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HEALTH RISKS FROM ELECTRIC POWER FACILITIES 1/

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INTRODUCTION

The emerging perception of man in relation to the environment is that of an adaptable animal attempting to cope with myriad factors that have potential physiological significance. The factors may be internal (such as a genetic predisposition) or external (substances in the air or water), and clinical disease is a manifestation of their cumulative impact -- it develops when the total physiological load exceeds the individual's adaptive capacity.

The total-load concept applies to any stimulus capable of eliciting an adaptive response. Man-made electromagnetic energy present in the environment is such a factor, and chronic exposure to it therefore has public-health consequences. My aim here is to broadly sketch the nature of environmental electromagnetic energy, its clinical consequences, and its implications for the electric power industry.

ELECTROMAGNETIC ENERGY IN THE ENVIRONMENT

The environment is heavily laden with electromagnetic fields from many sources including radio, television, microwave-relay stations, and powerlines. At the power-line frequency, the average background electric and magnetic fields are on the order of 1 V/m and 800 microgauss respectively. Background fields are pervasive and usually cannot be uniquely identified with a particular device, but

significantly stronger fields exist near high-voltage powerlines. The zone of influence of the electric field of powerlines (the distance from the centerline within which the field is greater than 1 V/m) is given in Table 1.

HURDLES

Why should we care about the electric or magnetic field of high-voltage powerlines? They are factors added to the environment and, consequently, it must be determined whether they cause or promote disease. Many hurdles have appeared along the road that leads to this knowledge (Figure 1), and I think that we gain valuable insights into the serious societal problem of powerline safety by considering some of the important ones.

The public should not be expected to prove that electric or magnetic fields from powerlines constitute a health risk; it is the power industry that has the burden of credibly showing safety. If this point is overlooked, subsequent discussion of the issue becomes distorted.

It is a matter of common experience that one can repeatedly pass near high-voltage powerlines, and not exhibit obvious deleterious changes in appearance. Furthermore, all high-voltage powerlines, substations, distribution lines, and the electrical devices that they serve exhibit predictable behavior in the sense that they obey a set of four mathematical equations. Yet, the equations give no hint that

electromagnetic fields can cause disease. These themes -- no acute effects, and no effects predicted by, theory -- can be found in the utility-company position in virtually every judicial and administrative proceedings involving powerlines since at least 1973. The simple fact, however, is that the arguments are irrelevant. The human disease associated with high-voltage powerlines is not an acute response, and all mathematical equations are silent on the question of what causes disease.

The next set of hurdles involves the kind of evidence one chooses to consider. I think it makes no sense to approach the question of safety of high-voltage powerlines by studying cells in a test-tube because cells are too simple, and the relationship between their response and the putative response of a higher organism is too tenuous. Nevertheless, many such studies have been undertaken for this avowed purpose, resulting in confusion and alarm among the public who sometimes assume that the studies have particular value with regard to the safety issue.

The most useful data would obviously come from studies employing human subjects, but such studies present almost insurmountable ethical and legal problems. For one thing, the quasi-invasive nature of measurement techniques routinely employed for animals renders most human studies unthinkable. Furthermore, because of the inherent health risks, Institutional Review Boards (which have the responsibility under federal law to review proposed human research) are unlikely to approve a study of the biological effects of chronic exposure of human subjects to simulated powerline fields.

We must rely on animal studies to provide relevent information regarding the nature of any health risk, or simply walk away from the problem. The uncertainty inherent in extrapolating animal data to human beings has always seemed preferable to me to the nihilism associated with the alternative choice. Thus, I dismiss the argument that animals do not react like human beings to environmental pollutants because, if followed, it would truncate all scientific consideration of the issue. A better approach is to deal with the basic concern by appropriately choosing and designing the animal studies that will form the basis of the extrapolation to human beings.

The choice of an animal experiment involves issues of experimental design and interpretation of data. Not every experiment that involves power-frequency electric or magnetic fields is useful for evaluating potential health risks of powerlines. If, as an example, one studied large old rats that were caged in cramped conditions, the possibility of observing a neuroendocrine response would be minimized because of both the confounding presence of the cage stress, and the use of an animal population with a reduced ability to respond to any environmental stimulus. Such a design is particularly useless when the theory being tested is that it is a neuroendocrine response that links power-frequency electromagnetic fields and human disease.

When the design hurdle is overcome, a subtle but crucially important hurdle must then be cleared. In the main, animal studies are useful for evaluating the existence and dynamics of physiological

responses, but without too fine a point. As an example, an animal experiment could determine whether bone will grow into a porous coating on a metallic hip prosthesis. The existence of bone in the pores could be determined by microscopic examination after the animal had been sacrificed. The further question whether such bony ingrowth would be clinically useful (more effective than no coating in preventing loosening of the prosthesis) could be answered only by clinically evaluating the results found after using the coated prosthesis in patients. It seems to me that the same principle applies when we evaluate the impact of electromagnetic fields using animal studies. It is normally not practical to do an animal study to determine whether fields cause cancer or stroke or heart disease. Animal experiments are capable of revealing the existence of physiological effects (a neuroendocrine response, altered brain waves, depressed serum enzyme levels are examples), but they are not generally useful for directly evaluating the presence of disease. The relationship of animal data to human disease is usually a matter of judgment, not demonstrable fact.

After evaluating appropriate animal experiments, it is possible to assess the existence and general nature of the health risk associated with exposure to electromagnetic fields, and to give general guidance regarding safety levels. In my view, human epidemiology, although useful and desirable, is merely confirmatory regarding the question of human health risks. Even more distant from the finish line is the hurdle involving considerations of the mechanism by which the electromagnetic field is related to human

disease. The term "mechanism" as used by those who speak for the industry typically connotes a cell-membrane or submolecular process. Knowledge of such processes would be of obvious scientific value, but placing the Mechanism hurdle before the finish line would be tantamount to a guarantee that the race will not be finished.

POWERLINES AND HEALTH RISKS

Electromagnetic fields caused changes in the brains of exposed rabbits (1), and altered brain-wave activity (2). Electromagnetic fields altered the innate orientational ability of birds (3,4), and the behavior of trained rats (5). Rabbits (6), rats (7), and mice (8) exhibited functional alterations in their immune systems following exposure to electromagnetic fields.

Rats continuously exposed to electromagnetic fields for 30 days exhibited lower average serum levels of corticoids, and large pituitaries (9). Sixteen tumors occurred in 100 chronically-exposed male rats, compared to 4 tumors found among 100 control rats (10). Exposure of monkeys produced an increase in urinary corticoids which lasted about 6 days, afterwards the corticoid levels returned to baseline despite continued exposure to the field (11). In another study, a similar effect on corticoids in rats persisted for 4 months (12). Exposure to electromagnetic fields delayed fracture-healing in rats (13), altered growth-rate in rats (14) and monkeys (15), produced skeletal abnormalities in chick eggs (16), and promoted

cancer (17-19) and mutagenic changes (20).

Various blood indices have been shown to be sensitive to a change in electromagnetic environment (21), and similar environmental changes have been shown to produce alterations in human subjects involving serum triglyceride levels (22), circadian rhythms (23), reaction time (24), and performance on standardized tests (25).

In some studies no effects were found, but I know of none in which it can be plausibly asserted that the findings amount to evidence that no effects exist. Industry-designed studies have simply not provided relevant scientific data. The industry's premiere effort has been the Battelle studies whose goal was to "obtain a scientifically sound data base for establishing reliable and valid exposure limits in order to insure public safety and health" (26). The goal was not achieved and consequently the Battelle studies are, in my judgment, a failure (27).

The literature on electromagnetic-field-induced changes in laboratory animals can be summarized this way (28): (1) exposure to electromagnetic fields can result in alteration of the metabolism of all body systems, including the nervous, endocrine, cardiovascular, hematological, immune, and reproductive systems; (2) the effects manifested in each tissue or system are largely independent of the type of electromagnetic field in the sense that common physiological responses are produced by spectrally different electromagnetic fields; (3) an organism's response to an electromagnetic field is determined by a combination of factors including its physiological history, genetic predisposition, and the totality of prevailing

environmental conditions; (4) electromagnetic-field-induced biological effects in animals are best characterized as adaptive or compensatory because the fields present the organism with an environmental factor to which it must accommodate. Simple dose-response relationships are generally not observed.

The animal studies show that the electromagnetic field can be a biological stressor, by which I mean that it can elicit an adaptive response. It is self-evident that the ability to adapt to chronic stressors is finite, and that the addition of any chronic stressor tends to make it more likely that the subject's ability to cope will be exhausted -- a condition manifested clinically as a disease. Thus, powerline fields tax adaptive capacity, and it is this characteristic that links them with human disease. In my opinion, 50 V/m is the absolute upper limit for chronic, involuntary, human exposure (28).

HUMAN EPIDEMIOLOGY

If electromagnetic energy is a nonspecific biological stressor that can elicit a systemic adaptive response in the exposed organism, what kinds of clinical signs will occur in exposed human beings? If an organism is subjected to, for example, a cold stress, adaptive changes occur. If the stress is maintained, the animal's defenses may break down resulting in a diagnosible disease. But there is no signature disease for a cold stress. The animal could exhibit any of

several diseases; infection (if a viral or bacterial agent were present in the environment) and pneumonia (if its respiratory system were already weakened for other reasons) are examples. The effects produced by environmental electromagnetic energy similarly depend on diverse factors, and therefore will be manifested as an increase in all diseases in the chronically-exposed population.

A pattern of elevated disease in both occupational and non-occupational groups has been seen for leukemia, nervous-system cancer and overall cancer (29-47). The frequency of cancer was increased when the electromagnetic field was added to the environment, and therefore the field was a risk factor for the disease (48).

The emergence of an epidemiological correlation between electromagnetic fields in the environment and cancer is largely a consequence of the fact that, as a society, we maintain adequate statistical records regarding cancer incidence. The studies do not mean that cancer, as opposed to other diseases, is a more likely manifestation in the chronically-exposed population. Electromagnetic fields have been linked with suicide (49), polycythemia (50), nervous-system disorders (51,52), sexual dysfunction (53) and fetal development (54), and future studies will undoubtedly link it with other diseases. The electromagnetic field is a potentiating factor for all diseases because it is one of a milieu of neurogenic and somatic stressors.

THE FUTURE

Evidence accumulates daily to show that living organisms are sensitive to electromagnetic fields (55). This trend will have strong ethical, public-relations, and legal implications for the electric power industry. The extremist position of the industry in the 1970s in New York (56) now seems largely gone, but it has been replaced by an equally flawed strategy in which a heavy reliance is placed on reports that have only a microscopic coating of relevance and objectivity. The Montana (57), Florida (58), and WHO (59) reports are faulty because the relevent studies were ignored and the significant issues were not addressed. Moreover, the reports lack credibility because of the obvious potential for conflict-of-interest on the part of many of the authors. The reports did not sustain the industry's position in recent cases in Houston, Tampa, or Riverside, and it is unlikely that they will be honored in any forum where the tryer of fact actually wants to hear both sides. As the public comes to learn that the method of delivery of their electricity is linked to their cancer, public perception of the industry itself will deteriorate. If the public learns further that there has been a sustained cover-up of this information, then it seems obvious that the industry's problems will simply be compounded.

The power industry is in an economic and legal position comparable to that of the air and water polluters of the 1960's. Degradation of a river was then legally permissible, and was not an internalized cost reflected in the price of the product. The

succeeding 20 years brought many changes in air and water pollution practices. Now, we know that electromagnetic pollution from powerlines must be controlled, even though the price of the product will be increased. If the industry fails to voluntarily internalize this cost in a rational and orderly fashion, then forces will spring into being and coerce this result. The industry will then have partly lost control of the process of the change.

Another important legal development during the last 20 years has been the growth of the law of product liability. The resulting insurance premiums have markedly raised the cost of doing business in many economic sectors. The premiums can amount to 10-20% of gross income for such diverse endeavors as the trucking industry and medical practice. If the utility industry continues on its present course, it may spend many more dollars in the products-liability area, than it would have spent in building safer highways for electrical energy.

SUMMARY

Environmental electromagnetic energy from high-voltage powerlines and other sources is pervasively present in the environment. Numerous laboratory studies with animals and human beings have shown that such energy is a biological stressor in the sense that it can elicit an adaptive response from the exposed organism. As with any stressor, chronic application is inimical to

the organism's well-being because it taxes adaptive capacity. Chronic stress may lead to disease, as has been shown in appropriately controlled epidemiological studies. Reports that whitewash the issue are both wrong and ineffective. If the industry persists in its present fiction that the environment which conducts electrical energy is also suitable for human habitation, resulting product-liability insurance premiums may drastically and adversely alter the nature of the industry.

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TABLE 1

Zone of Influence of High-Voltage Powerlines

POWERLINE VOLTAGE (volts)	LATERAL DISTANCE FROM CENTERLINE (feet)
765,000	2500
500,000	1700
345,000	1300
230,000	800
115,000	400

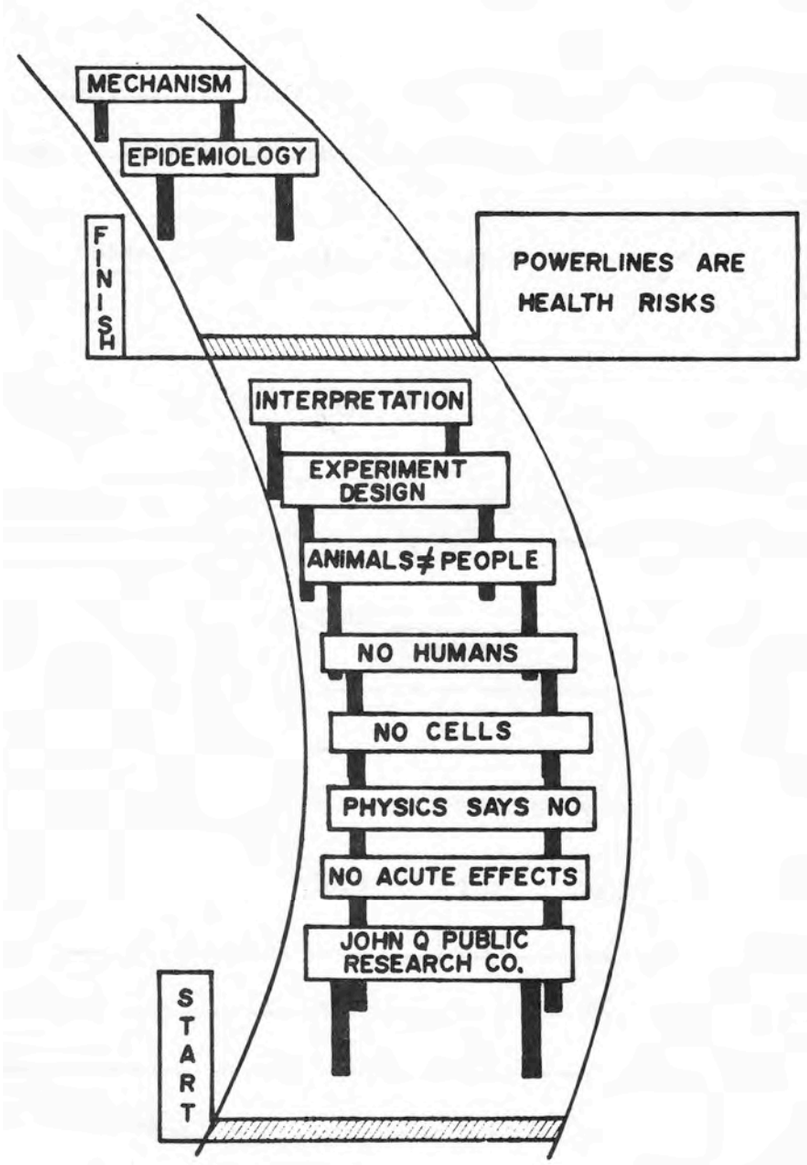

FIGURE 1

Hurdles in evaluating health risks of powerlines.