Can Public Health Policy Decisions Be Made On The Basis Of Currently Available Data On Electromagnetic Field Interactions With Biological Systems?

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In recent years, the public has been receiving conflicting information about electromagnetic fields: no danger, yes there is danger, well we don't know, etc. This has been unsettling for the public and has put pressure on health policy decision-makers to act. But can they act given the nature of the science that is available? I think not.

Significant research on electromagnetic field (emf) interactions with biological systems had its origin in the physics and engineering communities' concern about the hazards of their high power equipment in the 1940's. But the research did not evolve as biological research normally does. A number of factors, discussed below, distorted the research and most of it went down fruitless paths. The consequences of this have to be recognized and understood; if they are not, then we can go far astray in interpreting what data we have and in the Public Health decisions we make. As you will see in the discussion of the following issues, an argument can be made that most of the research that has been done is misleading and not relevant to setting Public Health policy. In fact, I believe it would be unethical to use much of it to make Public Health decisions.

Specifically, the issues include: 1) the misuse of a toxicology model, 2) the fruitless studies to resolve the "thermal vs nonthermal" non issue, 3) the misapplication of the Specific Absorption Rate (SAR) notion, 4) the unacknowledged implicit assumptions, 5) the conflicts of interest, 6) the misuse of epidemiology, and 7) the misuse of one set of emf parameters for another set.

SCIENTIFIC CONTEXT

Before discussing the issues in detail, I will first sketch the scientific context. If one used electromagnetic energy sensors to view the world from space 100 years ago, the world would have looked quite dim. Now, the world glows with electromagnetic (em) energy emissions at most frequencies of the non-ionizing portion of the spectrum. Living organisms are complex electrochemical systems, which evolved over millions of years in a world with a relatively weak magnetic field and with few electromagnetic energy emitters. As is characteristic of living organisms, they interacted with and adapted to their environment of electric and magnetic fields.

One example of adaptation is the visual system, which is exquisitely sensitive to emissions in the very narrow portion of the em spectrum that we call light. Organisms, including humans, also adapted by using em energy to regulate various critical cellular systems; we see this in the complex of circadian rhythms. Fish, birds, and higher animals developed systems to use electromagnetic fields to sense prey and to navigate. Electromagnetic fields are also involved in neural membrane function; even protein conformation involves the interactions of electrical fields. Since living organisms have only so recently found themselves immersed in this new and increasingly ubiquitous man-made environment, they have not had opportunity to adapt to it. Thus, it is not surprising that man-made electromagnetic fields affect living organisms (1). The question is whether the extremely rapid proliferation of energy emitters presents a hazard to humans and, if so, the nature of that hazard.

ISSUES

TOXICOLOGY MODEL: Since this area of biological research had its origin in the physics and engineering communities' concern about hazards, the tendency has been for researchers to use a toxicology model as their frame of reference in the selection, design and analyses of experiments. They often set up experiments to look for a "dose-response relationship" between electromagnetic field exposure and a biological variable. But is a toxicology model appropriate as a guide for biological research with electromagnetic fields? It's a crucial question for, as Burke (2) and others have made quite clear, our frame of reference determines what we look at and how we look. And as a consequence, this determines what we find.

Theory and data show that toxicology is the wrong model (3, 4, 5) Electromagnetic fields are not a foreign substance to living beings like lead or cyanide. With foreign substances, the greater the dose, the greater the effect - a dose-response relationship. Rather, living beings are themselves electrochemical systems that use electromagnetic fields in everything from protein folding through cellular communication to nervous system function. To model how em fields affect living beings, one might compare them to the radio we use to listen to music.

The em signal the radio picks up and transduces into the sound of music is almost unmeasureably weak. At the same time there are, in toto, strong em fields impinging on the radio. We don't notice the stronger em signals because they are not the appropriate frequency or modulation. Thus, they don't disturb the music we hear. However, if you impose on the radio an appropriately tuned em field or harmonic, even if it is very weak, it will interfere with the music. Similarly, if we impose a very weak em signal on a living being, it has the possibility of interfering with normal function if it is properly tuned. This is the model that much biological data and theory tell us to use, not a toxicology model. And this is a crucial point. The history of science makes clear, if you don't look appropriately, you don't see. Astronomy, for example, has a long history of observations made with optical telescopes. By chance, it was discovered that stars emit in another portion of the spectrum; radio astronomy was born and astronomy made a great leap forward.

Also, because of this origin in the physics and engineering communities' concern about hazards, little attention was paid to variables that are important in biology and notions arose that crippled the research. Thus, most of the literature on em field interactions is irrelevant to us as biologists and to health policy decision-makers. Some of these notions and their faults are detailed below.

THERMAL VS NON-THERMAL: From the 1940's through the 1970's there was a great deal of heated discussion concerning whether biological effects of man-made em fields were all "thermal" or if some could be "non-thermal". This led to much fruitless experimentation which continues even today. As I noted in one of my papers (6), the thermal vs non-thermal controversy was one of semantics, not science. There was no common definition of the words and the proponents talked past each other. Some were defining thermal in terms of core temperature measured with a rectal thermometer, whereas others were talking about molecular motion. Further, since the technology did not exist to measure molecular motion, for example, at a membrane interface during exposure to an em field, this was a fruitless argument. In addition, the words thermal and non-thermal are labels, not specifications of biological mechanisms.

SAR: In the 1970's there was a well-meaning effort to work out a dosimetry. The desire was to be able to specify the exposure to em energy at a relevant point within an organism. Thus, the specific absorption rate (SAR) concept was developed. In essence, the SAR is a calculated energy absorption in an assumed homogenous mass of tissue; or, more simply, the amount of energy to heat a cup of water. All of us are more comfortable when we can quantify in a neat sort of way. Thus, obtaining a number for dose by use of the SAR concept is satisfying. But does the SAR concept have any value in the context of living breathing organisms or is it misleading in that context?

If the SAR were a point measurement, within an organism, of the strength of the field at the location of an identified biological mechanism, then everything would be fine. But it is not that. It is a calculated value from calorimetry or incident field measurement, resting on a foundation of assumptions.

The SAR concept may have value now with very simple cell suspension systems. But it has been indiscriminately used to provide what amounts to a very precise appearing, but pseudo-exposure number, in reports of all sorts of biological experiments - right up to man. This is still a problem today. Living organisms are not a homogenous mass, a cup of tea. It matters where the energy is deposited. One example is all that is needed to illustrate the problem. If a bullet is fired into the calf of a person's leg, there will be a deposition of energy and he will be most unhappy. He might require a day of hospitalization. If the bullet was fired through his brain, there would be the same deposition of energy, but the result would be quite different. Thus, one must be wary of interpretations of much of the existing research, because of the misuse of the SAR concept.

IMPLICIT ASSUMPTIONS: I can think of no better way to start this section than with a quotation from James Burke (2)

"Today we live according to the latest version of how the universe functions. This view affects our behavior and thought, just as previous versions affected those who lived with them. Like the people of the past, we disregard phenomena which do not fit our view because they are 'wrong'.... Like our ancestors, we know the real truth.

At any time in the past, people have held a view of the way the universe works which was for them similarly definitive.... And at any time, that view they held was sooner or later altered by changes in the body of knowledge."

An example will illustrate his point. In 1915 a meteorologist named Alfred Wegener, noting the shape of the continents and the distribution of fossils, proposed that the continents drifted apart. He suggested that they floated on a sea of heavier basaltic material.

To paraphrase Burke, the proposal was greeted with universal scorn. The naysayers said that there was no known mechanism that could move the continents. The soft land masses obviously could not plow through the hard ocean floor. The problems Wegener had posed were called pseudo-problems. The bio-geographical similarities of the fossils were explained away as due to land bridges and blown seeds. Since the continents did not fit exactly, his proposal had to be wrong. For thirty years Wegener's view was ignored.

In the 1950s the newly invented magnetometers had shown that the earth has a magnetic field parallel to the axis of rotation. By 1966 magnetic profiles showed that the ocean floor was spreading outward from the mid-ocean ridges, and it was clear that this mechanism had slowly pushed the continents apart. This was a mechanism that had not, and until magnetometers were invented, could not have been envisioned by the naysayers; besides, they already knew the "real truth".

This area of biological research is not privileged, it also has its few naysayers who imagine that they are the possessors of "real truth". They like to talk about the dogma, the "laws of physics". If the data do not conform to the dogma, then the data must be wrong.

But one does not challenge data with the current dogma. That's upside down, it's the dogma that is tested by data obtained with constantly increasing precision of measurement and observation. Observations improve, particularly the ability to measure more and see more. The test of data is additional, more precise data or data obtained with new techniques. This is the great leap in thinking that created Science out of the thinking of the Medieval Age. It is to be expected that theories conceived at one level of observation will have to be modified as observational ability improves. This is what some scientists ignore. They implicitly assume that they have reached a "fundamental" level of understanding, which leaves no room for even more fundamental levels of understanding.

A brief illustration will make this point clear. In 1850, a trip from

Washington, D.C. to Los Angeles would have taken more than 6 months in a wagon pulled by mules. Many times I have had breakfast in Washington, DC, flown to Los Angeles and arrived in time for lunch. If I went back in time to 1850 and stated the above, I'm sure there would be some physicists who would flatly say that the laws of physics show this is impossible - and then "prove" it with elegant calculations on the muscle energy output of mules, wagon axle friction, etc. They would have been right in their calculations, but wrong in their implicit assumption that they knew everything that will ever be known. Thus, their conclusion would be wrong, as we all know. But this kind of upside down thinking has been frequent in this area of research. And it has crippled the research and resulted in misleading information in the literature.

CONFLICTS OF INTEREST: Pervading and crippling this area of research have been conflicts of interest. In the 1980s Steneck, who at the time was Director of the Collegiate Institute for Values and Science at the University of Michigan, received a major grant from the National Science Foundation's Program for Ethics and Values in Science and Technology. He and Institute Fellows in biology and physics used it to do an in-depth case study of this area of research; and many of the conflicts of interest they uncovered were documented in two books (7, 8). One example of such conflicts will suffice. For many years, there has been an Air Force office that decides what research the Air Force should fund to determine if emf exposure is hazardous. The same office has been responsible for assuring residents that there is no evidence of hazard when the Air Force wishes to place a radar (an emf source) in a residential area.

Among Steneck's conclusions was:

"...the establishment that controls RF bioeffects research has misled the public and researchers. ...key decisions on such research have been influenced by persons with vested interests ...."

These conflicts of interest have skewed and limited the amount of data that can be used to establish Public Health policy. And these conflicts of interest have continued since Steneck did his in-depth study of this research area.

MISUSE OF EPIDEMIOLOGY: Twenty years ago, an epidemiological study was done that indicated power lines may be associated with cancer genesis or promotion. Since then, there have been numerous epidemiological studies with the apparent intent to prove or disprove that emf causes or promotes cancer. These have yielded conflicting results, yet more are underway. This is a misuse of epidemiology. Epidemiological studies can't provide proof either way. They are only useful in this field for hypothesis generation; to provide a starting point for laboratory experiments.

How can they provide proof? Physicians do not have a full understanding of cancer genesis and promotion. So we have one set of unknowns. And then we have another set of unknowns. We lack measurements of individual residences in the years before the diagnosis of cancer. We don't even know how well a single current measurement characterizes present exposure, much less emf exposure years earlier when the cancer presumably started. We don't know what is the best indicator of emf exposure years ago when the cancer started or was promoted: is it wiring configuration, measurement of distance from source, direct measurement of fields, etc. We don't know what characteristics of the fields, those many years ago, were important. As one author admitted (9) "While power line magnetic field exposures are predominantly sine-wave fields, residential and occupational exposures may include square waves, sawtooth waves, and other wave forms. Harmonics (120 Hz, 180 Hz, etc.) may also be found. Further, as appliances are switched on and off, spikes or transients in fields may occur."

Clearly, endless epidemiological studies can not prove or disprove anything about emf and cancer. They are being misused. A few such studies to provide hypotheses to be explored in emf laboratory experiments are an appropriate use of epidemiology.

ASSUMED EMF PARAMETERS: The recent large National Toxicology Program studies on carcinogenesis and promotion of 60-Hz magnetic fields (9, 10) were carried out, apparently, with the intent to provide information that can be used in making health policy for humans. These studies cannot be used for this purpose because of two implicit assumptions that were made when the studies were being designed. Other recent studies, such as the study by Mandeville et al. (11), also make such assumptions.

First, it was assumed that the relevant magnetic field parameter for inducing biological effects is a pure 60-Hz sine-wave, and such was used. But the public is exposed to something very different, as the authors of the toxicology program studies admit (9):

"While power line magnetic field exposures are predominantly sine-wave fields, residential and occupational exposures may include square waves, sawtooth waves, and other wave forms. Harmonics (120 Hz, 180 Hz, etc.) may also be found. Further, as appliances are switched on and off, spikes or transients in fields may occur. It is not feasible to evaluate all possible variables in large animal studies. Therefore, this study used linearly polarized, pure sine-wave exposures at 60 Hz, with the fields turned on when the sine wave was at zero amplitude and gradually increased over seven to nine cycles (between 0.11 and 0.15 seconds) to full intensity, and similarly gradually decreased to avoid transients. The NIEHS studies evaluate the predominant component (60-Hz sine-wave magnetic fields) without all the complexities of the exposures that occur in residential and occupational settings."

Biological theory, as well as substantial published data, indicates that the field characteristics which people are actually exposed to, and which the authors eliminated from their experiments, are the effective agents (1, 5). Thus, if one wants to use the results of these studies in setting health policy for people exposed to power line fields, one must first prove that a pure sine-wave field is the relevant parameter for inducing biological effects.

The second implicit assumption made by the authors was that magnetic fields are an alien substance, such as arsenic, etc. Thus, they set up the experiments using a toxicology model--in a dose-response format. I spelled out above the problems with doing this. If one wants to use the results of these studies in setting health policy for people exposed to power line fields, one must first prove that a toxicology model is

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appropriate.

Although the technology in these experiments may be fine, it would not be ethical to use the results in the formulation of health policy for the human population without first proving that the implicit assumptions that were made are true.

CONCLUSIONS

As you can see by the foregoing, we have to be wary of using most of the published data in this area. Because of the unusual history of the research on electromagnetic field interactions with biological systems, there is relatively little data that can be used to establish Public Health policy. There are, though, specific lines of research that could yield useful data if they are undertaken. Since electromagnetic fields have become a pervasive factor in our environment in recent years, the sooner we know if fields of particular characteristics present a Public Health problem, the better for both individuals and Society. If we continue to wait, and effectively do an experiment on the whole population without informed consent, we open our Society to the potential of severe economic disruption when the results are in.

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