Epidemiology, human, animal and cell studies

Studies of potential health effects from radiofrequency (RF) electromagnetic exposures can be broadly classified according to the biological model that was studied, ranging from: epidemiological studies of human populations; human laboratory studies; animal (*in vivo*) studies, and; cellular (*in vitro*) studies. Although human studies are generally considered to be of most direct relevance to health effect assessments, each study type has complementary strengths and weaknesses that all contribute to a final health risk assessment.

Epidemiology (human populations)
Epidemiological studies are of primary importance in health risk assessment because of their direct relevance to human populations in their natural environment. They can be designed to investigate medium and long-term associations between RF exposures and a wide range of illnesses.

If large enough and well constructed, they can also detect interactions with other factors in the environment. Conversely, epidemiological results can be biased or confounded by unrecognised influences that affect the incidence of the health effects under study. They are also prone to difficulties with exposure assessment, often relying on approximate measures such as subject recall or administrative records (e.g. mobile phone bills). Long-term (>10 yrs) epidemiological studies are very expensive and of course take a long time to complete.

Human Laboratory Studies
Laboratory studies of human volunteers are complementary to epidemiological studies. They are conducted in controlled environments, which allow much better exposure assessments and control of potential biases and confounders. However, they generally use much smaller and less varied human subject groups, are limited to the study of short-term transient effects, and can miss potential interactions between the studied agent and other natural environmental factors.

The scope of human studies is also often limited by ethical and practical considerations.

Animal (*in vivo*) Studies
Animal studies can offer a quicker and more flexible approach for health effect studies. They are still bound by ethical constraints but they allow much greater diversity in the range of studied potential health effects and the level of exposure than would be permitted for human studies. Animals naturally are less able to communicate subjective symptoms (like headaches) but models have been devised for many types of human illness.

Animals with short life spans (e.g. 2 years for mice) provide opportunities to study 'whole of life' effects such as illness rates and life span, and exposure conditions can be rigorously controlled, even for continuous exposures. Some animal species, such as transgenic mice, have been specially bioengineered to provide models for the promotion of certain cancers, often over a shortened exposure period. The main drawback of animal studies is their more limited relevance to human health given their different physiological systems, which might reduce or increase the response to RF exposures compared to humans.

Cellular (*in vitro*) Studies
Studies in tissues, living cells and cell-free systems play a supporting role in health risk assessments. Cellular model systems are excellent candidates for testing the plausibility of mechanistic hypotheses and investigating the ability of RF exposures to have synergistic effects with agents of known biological activity. They can provide useful pointers for the optimal design of animal and epidemiology studies and are relatively cheap and unconstrained by ethical practicalities compared to the other study types. Thousands of endpoints can be quickly and cheaply tested for some assays, such as in genomics and proteomics. However, although useful for generating hypotheses, they do not generally provide definitive evidence for human health effects due to their lack of relevance to complex whole body systems.

Exposure Assessment
Expert assessment of RF exposure is needed for all study types and is critical to their proper design and interpretation. This is termed *dosimetry*. For epidemiological studies that rely on participant recall of past phone use this may be validated against objective measures such billing records or special phones. Other studies may require combinations of direct measurements and complicated computer models to determine the exposure to the area of interest.

Exposure systems must also ensure that other environmental factors such as temperature, noise or light do not affect the biological system under study.

Where to go for more information

GSMA: **http://www.gsmworld.com/health**

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