RECURRING THEMES

Several themes were sounded throughout the presentations and discussions at the EMF Engineering Results Symposium. They are briefly characterized below. This summary has been prepared from the symposium transcript.

Convergence on a Health-related Exposure Parameter

There is still no formal or understandable potential mechanism for any biological process (direct or indirect) that will link either magnetic- or electric-field exposure to health outcomes such as cancer. If such a mechanism exists, its actions are likely to be indirect, such as requiring a co-carcinogenic mechanism or some association between an environmental factor such as traffic, pollutants, and so on, and some feature of electricity distribution or use.

Without further guidance from biological research, the potential scope for combinations of parameters that could be considered is large—one estimate suggested 400,000 possible combinations. Some participants felt that the association indicated by epidemiology was strong enough to point towards the relevant parameters.

With an increasing body of knowledge and improved instrumentation/technology, it becomes possible to design and perform more sophisticated research, and to include many more parameters. Discussion centered on how to reduce the number of factors/parameters, and how to converge on factors of central importance.

Role of Engineering

Engineers now have the capability of measuring the magnetic-field characteristics found in the environment and reproducing them in exposure systems. They can also produce, in the laboratory, field characteristics that anyone proposes as a relevant exposure parameter.

In addition to responding to the needs for producing fields in biological studies and characterizing exposures for epidemiological research, engineering also should pro-actively and independently characterize environmental electric and magnetic fields.

Given the lack of an outcome-related environmental agent and the apparent subtlety of any effect, the approach to determining potential effects and risks must be an iterative one: biologists and engineers must work together to propose characteristics to measure, undertake measurements, report results, estimate effects, and propose additional research, as well as to evaluate the benefits of field management.

Nature of Fields

Electric Fields

Early research focused on electric fields. Biological research, and then epidemiological studies, did not link electric-field exposures to health outcomes. With the appearance of the Wertheimer-Leeper epidemiology studies, research emphasis shifted in the 1980s to magnetic fields. There was discussion as to whether present knowledge generated by the exploration of magnetic fields warranted a re-evaluation of electric fields. It was emphasized that the extent of elevated electric-field exposures was considerably smaller than that for magnetic fields; that electric-field exposures were difficult to quantify; and that exposed persons in electric-utility environments and in homes exposed to high-voltage transmission systems were often shielded.

Variability/Uncertainty

Electric- and magnetic-field exposures are highly variable within a day, between days for the same individual, and between different individuals (even within the same occupational group). It is therefore difficult to define groups with homogeneous exposures. Considerable information is available on the uncertainties associated with magnetic-field measurements and on the variability inherent in magnetic-field exposures. Additionally, field perturbation by humans precludes accurate determination of an electric-field meter similar to magnetic-field TWA.

Measures of Magnetic-field Exposure

Magnetic-field Measurement and TWA

Several studies have investigated the relationship between TWA magnetic-field exposure and other measures of field magnitude such as median, maximum, minimum, and time above threshold. It has been demonstrated that there is good correlation between TWA and several other common measures of magnetic-field magnitude, indicating that TWA may be sufficient for characterizing these other measures. However, there are other measures of magnitude, as well as measures of field variability and frequency, that are not related to TWA and that therefore require independent characterization. There was healthy disagreement over the sufficiency of TWA as a measure of exposure and its relationship to other measures of exposure.

Magnetic Fields and Wire Coding

While no clear pattern of association between measured magnetic fields and disease has emerged, residential wire-code category, which is linked to magnetic-field levels, has shown a fairly consistent association with disease. (The notable exception to such a relationship is the recently completed multi-state NCI childhood cancer study, which shows no association between wire-code category and disease outcome.) However, the correlation of wire-code category with *measured* fields is not strong (the overlap of fields in different categories is substantial), and it is possible that wire-code category could be a surrogate for other exposures that are related directly or indirectly to health outcome (e.g., air quality, traffic density, age or location of home). The efficacy of wire-code categories in delimiting exposures may also be related to geographic location. Consequently, uncertainties remain regarding the accuracy and value of wire-code categories as a universally applicable measure of historic magnetic-field exposure.

Other Exposure Factors

The emergence of a pattern of association between wire-code category and health outcome has prompted investigations of the possible association of wire-code category with other localized factors such as traffic density, air pollution, residence characteristics, neighborhood characteristics, and socioeconomic factors. To date, links of other factors to wire-code category remain hypothetical, unsubstantiated, or weak at best.

Study Design and Methodology

Changes in Object of Measurement

Over time, and as instrumentation and technology have matured, researchers are shifting away from early surrogates and measurement of sources towards measurements of area, micro-environments, and personal exposure. This means that it is now important to measure time/location/activity data as well: the point is not simply measurements, but *characterized* measurements.

Quality Control

Multiple-level Quality Control is a critical element in any EMF engineering study. Most studies have included an engineering quality-control component applied to both instruments and measurement protocols. However, several participants emphasized the need for quality assurance in both study design and study execution.

Correlation with Real World

Any ongoing and future research must be tied firmly to what is *useful*, and to effects in the real world; it must also be linked with previous studies—that is, be respectful of TWA exposures, wire-code categories, and other common historically applied factors. In general it was felt that there was no completely satisfactory substitute for direct PE measurement over an adequate time period.

Field Management

Electric and magnetic fields can be managed to yield designated environmental levels in most cases. However, reductions in field to common residential levels on transmission line rights-of-way and on electric trains may prove to be prohibitively expensive.

There are always tradeoffs in field management. Therefore, a complete engineering evaluation should identify the operational, environmental, and cost factors inherent in any proposed field management project. For example, in reducing fields from transmission and distribution lines, other factors such as reliability, worker safety, and corona-generated audible noise and electromagnetic interference must be considered.

Policy Issues

Implementation of a field-management strategy as policy requires a complete assessment of the consequences, not just a measure of field reduction. Other engineering factors include impacts on the electrical system, changes in exposure to the electric field as well as to the magnetic field, introduction of other exposures, and an assessment of cost versus number of affected persons.

Societal issues such as environmental justice and allocation of resources could be associated with siting of electrical facilities and field management policies. At present these are little explored for EMF exposures, although limited information is available on the characteristics of nearby populations.