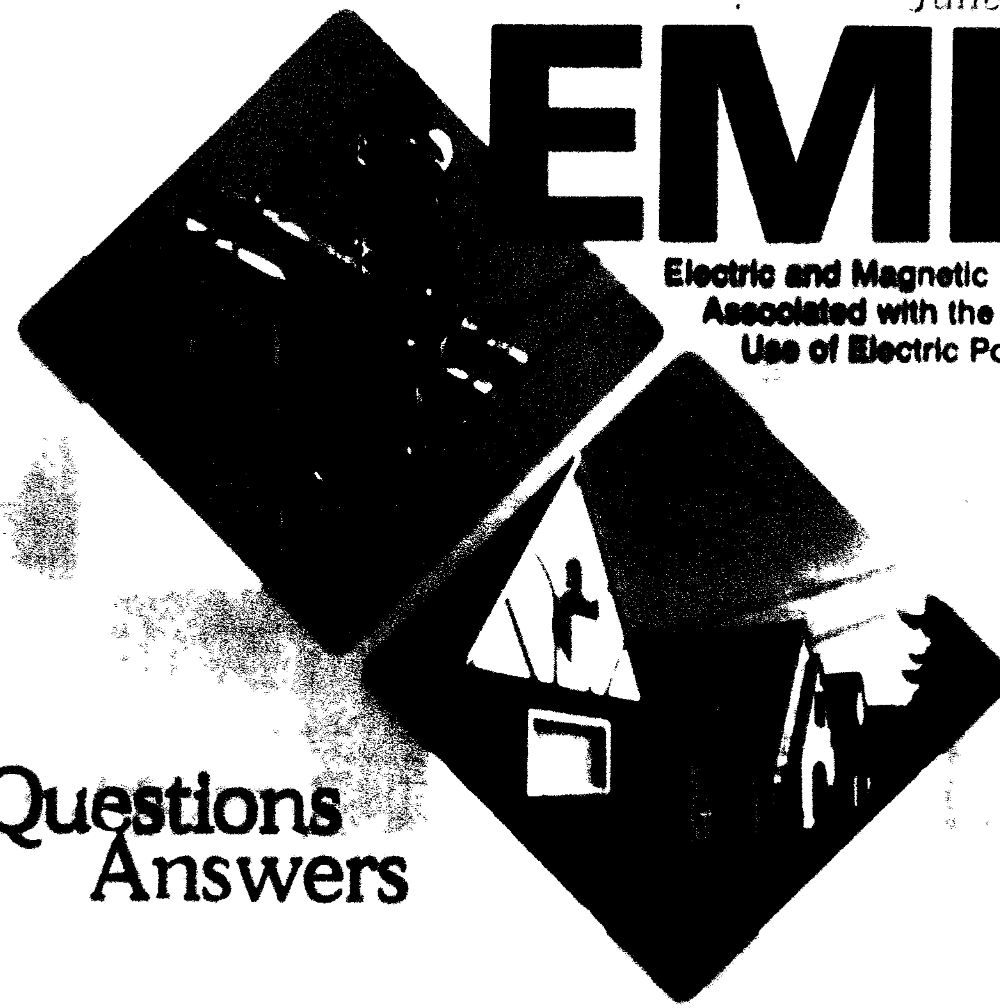
B21t—12 to 19 inches, reddish-brown (5YR 4/4) sandy cla dark reddish brown (5YR 3/4) moist; moderate, m dium, blocky structure; hard, firm, sticky and plastic common continuous clay films; neutral; gradual, wa boundary.

B22t—19 to 28 inches, reddish-brown (2.5YR 5/4) sandy cla reddish brown (2.5YR 4/4) moist; moderate, mediu blocky structure; hard, firm, sticky and plastic; co mon continuous clay films; a few fine soft masses a

June 2002

EMF

Electric and Magnetic Fields Associated with the Use of Electric Power



Questions Answers

prepared by the
National Institute of Environmental Health Sciences
National Institutes of Health

EMF RAPID

sponsored by the
NIEHS DOE EMF RAPID Program

Contents

n

ntury, electricity has been an essential part of our lives. ances, office equipment, and countless other devices that asier, and more interesting. Use of electric power is ited. However, some have wondered whether the electric produced through the generation, transmission, and use equency EMF, 50 or 60 hertz (Hz)] might adversely affect arch studies and scientific reviews have been conducted

s of the health effects of EMF did not provide ie study of the possible health effects of EMF has been sults have been reviewed by expert scientific panels in countries. This booklet summarizes the results of these is remain about the possibility of health effects related to ubstantially reduced the level of concern.

e was led by two U.S. government institutions, the imental Health Sciences (NIEHS) of the National Institutes nt of Energy (DOE), with input from a wide range of This evaluation, known as the Electric and Magnetic nformation Dissemination (EMF RAPID) Program, was a l of providing scientific evidence to determine whether y EMF involves a potential risk to human health.

In 1999, at the conclusion of the EMF RAPID Program, the NIEHS reported to the U.S. Congress that the overall scientific evidence for human health risk from EMF exposure is weak. No consistent pattern of biological effects from exposure to EMF had emerged from laboratory studies with animals or with cells. However, epidemiological studies (studies of disease incidence in human populations) had shown a fairly consistent pattern that associated potential EMF exposure with a small increased risk for leukemia in children and chronic lymphocytic leukemia in adults. Since 1999, several other assessments have been completed that support an association between childhood leukemia and exposure to power-frequency EMF. These more recent reviews, however, do not support a link between EMF exposures and adult leukemias. For both childhood and adult leukemias, interpretation of the epidemiological findings has been difficult due to the absence of supporting laboratory evidence or a scientific explanation linking EMF exposures with leukemia.

EMF exposures are complex and exist in the home and workplace as a result of all types of electrical equipment and building wiring as well as a result of nearby power lines. This booklet explains the basic principles of electric and magnetic fields, provides an overview of the results of major research studies, and summarizes conclusions of the expert review panels to help you reach your own conclusions about EMF-related health concerns.

ics

need to know to have a basic understanding of (EMF), compares EMF with other forms of 'iefly discusses how such fields may affect us.

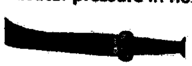
ɜnd magnetic fields?

(EMF) are invisible lines of force that surround any 's, electrical wiring, and electrical equipment all produce sources of EMF as well (see pages 33–35). The focus of quency EMF—that is, EMF associated with the ıd use of electric power.

** miliar Comparisons**

nected to an open faucet the nozzle turned off.

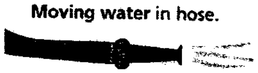
Water pressure in hose.



Nozzle closed

ıected to an open faucet the nozzle turned on.

Moving water in hose.



Nozzle open

magnetic field

Electric fields are produced by voltage and increase in strength as the voltage increases. The electric field strength is measured in units of volts per meter (V/m). Magnetic fields result from the flow of current through wires or electrical devices and increase in strength as the current increases. Magnetic fields are measured in units of gauss (G) or tesla (T)

Most electrical equipment has to be turned on, i.e., current must be flowing, for a magnetic field to be produced. Electric fields are often present even when the equipment is switched off, as long as it remains connected to the source of electric power. Brief bursts

of EMF (sometimes called "transients") can also occur when electrical devices are turned on or off.

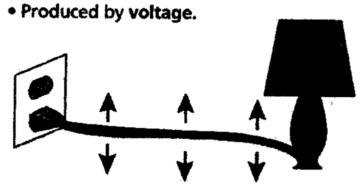
Electric fields are shielded or weakened by materials that conduct electricity—even materials that conduct poorly, including trees, buildings, and human skin. Magnetic fields, however, pass through most materials and are therefore more difficult to shield. Both electric fields and magnetic fields decrease rapidly as the distance from the source increases.

Even though electrical equipment, appliances, and power lines produce both electric and magnetic fields, most recent research has focused on potential health effects of magnetic field exposure. This is because some epidemiological studies have reported an increased cancer risk associated with estimates of magnetic field exposure (see pages 19 and 20 for a summary of these studies). No similar associations have been reported for electric fields; many of the studies examining biological effects of electric fields were essentially negative.

A Comparison of Electric and Magnetic Fields

Electric Fields

- **Produced by voltage.**

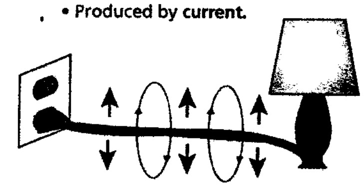


Lamp plugged in but turned off. Voltage produces an electric field.

- **Measured in volts per meter (V/m) or in kilovolts per meter (kV/m).**
- **Easily shielded (weakened) by conducting objects such as trees and buildings.**
- **Strength decreases rapidly with increasing distance from the source.**

Magnetic Fields

- **Produced by current.**

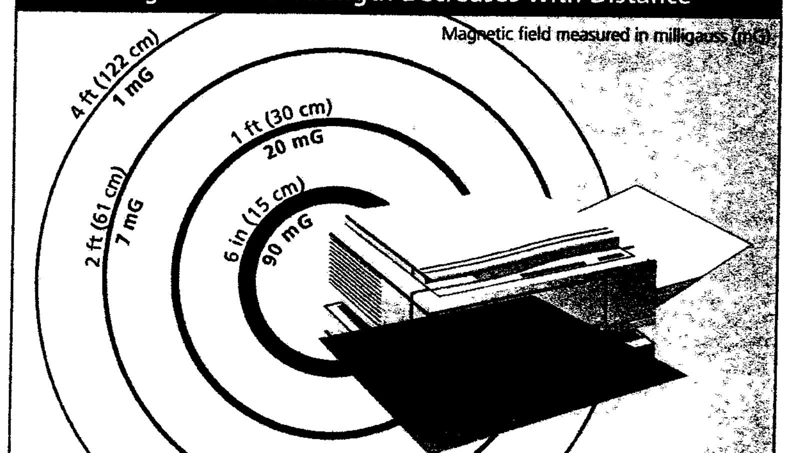


Lamp plugged in and turned on. Current now produces a magnetic field also.

- Measured in **gauss (G) or tesla (T).**
- **Not easily shielded** (weakened) by most material.
- **Strength decreases rapidly with increasing distance from the source.**

An appliance that is plugged in and therefore connected to a source of electricity has an electric field even when the appliance is turned off. To produce a magnetic field, the appliance must be plugged in and turned on so that the current is flowing

Magnetic Field Strength Decreases with Distance



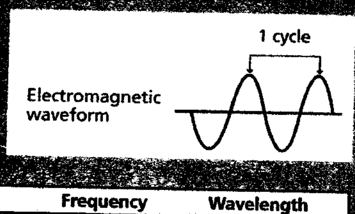
Source: EMF in Your Environment, EPA, 1992.

You cannot see a magnetic field, but this illustration represents how the strength of the magnetic field can diminish just 1–2 feet (30–61 centimeters) from the source. This magnetic field is a 60-Hz power-frequency field

ric and magnetic fields

fields can be characterized by their wavelength, trength). The graphic below shows the waveform of an etic field. The direction of the field alternates from one back to the first polarity in a period of time called one the distance between a peak on the wave and the next he frequency of the field, measured in hertz (Hz). les that occur in one second. Electricity in North America per second, or 60 Hz. In many other parts of the world ver is 50 Hz.

equency and Wavelength



MF used in this booklet?

rs to electric and magnetic fields at extremely low sociated with the use of electric power. The term EMF ler sense as well, encompassing electromagnetic fields s (see page 8).

suring EMF: Common Terms

volts per meter (V/m) or in kilovolts per meter [illegible]

ts of gauss (G) or tesla (T). Gauss is the unit [illegible] ationally accepted scientific term. 1 T = 10,000 G

sures involve magnetic fields that are only a fraction [illegible] d in units of microtesla (μT) or milligauss (mG). A milligauss is 1/1,000 00 of a tesla. 1 G = 1,000 mG; 1 T = 1,000,000 μT

otesla (μT) to milligauss (mG), multiply by 10.

When we use EMF in this booklet, we mean extremely low frequency (ELF) electric and magnetic fields, ranging from 3 to 3,000 Hz (see page 8). This range includes power-frequency (50 or 60 Hz) fields. In the ELF range, electric and magnetic fields are not coupled or interrelated in the same way that they are at higher frequencies. So, it is more useful to refer to them as "electric and magnetic fields" rather than "electromagnetic fields." In the popular press, however, you will see both terms used, abbreviated as EMF.

This booklet focuses on extremely low frequency EMF, primarily power-frequency fields of 50 or 60 Hz, produced by the generation, transmission, and use of electricity.

Q How are power-frequency EMF different from other types of electromagnetic energy?

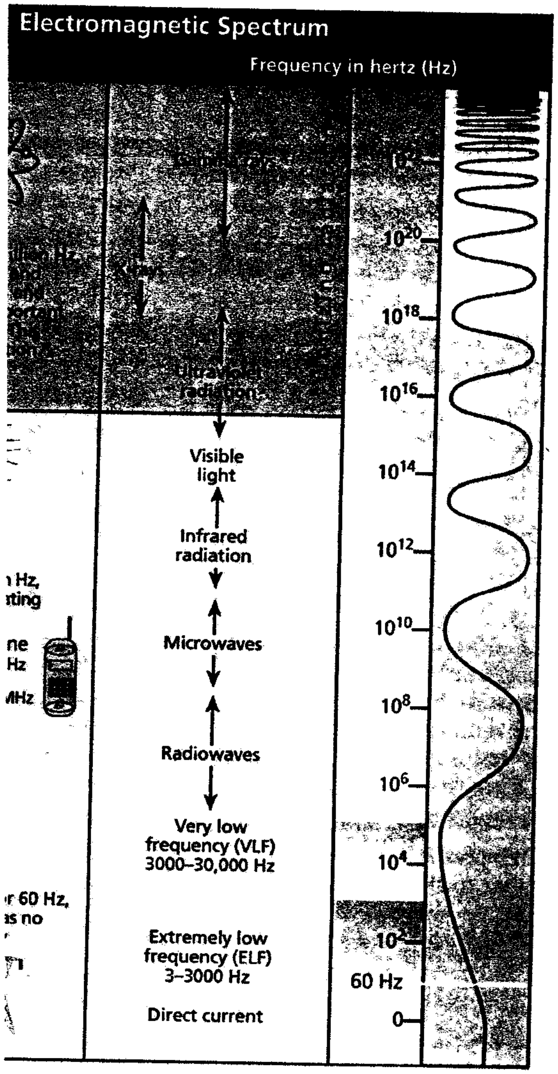
A X-rays, visible light, microwaves, radio waves, and EMF are all forms of electromagnetic energy. One property that distinguishes different forms of electromagnetic energy is the frequency, expressed in hertz (Hz). Power-frequency EMF, 50 or 60 Hz, carries very little energy, has no ionizing effects, and usually has no thermal effects (see page 8). Just as various chemicals affect our bodies in different ways, various forms of electromagnetic energy can have very different biological effects (see "Results of EMF Research" on page 16).

Some types of equipment or operations simultaneously produce electromagnetic energy of different frequencies. Welding operations, for example, can produce electromagnetic energy in the ultraviolet, visible, infrared, and radio-frequency ranges, in addition to power-frequency EMF. Microwave ovens produce 60-Hz fields of several hundred milligauss, but they also create microwave energy inside the oven that is at a much higher frequency (about 2.45 billion Hz). We are shielded from the higher frequency fields inside the oven by its casing, but we are not shielded from the 60-Hz fields.

Cellular telephones communicate by emitting high-frequency electric and magnetic fields similar to those used for radio and television broadcasts. These radio-frequency and microwave fields are quite different from the extremely low frequency EMF produced by power lines and most appliances.

Q How are alternating current sources of EMF different from direct current sources?

A Some equipment can run on either alternating current (AC) or direct current (DC). In most parts of the United States, if the equipment is plugged into a household wall socket, it is using AC electric current that reverses direction in the electrical wiring—or alternates—60 times per second, or at 60 hertz (Hz). If the equipment uses batteries, then electric current flows in one direction only. This



llustrates the concept that the higher the frequency, the more fields do not vary at 0 Hz (direct current) and vary trillions of op of the spectrum Note that 10^4 means 10 x 10 x 10 x 10 or ·) = 1,000 Hz. 1 megahertz (MHz) = 1,000,000 Hz

produces a "static" or stationary magnetic field, also called a direct current field. Some battery-operated equipment can produce time-varying magnetic fields as part of its normal operation.

Q What happens when I am exposed to EMF?

A In most practical situations, DC electric power does not induce electric currents in humans. Strong DC magnetic fields are present in some industrial environments, can induce significant currents when a person moves, and may be of concern for other reasons, such as potential effects on implanted medical devices (see page 47 for more information on pacemakers and other medical devices).

AC electric power produces electric and magnetic fields that create weak electric currents in humans. These are called "induced currents." Much of the research on how EMF may affect human health has focused on AC-induced currents.

Electric fields

A person standing directly under a high-voltage transmission line may feel a mild shock when touching something that conducts electricity. These sensations are caused by the strong electric fields from the high-voltage electricity in the lines. They occur only at close range because the electric fields rapidly become weaker as the distance from the line increases. Electric fields may be shielded and further weakened by buildings, trees, and other objects that conduct electricity.

Magnetic fields

Alternating magnetic fields produced by AC electricity can induce the flow of weak electric currents in the body. However, such currents are estimated to be smaller than the measured electric currents produced naturally by the brain, nerves, and heart.

Q Doesn't the earth produce EMF?

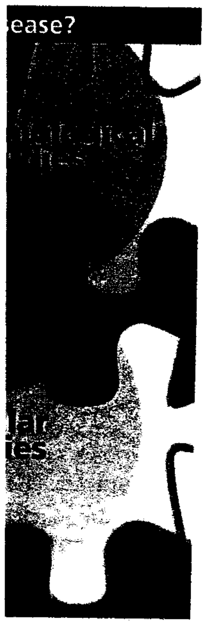
A Yes. The earth produces EMF, mainly in the form of static fields, similar to the fields generated by DC electricity. Electric fields are produced by air turbulence and other atmospheric activity. The earth's magnetic field of about 500 mG is thought to be produced by electric currents flowing deep within the earth's core. Because these fields are static rather than alternating, they do not induce currents in stationary objects as do fields associated with alternating current. Such static fields can induce currents in moving and rotating objects.

| Potential Health Effects

:ientific studies are conducted and evaluated
'cts.

ate whether EMF exposures cause

ory studies of cells, clinical studies, computer simulations, lemiological) studies all provide valuable information. hat certain exposures cause disease, scientists consider ıs disciplines. No single study or type of study is definitive



e puzzle, but no single

Laboratory studies

Laboratory studies with cells and animals can provide evidence to help determine if an agent such as EMF causes disease. Cellular studies can increase our understanding of the biological mechanisms by which disease occurs. Experiments with animals provide a means to observe effects of specific agents under carefully controlled conditions. Neither cellular nor animal studies, however, can recreate the complex nature of the whole human organism and its environment. Therefore, we must use caution in applying the results of cellular or animal studies directly to humans or concluding that a lack of an effect in laboratory studies proves that an agent is safe. Even with these limitations, cellular and animal studies have proven very

useful over the years for identifying and understanding the toxicity of numerous chemicals and physical agents.

Very specific laboratory conditions are needed for researchers to be able to detect EMF effects, and experimental exposures are not easily comparable to human exposures. In most cases, it is not clear how EMF actually produces the effects observed in some experiments. Without understanding how the effects occur, it is difficult to evaluate how laboratory results relate to human health effects.

Some laboratory studies have reported that EMF exposure can produce biological effects, including changes in functions of cells and tissues and subtle changes in hormone levels in animals. It is important to distinguish between a biological effect and a health effect. Many biological effects are within the normal range of variation and are not necessarily harmful. For example, bright light has a biological effect on our eyes, causing the pupils to constrict, which is a normal response.

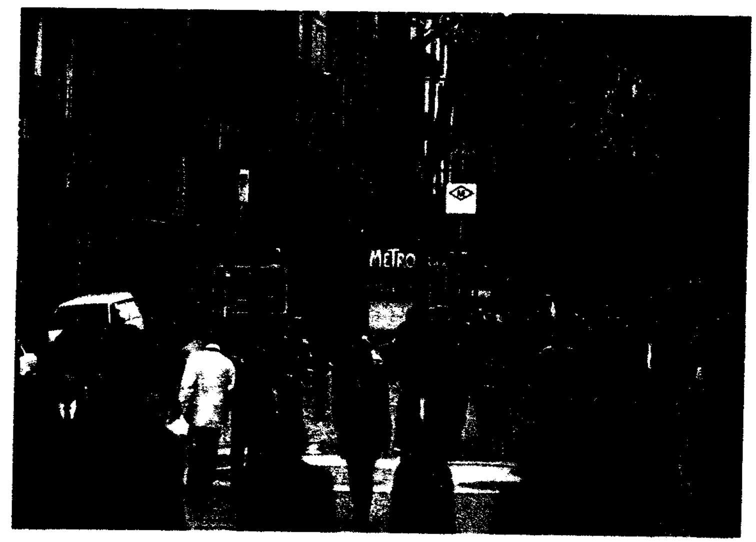
Clinical studies

In clinical studies, researchers use sensitive instruments to monitor human physiology during controlled exposure to environmental agents. In EMF studies, volunteers are exposed to electric or magnetic fields at higher levels than those commonly encountered in everyday life. Researchers measure heart rate, brain activity, hormonal levels, and other factors in exposed and unexposed groups to look for differences resulting from EMF exposure.

Epidemiology

A valuable tool to identify human health risks is to study a human population that has experienced the exposure. This type of research is called epidemiology.

The epidemiologist observes and compares groups of people who have had or have not had certain diseases and exposures to see if the risk of disease is different between the exposed and unexposed groups. The epidemiologist does not control the exposure and cannot experimentally control all the factors that might affect the risk of disease.



Most researchers agree that epidemiology—the study of patterns and possible causes of diseases—is one of the most valuable tools to identify human health risks

ɹate the results of epidemiological

ʼonsidered when determining whether an agent
ıre that an epidemiological study associates with
disease is not always the actual cause of the disease.
ıt actually causes a health effect, several issues are

n

ın between an exposure and disease, the more confident
is due to the exposure being studied. With cigarette
the association is very strong—20 times the normal risk
a relationship between EMF and certain rare cancers,
ɜaker (see page 19).

nore convincing if disease rates increase as exposure
-response relationships have appeared in only a few

ın association found in one study appears in other
study populations and methods. Associations found
ʸ to be causal. With regard to EMF, results from different
in important ways, such as what type of cancer is
ure. Because of this inconsistency, scientists cannot be
l risks are due to EMF or other factors.

‹ in an epidemiological study, results of laboratory
ırtant to support the association. Many scientists remain
ɔn between EMF exposure and cancer because laboratory
own any consistent evidence of adverse health effects.
ental studies revealed a plausible biological explanation

information

ːation with EMF epidemiological studies is how the
ɔbtained. Did the researchers simply estimate people's
eir job titles or how their houses were wired, or did
measurements? What did they measure (electric fields,
ʼow often were the EMF measurements made and at

what time? In how many different places were the fields measured? More recent studies have included measurements of magnetic field exposure. Magnetic fields measured at the time a study is conducted can only estimate exposures that occurred in previous years (at the time a disease process may have begun). Lack of comprehensive exposure information makes it more difficult to interpret the results of a study, particularly considering that everyone in the industrialized world has been exposed to EMF.

Confounding

Epidemiological studies show relationships or correlations between disease and other factors such as diet, environmental conditions, and heredity. When a disease is correlated with some factor, it does not necessarily mean that the correlated factor causes the disease. It could mean that the factor occurs together with some other factor, not measured in the study, that actually causes the disease. This is called confounding.

For example, a study might show that alcohol consumption is correlated with lung cancer. This could occur if the study group consists of people who drink and also smoke tobacco, as often happens. In this example, alcohol use is correlated with lung cancer, but cigarette smoking.is a confounding factor and the true cause of the disease.

Statistical significance

Researchers use statistical methods to determine the likelihood that the association between exposure and disease is due simply to chance. For a result to be considered "statistically significant," the association must be stronger than would be expected to occur by chance alone.

Meta-analysis

One way researchers try to get more information from epidemiological studies is to conduct a meta-analysis. A meta-analysis combines the summary statistics of many studies to explore their differences and, if appropriate, calculates an overall summary risk estimate. The main challenge faced by researchers performing meta-analyses is that populations, measurements, evaluation techniques, participation rates, and potential confounding factors vary in the original studies. These differences in the studies make it difficult to combine the results in a meaningful way.

Pooled analysis

Pooled analysis combines the original data from several studies and conducts a new analysis on the primary data. It requires access to the original data from individual studies and can only include diseases or factors included in all the studies, but it has the advantage that the same parameters can be applied to all studies. As with meta-analysis, pooled analysis is still subject to the limitations of the experimental

ies (for example, evaluation techniques, participation
ɜ differs from meta-analysis, which combines the
fferent studies, not their original data.

ıcterize EMF exposure?

ct of EMF exposure, if any, affects human health. Because
tion to the field strength, we must ask how long an
ɜs, and at what time of day or night it occurs. House
n a significant source of EMF exposure for an individual.
duced by the wiring depend on the amount of current
ıg, and appliance use varies during the day, magnetic field

ıers describe EMF exposures by estimating the average
ists believe that average exposure may not be the best
ɔsure and that other parameters, such as peak exposure
ɔe important.

ıge field strength?

ıation reported most often has been a person's EMF
ne (average field strength). With cancer-causing
ıge exposure over many years can be a good way to
of getting the disease.

calculate average magnetic field exposures. One method
ear a small monitor that takes many measurements over
er. Then the average of those measurements is calculated.
ɔlacing a monitor that takes many measurements in a
r 48-hour period. Sometimes averages are calculated for
pation, people working in similar environments, or
ɜ of the same type or similar types of equipment.

sure measured in epidemiological

ɜrns and possible causes of diseases in human
are usually observational rather than experimental. This means that the researcher observes and compares groups of people who have had certain diseases and exposures and looks for possible "associations." The epidemiologist must find a way to estimate the exposure that people had at an earlier time.

ɔsure (such as
ıosure *caused*
and disease
tronger is the
ıe disease.

Some exposure estimates for residential studies have been based on designation of households in terms of "wire codes." In other studies, measurements have been made in homes, assuming that EMF levels at the time of the measurement are similar to levels at some time in the past. Some studies involved "spot measurements." Exposure levels change as a person moves around in his or her environment, so spot measurements taken at specific locations only approximate the complex variations in exposure a person experiences. Other studies measured magnetic fields over a 24-hour or 48-hour period. Exposure levels for some occupational studies are measured by having certain employees wear personal monitors. The data taken from these monitors are sometimes used to estimate typical exposure levels for employees with certain job titles. Researchers can then estimate exposures using only an employee's job title and avoid measuring exposures of all employees.

Methods to Estimate EMF Exposure

Wire Codes

A classification of homes based on characteristics of power lines outside the home (thickness of the wires, wire configuration, etc.) and their distance from the home. This information is used to code the homes into groups with higher and lower predicted magnetic field levels.

Spot Measurement

An instantaneous or very short-term (e.g., 30-second) measurement taken at a designated location.

Time-Weighted Average

A weighted average of exposure measurements taken over a period of time that takes into account the time interval between measurements. When the measurements are taken with a monitor at a fixed sampling rate, the time-weighted average equals the arithmetic mean of the measurements.

Personal Monitor

An instrument that can be worn on the body for measuring exposure over time.

Calculated Historical Fields

An estimate based on a theoretical calculation of the magnetic field emitted by power lines using historical electrical loads on those lines.

EMF Research

results of EMF research worldwide, including hildren and adults, clinical studies of how F exposures, and laboratory research with

veen EMF exposure and childhood

des of research to determine whether elevated EMF netic fields, is related to an increased risk of childhood finitive answer. Much progress has been made. research leading to reasonably clear answers and l. The best available evidence at this time leads to the questions about the link between EMF exposure and

veen power line configurations (wire codes) and

veen measured fields and childhood leukemia? Yes, but and it is not clear whether it represents a cause

iiological evidence for evaluating a exposure and childhood leukemia?

ith the pioneering research of Dr. Nancy Wertheimer nver, Colorado, focused on power line configurations e systematically evaluated and coded for their elevated magnetic fields in homes and classified into r predicted magnetic field levels (see discussion of wire the first study and two that followed in Denver and iation between wire codes indicative of elevated d leukemia, larger, more recent studies in the central in several provinces of Canada did not find such an

association. In fact, combining the evidence from all the studies, we can conclude with some confidence that wire codes are not associated with a measurable increase in the risk of childhood leukemia.

The other approach to assessing EMF exposure in homes focused on the measurements of magnetic fields. Unlike wire codes, which are only applicable in North America due to the nature of the electric power distribution system, measured fields have been studied in relation to childhood leukemia in research conducted around the world, including Sweden, England, Germany, New Zealand, and Taiwan. Large, detailed studies have recently been completed in the United States, Canada, and the United Kingdom that provide the most evidence for making an evaluation. These studies have produced variable findings, some reporting small associations, others finding no associations.

National Cancer Institute Study

In 1997, after eight years of work, Dr. Martha Linet and colleagues at the National Cancer Institute (NCI) reported the results of their study of childhood acute lymphoblastic leukemia (ALL). The case-control study involved more than 1,000 children living in 9 eastern and midwestern U.S. states and is the largest epidemiological study of childhood leukemia to date in the United States. To help resolve the question of wire code versus measured magnetic fields, the NCI researchers carried out both types of exposure assessment. Overall, Linet reported little evidence that living in homes with higher measured magnetic-field levels was a disease risk and found no evidence that living in a home with a high wire code configuration increased the risk of ALL in children.

United Kingdom Childhood Cancer Study

In December 1999, Sir Richard Doll and colleagues in the United Kingdom announced that the largest study of childhood cancer ever undertaken—involving nearly 4,000 children with cancer in England, Wales, and Scotland—found no evidence of excess risk of childhood leukemia or other cancers from exposure to power-frequency magnetic fields. It should be noted, however, that because most power lines in the United Kingdom are underground, the EMF exposures of these children were mostly lower than 0.2 microtesla or 2 milligauss.

After reviewing all the data, the U.S. National Institute of Environmental Health Sciences (NIEHS) concluded in 1999 that the evidence was weak, but that it was still sufficient to warrant limited concern. The NIEHS rationale was that no individual epidemiological study provided convincing evidence linking magnetic field exposure with childhood leukemia, but the overall pattern of results for some methods of measuring exposure suggested a weak association between increasing exposure to EMF and increasing risk of childhood leukemia. The small number of cases in these studies made it impossible to firmly demonstrate this association. However, the fact that similar results had been observed in studies of different populations using a variety of study designs supported this observation.

A major challenge has been to determine whether the most highly elevated, but rarely encountered, levels of magnetic fields are associated with an increased risk of leukemia. Early reports focused on the risk associated with exposures above 2 or 3 milligauss, but the more recent studies have been large enough to also provide some information on levels above 3 or 4 milligauss. It is estimated that 4.5% of homes in the United States have magnetic fields above 3 milligauss, and 2.5% of homes have levels above 4 milligauss.

What is Cancer?

ɔe at least 200 different diseases, all involving uncontrolled cell growth
red by the incidence—the number of new cases diagnosed each year
ıe number of new cases diagnosed per 100,000 people per year

n the United States is 382 per 100,000 per year, and childhood cancers
:ers. The factors that influence risk differ among the forms of cancer
g, diet, and alcohol contribute to specific types of cancer (For example,
lung cancer, bladder cancer, and oral cancer.) For many other cancers,

ncers that arise in the bone marrow where blood cells are formed. The
of all cancer cases in adults but are the most common form of cancer
d under, the incidence of childhood leukemia is approximately 6 per
with age to about 2 per 100,000 per year for children 10 and older. In
adult leukemia is about 10 cases per 100,000 people per year Little is
ıia, although genetic factors play a role. The only known causes are
ther chemicals and drugs that suppress bone marrow function, and a

tem (the brain and spinal cord) is uncommon, with incidence in the
es in 100,000 people per year. The causes of the disease are largely
udies have reported an association with certain occupational chemical
: scalp is a known risk factor for brain cancer. Factors associated with
cancer—such as smoking, diet, and excessive alcohol use—have not
ɪrain cancer.

rated information from all the studies says about
ıd leukemia, two groups have conducted pooled
al data from relevant studies were integrated and
land et al., 2000) combined 12 relevant studies with
s, and the other considered 9 such studies (Ahlbom et
two pooled analyses are different, but their findings
idence for an association (relative risk of
ɜs above 3 mG. However, few individuals had high
ıerefore, even combining all studies, there is
th of the association.

zes the results for the epidemiological studies of EMF
emia analyzed in the pooled analysis by Greenland et
ummary review was the magnetic fields that occurred
sis. The results were derived from either calculated
ıeasurements of magnetic fields. The North American

Residential Exposure to Magnetic Fields and Childhood Leukemia

	Magnetic field category (mG)					
	>1 – ≤2 mG		>2 – ≤3 mG		>3 mG	
First author	Estimate	95% CL	Estimate	95% CL	Estimate	95% CL
Coghill	0.54	0.17, 1.74	No controls		No controls	
Dockerty	0.65	0.26, 1.63	2.83	0.29, 27.9	No controls	
Feychting	0.63	0.08, 4.77	0.90	0.12, 7.00	4.44	1.67, 11.7
Linet	1.07	0.82, 1.39	1.01	0.64, 1.59	1.51	0.92, 2.49
London	0.96	0.54, 1.73	0.75	0.22, 2.53	1.53	0.67, 3.50
McBride	0.89	0.62, 1.29	1.27	0.74, 2.20	1.42	0.63, 3.21
Michaelis	1.45	0.78, 2.72	1.06	0.27, 4.16	2.48	0.79, 7.81
Olsen	0.67	0.07, 6.42	No cases		2.00	0.40, 9.93
Savitz	1.61	0.64, 4.11	1.29	0.27, 6.26	3.87	0.87, 17.3
Tomenius	0.57	0.33, 0.99	0.88	0.33, 2.36	1.41	0.38, 5.29
Tynes	1.06	0.25, 4.53	No cases		No cases	
Verkasalo	1.11	0.14, 9.07	No cases		2.00	0.23, 17.7
Study summary	0.95	0.80, 1.12	1.06	0.79, 1.42	1.69*	1.25, 2.29
	1 – <2 mG		2 – <4 mG		≥4 mG	
**United Kingdom	0.84	0.57, 1.24	0.98	0.50, 1.93	1.00	0.30, 3.37

95% CL = 95% confidence limits.
Source Greenland et al , 2000.
* Mantel-Haenszel analysis (p = 0 01) Maximum-likelihood summaries differed by less than 1% from these summaries; based on 2,656 cases and 7,084 controls Adjusting for age, sex, and other variables had little effect on summary results.
** These data are from a recent United Kingdom study not included in the Greenland analysis but included in another pooled analysis (Ahlbom et al. 2000). The United Kingdom study included 1,073 cases and 2,224 controls.

For this table, the column headed "estimate" describes the relative risk. Relative risk is the ratio of the risk of childhood leukemia for those in a magnetic field exposure group compared to persons with exposure levels of 1.0 mG or less. For example, Coghill estimated that children with exposures between 1 and 2 mG have 0.54 times the risk of children whose exposures were less than 1 mG. London's study estimates that children whose exposures were greater than 3 mG have 1 53 times the risk of children whose exposures were less than 1 mG. The column headed "95% CL" (confidence limits) describes how much random variation is in the estimate of relative risk. The estimate may be off by some amount due to random variation, and the width of the confidence limits gives some notion of that variation. For example, in Coghill's estimate of 0 54 for the relative risk, values as low as 0 17 or as high as 1.74 would not be statistically significantly different from the value of 0.54 Note there is a wide range of estimates of relative risk across the studies and wide confidence limits for many studies. In light of these findings, the pooling of results can be extremely helpful to calculate an overall estimate, much better than can be obtained from any study taken alone.

studies (Linet, London, McBride, Savitz) were 60 Hz; all other studies were 50 Hz. Results from the recent study from the United Kingdom (see page 17) are also included in the table. This study was included in the analysis by Ahlbom et al. (2000). The relative risk estimates from the individual studies show little or no association of magnetic fields with childhood leukemia. The study summary for the pooled analysis by Greenland et al. (2000) shows a weak association between childhood leukemia and magnetic field exposures greater 3 mG.

ween EMF exposure and childhood her forms of cancer in children?

s suggested an association between EMF exposure and all those initial findings have not been confirmed by other lable series of studies indicates no association between od cancers other than leukemia. Far fewer of these studies studies of childhood leukemia.

ween residential EMF exposure and

een conducted to address EMF and adult cancer do not an association. Thus, a link has not been established posure and adult cancers, including leukemia, brain ee table below).

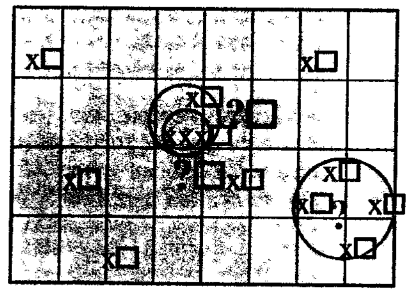
to Magnetic Fields and Adult Cancer

e of exposure data	Results (odds ratios) Leukemia	CNS tumors	All cancers
ulated historical fields	0.92	NA	NA
ulated & spot measurements	1.5*	0.7	NA
ulated historical fields	1.4*	1.1	NA
ulated historical fields		1.1 (breast cancer)	
ulated historical fields	1.43	NA	[illegible]
codes & spot measurements	0.75	NA	NA
codes & spot measurements	NA	0.9	NA
ulated historical fields	1.88	NA	NA

d by chance).
f 1.00 means there was no increase or decrease in risk. In other words, the odds se, cancer) and were exposed to a particular agent (in this case, EMF) are the disease. An odds ratio greater than 1 may occur simply by chance, unless it is

Q Have clusters of cancer or other adverse health effects been linked to EMF exposure?

A An unusually large number of cancers, miscarriages, or other adverse health effects that occur in one area or over one period of time is called a "cluster." Sometimes clusters provide an early warning of a health hazard. But most of the time the reason for the cluster is not known. There have been no proven instances of cancer clusters linked with EMF exposure.



The definition of a "cluster" depends on how large an area is included. Cancer cases (x's in illustration) in a city, neighborhood, or workplace may occur in ways that suggest a cluster due to a common environmental cause. Often these patterns turn out to be due to chance. Delineation of a cluster is subjective—where do you draw the circles?

Q If EMF does cause or promote cancer, shouldn't cancer rates have increased along with the increased use of electricity?

A Not necessarily. Although the use of electricity has increased greatly over the years, EMF exposures may not have increased. Changes in building wiring codes and in the design of electrical appliances have in some cases resulted in lower magnetic field levels. Rates for various types of cancer have shown both increases and decreases through the years, due in part to improved prevention, diagnosis, reporting, and treatment.

ween EMF exposure in electrical ancer?

e been concerned with residential exposure to EMF and rs have been studying workplace exposure to EMF and adult a and brain cancer. This research began with surveys of job s progressed to include very large, detailed studies of the electric utility workers, in the United States, Canada, France, n European countries. Some studies have found evidence EMF exposure and both leukemia and brain cancer, whereas nd quality have not found such associations.

California electric utility workers reported no nce of an association between magnetic fields and

han 200,000 utility workers in 3 utility companies eported no significant association between all d cumulative exposure to magnetic fields. There tistically significant, increase in brain cancer. The hat the study did not provide clear-cut evidence osures caused leukemia or brain cancer.

involving more than 138,000 utility workers at United States did not support an association nagnetic field exposure and leukemia, but n cancer.

ers employed in all Danish utility companies tistically significant, excess risk for all cancers cancer. No excess risk was observed for leukemia. ~~cancer~~.

ctrical workers in the United Kingdom did not find cancer. An extension of this work reported in 2001 risk for brain cancer.

to pool the findings across several of the above studies timates of the association between EMF and cancer ombined summary statistics across studies provide ssociation between EMF exposure in the workplace cancer.

Q Have studies of workers in other industries suggested a link between EMF exposure and cancer?

A One of the largest studies to report an association between cancer and magnetic field exposure in a broad range of industries was conducted in Sweden (1993). The study included an assessment of EMF exposure in 1,015 different workplaces and involved more than 1,600 people in 169 different occupations. An association was reported between estimated EMF exposure and increased risk for chronic lymphocytic leukemia. An association was also reported between exposure to magnetic fields and brain cancer, but there was no dose-response relationship.

Another Swedish study (1994) found an excess risk of lymphocytic leukemia among railway engine drivers and conductors. However, the total cancer incidence (all tumors included) for this group of workers was lower than in the general Swedish population. A study of Norwegian railway workers found no evidence for an association between EMF exposure and leukemia or brain cancer. Although both positive and negative effects of EMF exposure have been reported, the majority of studies show no effects.

Q Is there a link between EMF exposure and breast cancer?

A Researchers have been interested in the possibility that EMF exposure might cause breast cancer, in part because breast cancer is such a common disease in adult women. Early studies identified a few electrical workers with male breast cancer, a very rare disease. A link between EMF exposure and alterations in the hormone melatonin was considered a possible hypothesis (see page 24). This idea provided motivation to conduct research addressing a possible link between EMF exposure and breast cancer. Overall, the published epidemiological studies have not shown such an association.

Q What have we learned from clinical studies?

A Laboratory studies with human volunteers have attempted to answer questions such as,

Does EMF exposure alter normal brain and heart function?
Does EMF exposure at night affect sleep patterns?
Does EMF exposure affect the immune system?
Does EMF exposure affect hormones?

The following kinds of biological effects have been reported. Keep in mind that a biological effect is simply a measurable change in some biological response. It may or may not have any bearing on health.

ıeart rate by EMF exposure has been reported. When ıponse is small (on average, a slowing of about three to l the response does not persist once exposure has ended

ı United States and one in Australia, have reported effects ıility. Exposures used in these experiments were relatively ower exposures failed to produce the effect. Effects have ıtly in repeated experiments.

y

ed that overnight exposure to 60-Hz magnetic fields may ity (EEG) during night sleep. In this study subjects were ıs or intermittent magnetic fields of 283 mG. Individuals magnetic fields showed alterations in traditional EEG of a pattern of poor and disrupted sleep. Several studies ı continuous exposure.

ıtem, and blood chemistry

ı human volunteers have evaluated the effects of power- n hormones, the immune system, and blood chemistry evidence for any consistent effect.

secreted mainly at night and primarily by the pineal d to the brain. Some laboratory experiments with vn that melatonin can slow the growth of cancer cells. . Suppressed nocturnal melatonin levels have been laboratory animals exposed to both electric and vations led to the hypothesis that EMF exposure might by weaken one of the body's defenses against cancer.

ıuman volunteers have now examined whether nagnetic field exposure affect blood levels of nan volunteers at night to power-frequency EMF conditions has no apparent effect on melatonin. Some) EMF at work or at home do report evidence for a nin. It is not clear whether the decreases in melatonin ıtal conditions are related to the presence of EMF

Q What effects of EMF have been reported in laboratory studies of cells?

A Over the years, scientists have conducted more than 1,000 laboratory studies to investigate potential biological effects of EMF exposure. Most have been *in vitro* studies; that is, studies carried out on cells isolated from animals and plants, or on cell components such as cell membranes. Other studies involved animals, mainly rats and mice. In general, these studies do not demonstrate a consistent effect of EMF exposure.

Most *in vitro* studies have used magnetic fields of 1,000 mG (100 μT) or higher, exposures that far exceed daily human exposures. In most incidences, when one laboratory has reported effects of EMF exposure on cells, other laboratories have not been able to reproduce the findings. For such research results to be widely accepted by scientists as valid, they must be replicated—that is, scientists in other laboratories should be able to repeat the experiment and get similar results. Cellular studies have investigated potential EMF effects on cell proliferation and differentiation, gene expression, enzyme activity, melatonin, and DNA. Scientists reviewing the EMF research literature find overall that the cellular studies provide little convincing evidence of EMF effects at environmental levels.

Q Have effects of EMF been reported in laboratory studies in animals?

A Researchers have published more than 30 detailed reports on both long-term and short-term studies of EMF exposures in laboratory animals (bioassays). Long-term animal bioassays constitute an important group of studies in EMF research. Such studies have a proven record for predicting the carcinogenicity of chemicals, physical agents, and other suspected cancer-causing agents. In the EMF studies, large groups of mice or rats were continuously exposed to EMF for two years or longer and were then evaluated for cancer. The U.S. National Toxicology Program (http://ntp-server.niehs.nih.gov/) has an extensive historical database for hundreds of different chemical and physical agents evaluated using this model. EMF long-term bioassays examined leukemia, brain cancer, and breast cancer—the diseases some epidemiological studies have associated with EMF exposure (see pages 16–23).

Several different approaches have been used to evaluate effects of EMF exposure in animal bioassays. To investigate whether EMF could promote cancer after genetic damage had occurred, some long-term studies used cancer initiators such as ultraviolet light, radiation, or certain chemicals that are known to cause genetic damage. Researchers compared groups of animals treated with cancer initiators to groups treated with cancer initiators and then exposed to EMF, to see if EMF exposure promoted the cancer growth (initiation-promotion model). Other studies tested the cancer promotion potential of EMF using mice that were predisposed to cancer because they had defects in the genes that control cancer.

ntinuous Exposure Studies, Two or More Years in Length

Exposure/animal numbers	Results
14,000 mG, 190 or 380 mice per group. Some groups treated with ionizing radiation.	No effect
20 to 10,000 mG, 100 per group	No effect
20 to 10,000 mG, 100 per group	No effect
20 to 20,000 mG, 50 per group *In utero* exposure	No effect
5,000 to 50,000 mG, 50 per group	No effect

)

udies have been completed and reported. Most tested for
ɛr-frequency (60-Hz) magnetic fields using rodents.
re largely negative. The Babbitt study evaluated the
data provide no support for the reported epidemiology
EMF exposure. Many scientists feel that the lack of
tory leukemia studies significantly weakens the case for
a.

, Germany, Sweden, and the United States have used
s to investigate whether EMF exposure promotes breast

are mixed; while the German studies showed some
S. studies showed none. Studies in Germany reported
ımors and tumor volume. A National Toxicology
performed without the use of other cancer-initiating
s of EMF exposure on the development of mammary

erved difference among these studies is not readily
of the experimental rodent model of mammary
ons are possible regarding a promoting effect of EMF on
ıry cancer.

cancer, liver cancer, and brain cancer have been
ion-promotion models and non-initiated long-term

reported for a co-promotion model of skin cancer in
d to EMF plus cancer-causing chemicals after cancers

had already been initiated. The same research team as well as an independent laboratory were unable to reproduce these results in subsequent experiments.

Non-cancer effects

Many animal studies have investigated whether EMF can cause health problems other than cancer. Researchers have examined many endpoints, including birth defects, immune system function, reproduction, behavior, and learning. Overall, animal studies do not support EMF effects on non-cancer endpoints.

Q Can EMF exposure damage DNA?

A Studies have attempted to determine whether EMF has genotoxic potential; that is, whether EMF exposure can alter the genetic material of living organisms. This question is important because genotoxic agents often also cause cancer or birth defects. Studies of genotoxicity have included tests on bacteria, fruit flies, and some tests on rats and mice. Nearly 100 studies on EMF genotoxicity have been reported. Most evidence suggests that EMF exposure is not genotoxic. Based on experiments with cells, some researchers have suggested that EMF exposure may inhibit the cell's ability to repair normal DNA damage, but this idea remains speculative because of the lack of genotoxicity observed in EMF animal studies.

Environment

'l magnetic field exposures in home and work common EMF sources and field intensities 's.

e EMF exposure?

ı about the best way to define "exposure" because ow which aspect of the field, if any, may be relevant to mportant aspects of exposure could be the highest sity, or the amount of time spent above a certain dely used measure of EMF exposure has been the time-field level (see discussion on page 15).

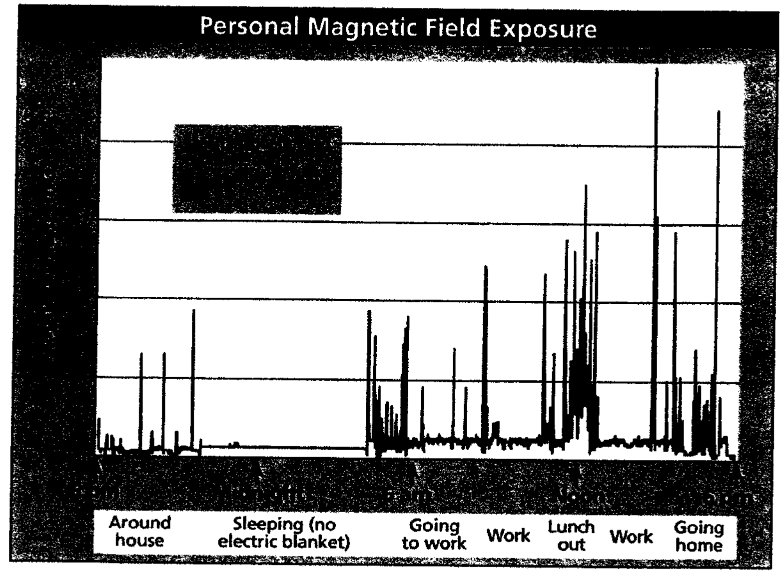
ıure measured?

ɛposure meters are now available. These automatically it varies over time. To determine a person's EMF ɔsure meter is usually worn at the waist or is placed as ɔn during the course of a work shift or day.

ɹsing survey meters, sometimes called "gaussmeters." els in a given location at a given time. Such sarily reflect personal EMF exposure because they are ance from the EMF source that the person would . Measurements are not always made in a location for at a person spends there. Such "spot measurements" s of the field over time, which can be significant.

Q What are some typical EMF exposures?

A The figure below is an example of data collected with a personal exposure meter.



In the above example, the magnetic field was measured every 1.5 seconds over a period of 24 hours. For this person, exposure at home was very low. The occasional spikes (short exposure to high fields) occurred when the person drove or walked under power lines or over underground power lines or was close to appliances in the home or office.

Several studies have used personal exposure meters to measure field exposure in different environments. These studies tend to show that appliances and building wiring contribute to the magnetic field exposure that most people receive while at home. People living close to high voltage power lines that carry a lot of current tend to have higher overall field exposures. As shown on page 32, there is considerable variation among houses.

Q What are typical EMF exposures for people living in the United States?

A Most people in the United States are exposed to magnetic fields that average less than 2 milligauss (mG), although individual exposures vary.

The following table shows the estimated average magnetic field exposure of the U.S. population, according to a study commissioned by the U.S. government as part

Public Information Dissemination (EMF RAPID) Program
neasured magnetic field exposure of about 1,000 people
ed among the U.S. population. Participants wore or
personal exposure meter and kept a diary of their
l away from home. Magnetic field values were
ice a second for 24 hours. The study reported that
s is similar in different regions of the country and similar

e Magnetic Field Exposure of the U.S. Population

ion (%)	95% confidence interval (%)	People exposed* (millions)
	73.8–78.9	197–211
	40.9–46.5	109–124
	11.8–17.3	31.5–46.2
	4.7–8.5	12.5–22 7
	2.5–5.2	6.7–13.9
	1.65–3.55	4.4–9 5
	0.29–1 16	0.77–3 1
	0 20–1 05	0 53–2 8
	0.035–0.83	0.09–2 2

his table summarizes some of the results of a study that sampled about 1,000 people
or example, we find that 76.3% of the sample population had a 24-hour average
ming that the sample was random, we can use statistics to say that we are 95%
rall U S. population exposed to greater than 0.5 mG is between 73 8% and 78 9%.

verage magnetic fields experienced during different
l, magnetic fields are greater at work than at home.

Magnetic Field Exposure of the U.S. Population for Various Activities

Population exposed (%)			
Bed	Work	School	Travel
48	81	63	87
30	49	25	48
14	20	3.5	13
7.2	13	1.6	4.1
4.7	8.0	< 1	1.5
3.7	4.6		1.0
1.6	2.5		0 5
0.8	1.3		< 0.2
0 1	0.9		

Q What levels of EMF are found in common environments?

A Magnetic field exposures can vary greatly from site to site for any type of environment. The data shown in the following table are median measurements taken at four different sites for each environment category.

EMF Exposures in Common Environments
Magnetic fields measured in milligauss (mG)

Environment	Median* exposure	Top 5th percentile	Environment	Median* exposure	Top 5th percentile
OFFICE BUILDING			MACHINE SHOP		
Support staff	0.6	3.7	Machinist	0.4	6.0
Professional	0.5	2.6	Welder	1.1	24.6
Maintenance	0.6	3.8	Engineer	1.0	5.1
Visitor	0.6	2.1	Assembler	0.5	6.4
SCHOOL			Office staff	0.7	4.7
Teacher	0.6	3.3	GROCERY STORE		
Student	0.5	2.9	Cashier	2.7	11.9
Custodian	1.0	4.9	Butcher	2.4	12.8
Administrative staff	1.3	6.9	Office staff	2.1	7.1
HOSPITAL			Customer	1.1	7.7
Patient	0.6	3.6			
Medical staff	0.8	5.6			
Visitor	0.6	2.4			
Maintenance	0.6	5.9			

*The median of four measurements. For this table, the median is the average of the two middle measurements.
Source: National Institute for Occupational Safety and Health.

Q What EMF field levels are encountered in the home?

A

Electric fields

Electric fields in the home, on average, range from 0 to 10 volts per meter. They can be hundreds, thousands, or even millions of times weaker than those encountered outdoors near power lines. Electric fields directly beneath power lines may vary from a few volts per meter for some overhead distribution lines to several thousands of volts per meter for extra high voltage power lines. Electric fields from power lines rapidly become weaker with distance and can be greatly reduced by walls and roofs of buildings.

Magnetic fields

Magnetic fields are not blocked by most materials. Magnetic fields encountered in homes vary greatly. Magnetic fields rapidly become weaker with distance from the source.

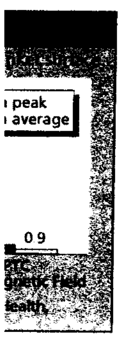
The chart on the left summarizes data from a study by the Electric Power Research Institute (EPRI) in which spot measurements of magnetic fields were made in the center of rooms in 992 homes throughout the United States. Half of the houses studied had magnetic field measurements of 0.6 mG or less, when the average of measurements from all the rooms in the house was calculated (the all-room mean magnetic field). The all-room mean magnetic field for all houses studied was 0.9 mG. The measurements were made away from electrical appliances and reflect primarily the fields from household wiring and outside power lines.

If you are comparing the information in this chart with measurements in your own home, keep in mind that this chart shows averages of measurements taken throughout the homes, not the single highest measurement found in the home

ls close to electrical appliances?

trical appliances are often much stronger than those ıg magnetic fields directly under power lines. Appliance /ith distance more quickly than do power line fields.

ın data gathered in 1992, lists the EMF levels generated nces. Magnetic field strength (magnitude) does not lex, powerful, or noisy the appliance is. Magnetic fields en weaker than those near small devices. Appliances in redesigned since the data in the table were collected. nay differ considerably from the levels shown here.



The graph shows magnetic fields produced by electric blankets, including conventional 110-V electric blankets as well as the PTC (positive temperature coefficient) low-magnetic-field blankets The fields were measured at a distance of about 2 inches from the blanket's surface, roughly the distance from the blanket to the user's internal organs Because of the wiring, magnetic field strengths vary from point to point on the blanket. The graph reflects this and gives both the peak and the average measurement

Sources of Magnetic Fields (mG)*

	Distance from source 6"	1'	2'	4'
Office Sources				
AIR CLEANERS				
Lowest	110	20	3	–
Median	180	35	5	1
Highest	250	50	8	2
COPY MACHINES				
Lowest	4	2	1	–
Median	90	20	7	1
Highest	200	40	13	4
FAX MACHINES				
Lowest	4	–	–	–
Median	6	–	–	–
Highest	9	2	–	–
FLUORESCENT LIGHTS				
Lowest	20	–	–	–
Median	40	6	2	–
Highest	100	30	8	4
ELECTRIC PENCIL SHARPENERS				
Lowest	20	8	5	–
Median	200	70	20	2
Highest	300	90	30	30
VIDEO DISPLAY TERMINALS (see page 48) (PCs with color monitors)**				
Lowest	7	2	1	–
Median	14	5	2	–
Highest	20	6	3	–
Bathroom Sources				
HAIR DRYERS				
Lowest	1	–	–	–
Median	300	1	–	–
Highest	700	70	10	1
ELECTRIC SHAVERS				
Lowest	4	–	–	–
Median	100	20	–	–
Highest	600	100	10	1

	Distance from source 6"	1'	2'	4'
Workshop Sources				
BATTERY CHARGERS				
Lowest	3	2	–	–
Median	30	3	–	–
Highest	50	4	–	–
DRILLS				
Lowest	100	20	3	–
Median	150	30	4	–
Highest	200	40	6	–
POWER SAWS				
Lowest	50	9	1	–
Median	200	40	5	–
Highest	1000	300	40	4
ELECTRIC SCREWDRIVERS (while charging)				
Lowest	–	–	–	–
Median	–	–	–	–
Highest	–	–	–	–

	Distance from source 1'	2'	4'
Living/Family Room Sources			
CEILING FANS			
Lowest	–	–	–
Median	3	–	–
Highest	50	6	1
WINDOW AIR CONDITIONERS			
Lowest	–	–	–
Median	3	1	–
Highest	20	6	4
COLOR TELEVISIONS**			
Lowest	–	–	–
Median	7	2	–
Highest	20	8	4

Continued

ources of Magnetic Fields (mG)*

e from source 2'	4'
–	–
2	–
3	–
3	–
20	2
30	4
–	–
–	–
–	–
2	–
4	–
7	1
–	–
2	–
3	–
1	–
2	–
3	–
1	–
10	2
30	20
–	–
1	–
10	–

	Distance from source 6"	1'	2'	4'
Kitchen Sources				
ELECTRIC OVENS				
Lowest	4	1	–	–
Median	9	4	–	–
Highest	20	5	1	–
ELECTRIC RANGES				
Lowest	20	–	–	–
Median	30	8	2	–
Highest	200	30	9	6
REFRIGERATORS				
Lowest	–	–	–	–
Median	2	2	1	–
Highest	40	20	10	10
TOASTERS				
Lowest	5	–	–	–
Median	10	3	–	–
Highest	20	7	–	–
Bedroom Sources				
DIGITAL CLOCK****				
Lowest		–	–	–
Median		1	–	–
High		8	2	1
ANALOG CLOCKS (conventional clockface)****				
Lowest		1	–	–
Median		15	2	–
Highest		30	5	3
BABY MONITOR (unit nearest child)				
Lowest	4	–	–	–
Median	6	1	–	–
Highest	15	2	–	–

Continued

Sources of Magnetic Fields (mG)*

	Distance from source 6"	1'	2'	4'
Laundry/Utility Sources				
ELECTRIC CLOTHES DRYERS				
Lowest	2	–	–	–
Median	3	2	–	–
Highest	10	3	–	–
WASHING MACHINES				
Lowest	4	1	–	–
Median	20	7	1	–
Highest	100	30	6	–
IRONS				
Lowest	6	1	–	–
Median	8	1	–	–
Highest	20	3	[illegible]	–

	Distance from source 6"	1'	2'	4'
Laundry/Utility Sources				
PORTABLE HEATERS				
Lowest	5	1	–	–
Median	100	20	4	–
Highest	150	40	8	1
VACUUM CLEANERS				
Lowest	100	20	4	–
Median	300	60	10	1
Highest	700	200	50	10
SEWING MACHINES				

Home sewing machines can produce magnetic fields of 12 mG at chest level and 5 mG at head level. Magnetic fields as high as 35 mG at chest level and 215 mG at knee level have been measured from industrial sewing machine models (Sobel, 1994).

Source: EMF In Your Environment, U.S. Environmental Protection Agency, 1992.

* Dash (–) means that the magnetic field at this distance from the operating appliance could not be distinguished from background measurements taken before the appliance had been turned on.

** Some appliances produce both 60-Hz and higher frequency fields. For example, televisions and computer screens produce fields at 10,000-30,000 Hz (10-30 kHz) as well as 60-Hz fields.

*** Microwave ovens produce 60-Hz fields of several hundred milligauss, but they also create microwave energy inside the appliance that is at a much higher frequency (about 2.45 billion hertz). We are shielded from the higher frequency fields but not from the 60-Hz fields.

**** Most digital clocks have low magnetic fields. In some analog clocks, however, higher magnetic fields are produced by the motor that drives the hands. In the above table, the clocks are electrically powered using alternating current, as are all the appliances described in these tables.

Q What EMF levels are found near power lines?

A Power transmission lines bring power from a generating station to an electrical substation. Power distribution lines bring power from the substation to your home. Transmission and distribution lines can be either overhead or underground. Overhead lines produce both electric fields and magnetic fields. Underground lines do not produce electric fields above ground but may produce magnetic fields above ground.

Power transmission lines

Typical EMF levels for transmission lines are shown in the chart on page 37. At a distance of 300 feet and at times of average electricity demand, the magnetic fields from many lines can be similar to typical background levels found in most homes. The distance at which the magnetic field from the line becomes indistinguishable from typical background levels differs for different types of lines.

es

istribution lines in North America ranges from 4 to 24 levels directly beneath overhead distribution lines may ıeter to 100 or 200 volts per meter. Magnetic fields listribution lines typically range from 10 to 20 mG for 10 mG for laterals. Such levels are also typical directly 'eak EMF levels, however, can vary considerably ɔf current carried by the line. Peak magnetic field levels as ıeasured directly below overhead distribution lines and as ground lines.

EMF from electric power substations?

IF around the outside of a substation comes from the ıving the substation. The strength of the EMF from ations, such as transformers, reactors, and capacitor h increasing distance. Beyond the substation fence or the substation equipment is typically indistinguishable

ers have higher EMF exposure than

have about occupational EMF exposure comes from kers. It is therefore difficult to compare electrical h those of other workers because there is less ɔsures in work environments other than electric utilities. actual measurements of EMF exposure on the job but of EMF exposure among electrical workers. Recent ded extensive EMF exposure assessments.

provides some information about estimated EMF Angeles in a number of electrical jobs in electric . Electrical workers had higher average EMF exposures in other jobs (1.7 mG). For this study, the category l electrical engineering technicians, electrical engineers, kers, power station operators, telephone line workers.

Typical EMF Levels for Power Transmission Lines*

115 kV

		Approx. Edge of Right-of-Way 15 m (50 ft)	30 m (100 ft)	61 m (200 ft)	91 m (300 ft)
Electric Field (kV/m)	1.0	0.5	0.07	0.01	0.003
Mean Magnetic Field (mG)	29.7	6.5	1.7	0.4	0.2

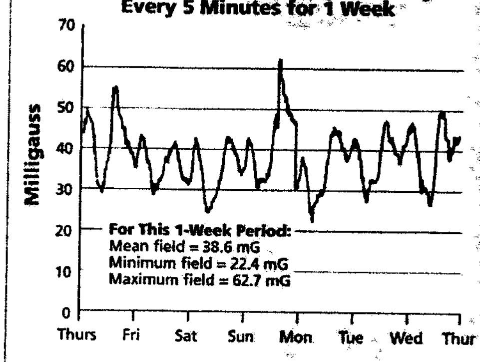
230 kV

		Approx. Edge of Right-of-Way 15 m (50 ft)	30 m (100 ft)	61 m (200 ft)	91 m (300 ft)
Electric Field (kV/m)	2.0	1.5	0.3	[illegible]	0.01
Mean Magnetic Field (mG)	57.5	19.5	7.1	1.8	0.8

500 kV

		Approx. Edge of Right-of-Way 20 m (65 ft)	30 m (100 ft)	61 m (200 ft)	91 m (300 ft)
Electric Field (kV/m)	7.0	3.0	1.0	0.3	0.1
Mean Magnetic Field (mG)	86.7	29.4	12.6	3.2	1.4

Magnetic Field from a 500-kV Transmission Line Measured on the Right-of-Way Every 5 Minutes for 1 Week



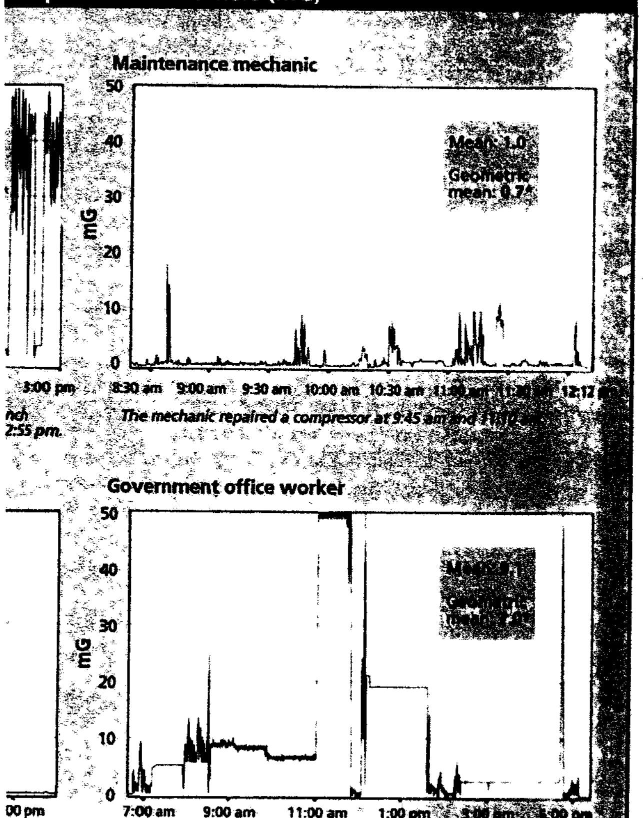
Electric fields from power lines are relatively stable because line voltage doesn't change very much. Magnetic fields on most lines fluctuate greatly as current changes in response to changing loads. Magnetic fields must be described statistically in terms of averages, maximums, etc. The magnetic fields above are means calculated for 321 power lines for 1990 annual mean loads. During peak loads (about 1% of the time), magnetic fields are about twice as strong as the mean levels above. The graph on the left is an example of how the magnetic field varied during one week for one 500-kV transmission line.

*These are typical EMFs at 1 m (3.3 ft) above ground for various distances from power lines in the Pacific Northwest. They are for general information. For information about a specific line, contact the utility that operates the line.
Source: Bonneville Power Administration, 1994.

ɜ EMF exposures in the workplace?

ɱples of magnetic field exposures determined with four workers in different occupations. These .e how EMF exposures vary among individual workers present typical EMF exposures for workers in these

ɟ Exposures of Workers (mG)



The government worker was at the copy machine at 8:00 am at the computer from 11:00 am to 1:00 pm and also from 2:30 pm to 4:30 pm.

ɪres, and then taking the square root of the sum.
partment of Energy.

The tables below and on page 41 can give you a general idea about magnetic field levels for different jobs and around various kinds of electrical equipment. It is important to remember that EMF levels depend on the actual equipment used in

EMF Measurements During a Workday

Industry and occupation	ELF magnetic fields measured in mG: Median for occupation*	ELF magnetic fields measured in mG: Range for 90% of workers**
ELECTRICAL WORKERS IN VARIOUS INDUSTRIES		
Electrical engineers	1.7	0.5–12.0
Construction electricians	3.1	1.6–12.1
TV repairers	4.3	0.6–8.6
Welders	9.5	1.4–66.1
ELECTRIC UTILITIES		
Clerical workers without computers	0.5	0.2–2.0
Clerical workers with computers	1.2	0.5–4.5
Line workers	2.5	0.5–34.8
Electricians	5.4	0.8–34.0
Distribution substation operators	7.2	1.1–36.2
Workers off the job (home, travel, etc.)	0.9	0.3–3.7
TELECOMMUNICATIONS		
Install, maintenance, & repair technicians	1.5	0.7–3.2
Central office technicians	2.1	0.5–8.2
Cable splicers	3.2	0.7–15.0
AUTO TRANSMISSION MANUFACTURE		
Assemblers	0.7	0.2–4.9
Machinists	1.9	0.6–27.6
HOSPITALS		
Nurses	1.1	0.5–2.1
X-ray technicians	1.5	1.0–2.2
SELECTED OCCUPATIONS FROM ALL ECONOMIC SECTORS		
Construction machine operators	0.5	0.1–1.2
Motor vehicle drivers	1.1	0.4–2.7
School teachers	1.3	0.6–3.2
Auto mechanics	2.3	0.6–8.7
Retail sales	2.3	1.0–5.5
Sheet metal workers	3.9	0.3–48.4
Sewing machine operators	6.8	0.9–32.0
Forestry and logging jobs	7.6	0.6–95.5***

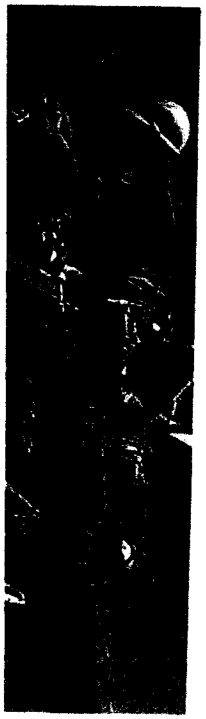
Source: National Institute for Occupational Safety and Health.
ELF (extremely low frequency)—frequencies 3–3,000 Hz.
* The median is the middle measurement in a sample arranged by size. These personal exposure measurements reflect the median magnitude of the magnetic field produced by the various EMF sources and the amount of time the worker spent in the fields.
** This range is between the 5th and 95th percentiles of the workday averages for an occupation.
*** Chain saw engines produce strong magnetic fields that are not pure 60-Hz fields.

nds or models of the same type of equipment can have ıgths. It is also important to keep in mind that the decreases quickly with distance.

nt more information about your EMF exposure at :er, industrial hygienist, or other local safety official can tion. The National Institute for Occupational Safety and ·asionally to conduct health hazard evaluations in suspected cause for concern. For further technical 800-356-4674.

ical sources of EMF in the workplace?

; so far have shown that most people's EMF exposure al appliances and tools and from the building's power



supply. People who work near transformers, electrical closets, circuit boxes, or other high current electrical equipment may have 60-Hz magnetic field exposures of hundreds of milligauss or more. In offices, magnetic field levels are often similar to those found at home, typically 0.5 to 4.0 mG. However, these levels can increase dramatically near certain types of equipment.

EMF Spot Measurements

Industry and sources	ELF magnetic fields (mG)	Other frequencies	Comments
ELECTRICAL EQUIPMENT USED IN MACHINE MANUFACTURING			
Electric resistance heater	6,000–14,000	VLF	
Induction heater	10 460	High VLF	
Hand held grinder	3,000	–	Tool exposures measured at operator's chest.
Grinder	110	–	Tool exposures measured at operator's chest.
Lathe, drill press, etc	1–4	–	Tool exposures measured at operator's chest.
ALUMINUM REFINING			
Aluminum pot rooms	3.4–30	Very high static field	Highly-rectified DC current (with an ELF ripple) refines aluminum.
Rectification room	300–3,300	High static field	
STEEL FOUNDRY			
Ladle refinery			
Furnace active	170–1,300	High ULF from the ladle's big magnetic stirrer	Highest ELF field was at the chair of control room operator.
Furnace inactive	0.6–3.7	High ULF from the ladle's big magnetic stirrer	Highest ELF field was at the chair of control room operator.
Electrogalvanizing unit	2–1,100	High VLF	
TELEVISION BROADCASTING			
Video cameras (studio and minicams)	7.2–24.0	VLF	
Video tape degaussers	160–3,300	–	Measured 1 ft away.
Light control centers	10–300	–	Walk-through survey.
Studio and newsrooms	2–5	–	Walk-through survey.
HOSPITALS			
Intensive care unit	0.1–220	VLF	Measured at nurse's chest.
Post-anesthesia care unit	0.1–24	VLF	
Magnetic resonance imaging (MRI)	0.5–280	Very high static field, VLF and RF	Measured at technician's work locations.
TRANSPORTATION			
Cars, minivans, and trucks	0 1–125	Most frequencies less than 60 Hz	Steel-belted tires are the principal ELF source for gas/diesel vehicles.
Bus (diesel powered)	0.5–146	Most frequencies less than 60 Hz	
Electric cars	0.1–81	Some elevated static fields	
Chargers for electric cars	4–63	–	Measured 2 ft from charger
Electric buses	0.1–88	–	Measured at waist. Fields at ankles 2-5 times higher.
Electric train passenger cars	0 1–330	25 & 60 Hz power on U.S. trains	Measured at waist. Fields at ankles 2-5 times higher.
Airliner	0.8–24.2	400 Hz power on airliners	Measured at waist.
GOVERNMENT OFFICES			
Desk work locations	0.1–7	–	Peaks due to laser printers.
Desks near power center	18 50		
Power cables in floor	15–170	–	
Building power supplies	25–1,800	–	
Can opener	3,000	–	Appliance fields measured 6 in away
Desktop cooling fan	1,000	–	Appliance fields measured 6 in away
Other office appliances	10–200	–	

Source National Institute for Occupational Safety and Health, 2001
ULF (ultra low frequency)—frequencies above 0, below 3 Hz
ELF (extremely low frequency)—frequencies 3–3,000 Hz.
VLF (very low frequency)—frequencies 3,000–30,000 Hz (3–30 kilohertz).

ıre occurs during travel?

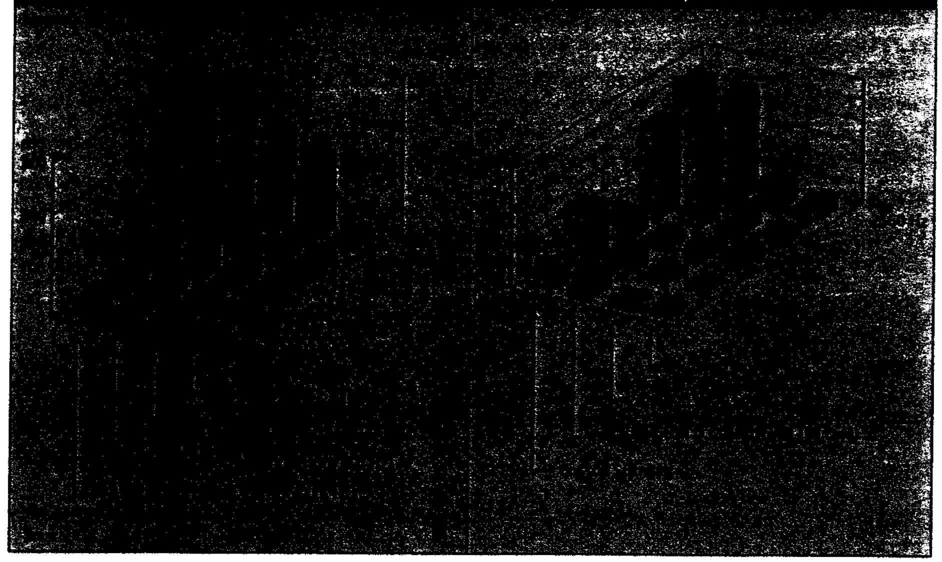
in sources of magnetic field exposure are those you pass
, such as power lines. Car batteries involve direct
lternating current (AC). Alternators can create EMF,
an 60 Hz. The rotation of steel-belted tires is also a

tates are diesel powered. Some electrically powered
as the passenger trains between Washington, D.C. and
Aeasurements taken on these trains using personal
ggested that average 60-Hz magnetic field exposures for
may exceed 50 mG. A U.S. government-sponsored
of electric rail systems found average 60-Hz magnetic
compartments that ranged from 0.4 mG (Boston high
North Jersey transit). The graph on the next page shows
netic field measurements in operator compartments of
It illustrates that 60 Hz is one of several
to which train operators are exposed.

tracks on electric rail lines, primarily in the
also have elevated magnetic field exposures at both
ients taken by the National Institute for Occupational
t typical average daily exposures range from 3 to
often trains pass the work site.

ystems in the United States, such as the Washington
ncisco Bay Area Rapid Transit, run on DC electricity.
ntain equipment that produces AC fields. For example,
fields have been measured on the Washington Metro
iking and acceleration, presumably near equipment
vay cars.

Magnetic Field Measurements in Train Operators' Compartments



These graphs illustrate that 60 Hz is one of several electromagnetic frequencies to which train operators are exposed. The maximum exposure is the top of the blue (upper) portion of the bar; the average exposure is the top of the red (lower) portion

Q How can I find out how strong the EMF is where I live and work?

A The tables throughout this chapter can give you a general idea about magnetic field levels at home, for different jobs, and around various kinds of electrical equipment. For specific information about EMF from a particular power line, contact the utility that operates the line. Some will perform home EMF measurements.

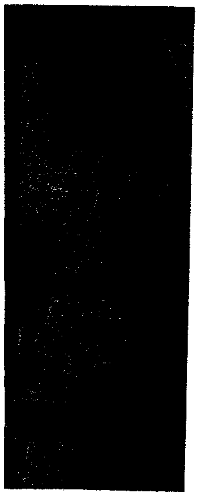
You can take your own EMF measurements with a magnetic field meter. For a spot measurement to provide a useful estimate of your EMF exposure, it should be taken at a time of day and location when and where you are typically near the equipment. Keep in mind that the strength of a magnetic field drops off quickly with distance.

Independent technicians will conduct EMF measurements for a fee. Search the Internet under "EMF meters" or "EMF measurement." You should investigate the experience and qualifications of commercial firms, since governments do not standardize EMF measurements or certify measurement contractors.

officer, industrial hygienist, or other local safety official
'ormation. The National Institute for Occupational Safety
imes conducts health hazard evaluations in workplaces
:ause for concern. For further technical assistance,
4674.

nputers contribute to my EMF

elves produce very little EMF. However, the video
nonitor provides some magnetic field exposure unless it is of the new flat-panel design.



Conventional VDTs containing cathode ray tubes use magnetic fields to produce the image on the screen, and some emission of those magnetic fields is unavoidable. Unlike most other appliances which produce predominantly 60-Hz magnetic fields, VDTs emit magnetic fields in both the extremely low frequency (ELF) and very low frequency (VLF) frequency ranges (see page 8). Many newer VDTs have been designed to minimize magnetic field emissions, and those identified as "TCO'99 compliant" meet a standard for low emissions (see page 48).

to limit EMF exposure?

epends on three things: the strength of the magnetic
ıment, your distance from those sources, and the time

!MF exposure, your first step should be to find out
es are and move away from them or limit the time you
ields from appliances decrease dramatically about an
ource. In many cases, rearranging a bed, a chair, or a
istance from an electrical panel or some other EMF
exposure.

Another way to reduce EMF exposure is to use equipment designed to have relatively low EMF emissions. Sometimes electrical wiring in a house or a building can be the source of strong magnetic field exposure. Incorrect wiring is a common source of higher-than-usual magnetic fields. Wiring problems are also worth correcting for safety reasons.

In its 1999 report to Congress, the National Institute of Environmental Health Sciences suggested that the power industry continue its current practice of siting power lines to reduce EMF exposures.

There are more costly actions, such as burying power lines, moving out of a home, or restricting the use of office space that may reduce exposures. Because scientists are still debating whether EMF is a hazard to health, it is not clear that the costs of such measures are warranted. Some EMF reduction measures may create other problems. For instance, compacting power lines reduces EMF but increases the danger of accidental electrocution for line workers.

We are not sure which aspects of the magnetic field exposure, if any, to reduce. Future research may reveal that EMF reduction measures based on today's limited understanding are inadequate or irrelevant. No action should be taken to reduce EMF exposure if it increases the risk of a known safety hazard.

sure Standards

ds and guidelines established by state, national, izations for some EMF sources and exposures.

e standards for 60-Hz EMF?

are no federal standards limiting occupational or Iz EMF.

tandards for transmission line electric fields; two of r magnetic fields (see table below). In most cases, the y each state are the maximum fields that existing lines arrying conditions. Some states further limit electric gs to ensure that electric current induced into large and buses does not represent an electric shock hazard.

nission Line Standards and Guidelines

ric Field	Magnetic Field	
Edge R.O.W.	On R.O.W.	Edge R.O.W.
2 kV/m	—	150 mG[a] (max. load) 200 mG[b] (max. load) 250 mG[c] (max. load)
—	—	—
1 kV/m[e]		
3 kV/m		
1.6 kV/m	—	200 mG (max. load)
—	—	—

standard, certain additional areas adjoining the right-of-way). kV/m = kilovolt r lines of 69-230 kV. [b]For 500 kV lines. [c]For 500 kV lines on certain existing [e]May be waived by the landowner. [f]Maximum for private road crossings.

oped voluntary occupational exposure guidelines for es are intended to prevent effects, such as induced ulation, which are known to occur at high magnitudes, 0 times higher) than EMF levels found typically in

occupational and residential environments. These guidelines are summarized in the tables on the right.

The International Commission on Non Ionizing Radiation Protection (ICNIRP) concluded that available data regarding potential long-term effects, such as increased risk of cancer, are insufficient to provide a basis for setting exposure restrictions.

The American Conference of Governmental Industrial Hygienists (ACGIH) publishes "Threshold Limit Values" (TLVs) for various physical agents. The TLVs for 60-Hz EMF shown in the table are identified as guides to control exposure; they are not intended to demarcate safe and dangerous levels.

ICNIRP Guidelines for EMF Exposure

Exposure (60 Hz)	Electric field	Magnetic field
Occupational	8.3 kV/m	4.2 G (4,200 mG)
General Public	4.2 kV/m	0.833 G (833 mG)

International Commission on Non-Ionizing Radiation Protection (ICNIRP) is an organization of 15,000 scientists from 40 nations who specialize in radiation protection.
Source: ICNIRP, 1998.

ACGIH Occupational Threshold Limit Values for 60-Hz EMF

	Electric field	Magnetic field
Occupational exposure should not exceed	25 kV/m	10 G (10,000 mG)
Prudence dictates the use of protective clothing above	15 kV/m	–
Exposure of workers with cardiac pacemakers should not exceed	1 kV/m	1 G (1,000 mG)

American Conference of Governmental Industrial Hygienists (ACGIH) is a professional organization that facilitates the exchange of technical information about worker health protection. It is not a government regulatory agency.
Source: ACGIH, 2001.

Q Does EMF affect people with pacemakers or other medical devices?

A According to the U.S. Food and Drug Administration (FDA), interference from EMF can affect various medical devices including cardiac pacemakers and implantable defibrillators. Most current research in this area focuses on higher frequency sources such as cellular phones, citizens band radios, wireless computer links, microwave signals, radio and television transmitters, and paging transmitters.

Sources such as welding equipment, power lines at electric generating plants, and rail transportation equipment can produce lower frequency EMF strong enough to interfere with some models of pacemakers and defibrillators. The occupational exposure guidelines developed by ACGIH state that workers with cardiac pacemakers should not be exposed to a 60-Hz magnetic field greater than 1 gauss (1,000 mG) or a 60-Hz electric field greater than 1 kilovolt per meter (1,000 V/m) (see ACGIH guidelines above). Workers who are concerned about EMF exposure effects on pacemakers, implantable defibrillators, or other implanted electronic medical devices should consult their doctors or industrial hygienists.

dical implants (such as artificial joints, pins, nails, screws, l by high magnetic fields such as those from magnetic devices and aluminum refining equipment, but are e lower fields from most other sources.

am is collecting information about medical device sociated with exposure to or interference from EMF. oblem that might be due to such interference is ort it (800-332-1088).

ucts advertised as producing low or fields?

nces and devices emit electric and magnetic fields. The ppreciably both between types of devices and among of the same type of device. Some appliance manufacturers hat, in general, have lower EMF than older models. As a or "reduced field" may be relative to older models and her manufacturers or devices. At this time, there are no ndards or guidelines limiting the EMF emissions of

no standards for magnetic fields from computer minals (VDTs). The Swedish Confederation of)) established in 1992 a standard recommending strict of computer monitors. The VDTs should produce han 2 mG at a distance of 30 cm (about 1 ft) from the and 50 cm (about 1 ft 8 in) from the sides and back of ndard has become a *de facto* standard in the VDT industry promulgated by the Swedish TCO (known as the or international and environmental labeling of personal monitors marketed in the U.S. are certified as compliant assured to produce low magnetic fields.

iming that the federal government has certified that the es little or no EMF. The federal government has no such for the emissions of low-frequency EMF. The U.S. Food nter for Devices and Radiological Health (CDRH) does d equipment producing high levels of ionizing radiation mation about certain devices as well as general ilable from the CDRH at 888-463-6332.

Q Are cellular telephones and towers sources of EMF exposure?

A Cellular telephones and towers involve radio-frequency and microwave-frequency electromagnetic fields (see page 8). These are in a much higher frequency range than are the power-frequency electric and magnetic fields associated with the transmission and use of electricity.

The U.S. Federal Communications Commission (FCC) licenses communications systems that use radio-frequency and microwave electromagnetic fields and ensures that licensed facilities comply with exposure standards. Public information on this topic is published on two FCC Internet sites: http://www.fcc.gov/oet/info/documents/bulletins/#56 and http://www.fcc.gov/oet/rfsafety/

The U.S. Food and Drug Administration also provides information about cellular telephones on its web site (http://www.fda.gov/cdrh/ocd/mobilphone.html).

ıd International EMF Reviews

findings and recommendations of major luding the U.S. government's EMF RAPID

ıal and international agencies :he impact of EMF exposure on

reports have concluded that limited evidence exists for F exposure and increased leukemia risk, but that when considered, the link between EMF exposure and cancer Organization in 1997 reached a similar conclusion.

.S. National Academy of Sciences report in 1996 and, in of Environmental Health Sciences report to the U.S. J.S. EMF Research and Public Information gram.

›gram

the U.S. Congress and established by law in 1992, the esearch and Public Information Dissemination (EMF gram set out to study whether exposure to electric and elds produced by the generation, transmission, or use of ver posed a risk to human health. For more information am, visit the web site (http://www.niehs.nih.gov/

rgy (DOE) administered the overall EMF RAPID esearch and risk assessment were supervised by the imental Health Sciences (NIEHS), a branch of the U.S. (NIH). Together, DOE and NIEHS oversaw more than ies, as well as engineering and exposure assessment RAPID Program did not fund any additional nalysis of the many studies already conducted was an port.

The electric power industry contributed about half, or $22.5 million, of the $45 million eventually spent on EMF research over the course of the EMF RAPID Program. The NIEHS received $30.1 million from this program for research, public outreach, administration, and the health assessment evaluation of extremely low frequency (ELF) EMF. The DOE received approximately $15 million from this program for engineering and EMF mitigation research. The NIEHS contributed an additional $14.5 million for support of extramural and intramural research including long-term toxicity and carcinogenicity studies conducted by the National Toxicology Program.

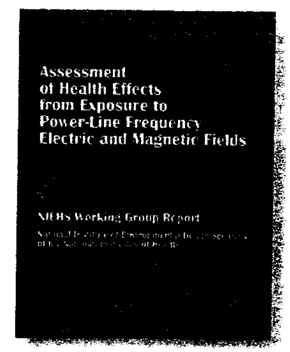
EMF RAPID Program Interagency Committee

- National Institute of Environmental Health Sciences
- Department of Energy
- Department of Defense
- Department of Transportation
- Environmental Protection Agency
- Federal Energy Regulatory Commission
- National Institute of Standards and Technology
- Occupational Safety and Health Administration
- Rural Electrification Administration

An interagency committee was established by the President of the United States to provide oversight and program management support for the EMF RAPID Program. The interagency committee included representatives from NIEHS, DOE, and seven other federal agencies with EMF-related responsibilities.

The EMF RAPID Program also received advice from a National EMF Advisory Committee (NEMFAC), which included representatives from citizen groups, labor, utilities, the National Academy of Sciences, and other groups. They met regularly with DOE and NIEHS staff to express their views. NEMFAC meetings were open to the public. The EMF RAPID Program sponsored citizen participation in some scientific meetings as well. A broad group of citizens reviewed all major public information materials produced for the program.

NIEHS Working Group Report 1998



In preparation for the EMF RAPID Program's goal of reporting to the U.S. Congress on possible health effects from exposure to EMF from power lines, the NIEHS convened an expert working group in June 1998. Over 9 days, about 30 scientists conducted a complete review of EMF studies, including those sponsored by the EMF RAPID Program and others. Their conclusions offered guidance to the NIEHS as it prepared its report to Congress.

Using criteria developed by the International Agency for Research on Cancer, a majority of the members of the working group concluded that exposure to power-frequency EMF is a possible human carcinogen.

The majority called their opinion "a conservative public health decision based on limited evidence for an increased occurrence of childhood leukemias and an increased occurrence of chronic lymphocytic leukemia (CLL) in occupational settings." For these

reported that animal and cellular studies neither confirm
ıl studies' suggestion of a disease risk. This report is
F RAPID web site (http://www.niehs.nih.gov/emfrapid).

ess at Conclusion of EMF RAPID Program

:he NIEHS reported to the U.S. Congress that scientific
ı EMF-cancer link is weak.

ıre excerpts from the 1999 NIEHS report:

> ʼes that the probability that ELF-EMF exposure is truly a
> urrently small. The weak epidemiological associations and
> tory support for these associations provide only marginal,
> that exposure to this agent is causing any degree of harm
>
> idence suggesting that extremely low frequency EMF
> ıy health risk is weak. The strongest evidence for health
> n associations observed in human populations with two
> hildhood leukemia and chronic lymphocytic leukemia in
> posed adults. While the support from individual studies
> emiological studies demonstrate, for some methods of
> ıre, a fairly consistent pattern of a small, increased risk
> exposure that is somewhat weaker for chronic
> emia than for childhood leukemia. In contrast, the
> he animal toxicology literature fail to demonstrate any
> studies, although sporadic findings of biological effects
> :ers in animals) have been reported. No indication of
> perimental animals has been observed.

ı the NIEHS EMF RAPID web site
mfrapid).

nmended or taken based on the NIEHS report. The NIEHS
ıld the Congress that, in his opinion, the conclusion of the
t to warrant aggressive regulatory action.

ıd adopting EMF standards for electric appliances or
Instead, it recommended providing public information
e EMF exposure. The NIEHS also suggested that
ʒ "continue siting power lines to reduce exposures
ce the creation of magnetic fields around transmission
. creating new hazards." The NIEHS encouraged
netic fields at a minimal cost, but noted that the risks
esign of electrical appliances.

iividuals who are concerned about EMF in their homes
ıre properly wired and grounded, since incorrect wiring
ommon source of higher-than-usual magnetic fields.

National Academy of Sciences Report

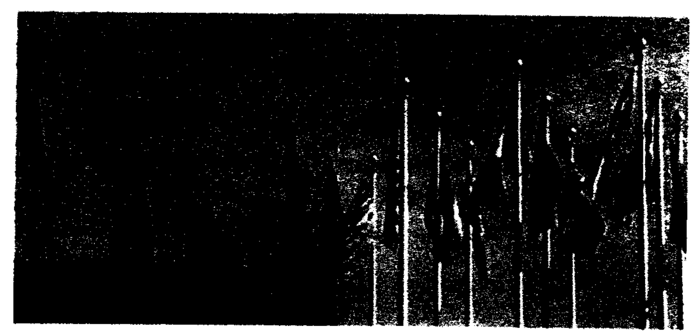
In October 1996, a National Research Council committee of the National Academy of Sciences (NAS) released its evaluation of research on potential associations between EMF exposure and cancer, reproduction, development, learning, and behavior The report concluded:

> Based on a comprehensive evaluation of published studies relating to the effects of power-frequency electric and magnetic fields on cells, tissues, and organisms (including humans), the conclusion of the committee is that the current body of evidence does not show that exposure to these fields presents a human-health hazard Specifically, no conclusive and consistent evidence shows that exposures to residential electric and magnetic fields produce cancer, adverse neurobehavioral effects, or reproductive and developmental effects.

The NAS report focused primarily on the association of childhood leukemia with the proximity of the child's home to power lines. The NAS panel found that although a link between EMF exposure and increased risk for childhood leukemia was observed in studies that had estimated EMF exposure using the wire code method (distance of home from power line), such a link was not found in studies that had included actual measurements of magnetic fields at the time of the study. The panel called for more research to pinpoint the unexplained factors causing small increases in childhood leukemia in houses close to power lines.

World Health Organization International EMF Project

The World Health Organization (WHO) International EMF Project, with headquarters in Geneva, Switzerland, was launched at a 1996 meeting with representatives of 23 countries attending. It was intended to respond to growing concerns in many member states over possible EMF health effects and to address the conflict between such concerns and technological and economic progress. In its advisory role, the WHO International EMF Project is now reviewing laboratory and epidemiological evidence, identifying gaps in scientific knowledge, developing an agenda for future research, and developing risk communication booklets and other public information. The WHO International EMF Project is funded with contributions from governments and institutions and is expected to provide an overall EMF health risk assessment. Additional information about this program can be found on the WHO EMF web site (http://www.who.int/peh-emf).



As part of this project, in 1997 a working group of 45 scientists from around the world surveyed the evidence for adverse

reported that, "taken together, the findings of all
;estive of an association between childhood leukemia and
ly low frequency or power-frequency) magnetic fields."

S report, the WHO report noted that living in homes near
vith an approximate 1.5-fold excess risk of childhood
S panel, WHO scientists had seen the results of the 1997 U.S.
dy of EMF and childhood leukemia (see page 17). This work
the inconsistency between results of studies that used a wire
ıre and studies that actually measured magnetic fields.

her than cancer, the WHO scientists reported that the
not provide sufficient evidence to support an
ıely-low-frequency magnetic-field exposure and adult
e, or neurobehavioural disorders."

tion International Agency for Research on Cancer

ency for Research on Cancer (IARC) produces a
ws the scientific evidence regarding potential
ith exposure to environmental agents. An international
s from 10 countries met in June 2001 to review the
the potential carcinogenicity of static and ELF
r power-frequency) EMF. The panel categorized its
ity based on the IARC classification system—a system
f evidence from epidemiological, laboratory (human
ic studies. The panel classified power-frequency EMF
humans" based on a fairly consistent statistical
ing of risk of childhood leukemia and magnetic field
la (0.4 μT, 4 milligauss or 4 mG).

ısistent evidence that childhood EMF exposures are
cancer or that adult EMF exposures are associated with
cancer. The IARC panel reported that no consistent
posure have been observed in experimental animals and
ıtific explanation for the observed association between
exposure. Further information can be obtained at the
rc.fr and http://monographs.iarc.fr).

n on Non-Ionizing Radiation Protection

on Non-Ionizing Radiation Protection (ICNIRP) issued
gainst known adverse effects such as stimulation of
h EMF levels, as well as shocks and burns caused by
electricity (see page 47). In April 1998, ICNIRP revised
racterized as "unconvincing" the evidence for an
power-frequency EMF and cancer.

European Union

In 1996, a European Union (EU) advisory panel provided an overview of the state of science and standards among EU countries. With respect to power-frequency EMF, the panel members said that there is no clear evidence that exposure to EMF results in an increased risk of cancer.

Australia—Radiation Advisory Committee Report to Parliament

In 1997, Australia's Radiation Advisory Committee briefly reviewed the EMF scientific literature and advised the Australian Parliament that, overall, there is insufficient evidence to come to a firm conclusion regarding possible health effects from exposure to power-frequency magnetic fields.

The committee also reported that "the weight of opinion as expressed in the U.S. National Academy of Sciences report, and the negative results from the National Cancer Institute study (Linet et al., 1997) would seem to shift the balance of probability more towards there being no identifiable health effects" (see pages 17 and 53).

Canada—Health Canada Report

In December 1998, a working group of public health officers at Health Canada, the federal agency that manages Canada's health care system, issued a review of the scientific literature regarding power-frequency EMF health effects. They found the evidence to be insufficient to conclude that EMF causes a risk of cancer.

The report concluded that while EMF effects may be observed in biological systems in a laboratory, no adverse health effects have been demonstrated at the levels to which humans and animals are typically exposed.

As for epidemiology, 25 years of study results are inconsistent and inconclusive, the panel said, and a plausible EMF-cancer mechanism is missing. Health Canada pledged to continue monitoring EMF research and to reassess this position as new information becomes available.

Germany—Ordinance 26

On January 1, 1997, Germany became the first nation to adopt a national rule on EMF exposure for the general public. Ordinance 26 applies only to facilities such as overhead and underground transmission and distribution lines, transformers, switchgear and overhead lines for electric-powered trains. Both electric (5 kV/m) and magnetic field exposure limits (1 Gauss) are high enough that they are unlikely to be encountered in ordinary daily life. The ordinance also requires that precautionary measures be taken on a case-by-case basis when electric facilities are sited or upgraded near homes, hospital, schools, day care centers, and playgrounds.

al Radiological Protection Board Report

Protection Board (NRPB) in Great Britain advises the Kingdom regarding standards of protection for exposure The NRPB's advisory group on non-ionizing radiation 'evelopments in EMF research and reports its findings. up's latest review were published in 2001. The report ccupational epidemiological studies, as well as cellular, eer studies that had been published.

hat there is "some epidemiological evidence that er levels of power frequency magnetic fields is associated nia in children." Specifically, the NRPB advisory group's vely heavy average exposures of 0.4 μT [4 mG] or more ng of the risk of leukaemia in children under 15 years of , however, that laboratory experiments have provided emely low frequency electromagnetic fields are capable

elopments

Swedish researchers and government officials published e in the workplace. This "Criteria Group" reviewed EMF g the IARC classification system, ranked occupational arcinogenic to humans." They also endorsed the policy statement that public exposure limits to EMFs ople might simply want to use caution with EMFs.

nment agencies further explained their precautionary osure should be reduced, they said, but only when nvenience or cost.

nmark, and Finland generally agreed in reviews an EMF health risk exists, it is small. They ween residential magnetic fields and childhood d or denied. In 1994, several Norwegian government increasing the distance between residences and be done at low cost and with little inconvenience.

anizations have reported on EMF?

ation

l Association advised physicians that no scientifically en associated with "usually occurring" EMF, based on al, laboratory studies, and major literature reviews.

Society released a review of 20 years of EMF ling occupational studies and residential studies of

adult and childhood cancer. The society noted that some data support a possible relationship of magnetic field exposure with leukemia and brain cancer, but further research may not be justified if studies continue to find uncertain results. Of particular interest is the summary of results from eight studies of risk from use of household appliances with relatively high magnetic fields, such as electric blankets and electric razors. The summary suggested that there is no persuasive evidence for increased risk with more frequent or longer use of these appliances.

American Physical Society

The American Physical Society (APS) represents thousands of U.S. physicists. Responding to the NIEHS Working Group's conclusion that EMF is a possible human carcinogen, the APS executive board voted in 1998 to reaffirm its 1995 opinion that there is "no consistent, significant link between cancer and power line fields."

California's Department of Health Services

In 1996, California's Department of Health Services (DHS) began an ambitious five-year effort to assess possible EMF public health risk and offer guidance to school administrators and other decision-makers. The California Electric and Magnetic Fields (EMF) Program is a research, education, and technical assistance program concerned with the possible health effects of EMF from power lines, appliances, and other uses of electricity. The program's goal is to find a rational and fair approach to dealing with the potential risks, if any, of exposure to EMF. This is done through research, policy analysis, and education. The web site has educational materials on EMF and related health issues for individuals, schools, government agencies, and professional organizations (http://www.dhs.ca.gov/ps/deodc/ehib/emf).

Q What can we conclude about EMF at this time?

A Electricity is a beneficial part of our daily lives, but whenever electricity is generated, transmitted, or used, electric and magnetic fields are created. Over the past 25 years, research has addressed the question of whether exposure to power-frequency EMF might adversely affect human health. For most health outcomes, there is no evidence that EMF exposures have adverse effects. There is some evidence from epidemiology studies that exposure to power-frequency EMF is associated with an increased risk for childhood leukemia. This association is difficult to interpret in the absence of reproducible laboratory evidence or a scientific explanation that links magnetic fields with childhood leukemia.

EMF exposures are complex and come from multiple sources in the home and workplace in addition to power lines. Although scientists are still debating whether EMF is a hazard to health, the NIEHS recommends continued education on ways of reducing exposures. This booklet has identified some EMF sources and some simple steps you can take to limit your exposure. For your own safety, it is important that any steps you take to reduce your exposures do not increase other obvious hazards such as those from electrocution or fire. At the current time in the United States, there are no federal standards for occupational or residential exposure to 60-Hz EMF.

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