

benefits to society. With this, an increasingly large population will be exposed, and for longer and longer periods of time. Undoubtedly, questions will continue to arise about the health risks of mobile-phone use and possibly other emerging sources of exposure to RF radiation. This *Monograph* is a comprehensive review of the currently published evidence that also identifies gaps in the available information. These gaps should be resolved with further research if ongoing concerns about the health risks of mobile-phone use are to be addressed with greater certainty.

The Working Group agreed to consider three categories of human exposure to RF radiation: (a) environmental sources such as mobile-phone base stations, broadcast antennae, smart meters, and medical applications; (b) occupational sources such as high-frequency dielectric and induction heaters, and high-power pulsed radars; and (c) the use of personal devices such as mobile phones, cordless phones, Bluetooth devices, and amateur radios.

The general population receives the highest exposure from transmitters close to the body, including hand-held devices such as mobile phones, which deposit most of the RF energy in the brain. Holding a mobile phone to the ear to make a voice call can result in high specific rates of absorption (SAR) of RF energy in the brain, depending on the design and position of the phone and its antenna in relation to the head, the anatomy of the head, and the quality of the connection with the base-station antenna: the better the connection, which is ensured by a dense network of base stations, the lower the energy output from the phone. In children using mobile phones, the average deposition of RF energy may be two times higher in the brain and up to ten times higher in the bone marrow of the skull than in adult users. The use of hands-free kits lowers exposure of the brain to less than 10% of the exposure from use at the ear, but it may increase exposure to other parts of the body.

Typical environmental exposures to the brain from mobile-phone base stations on rooftops and from television and radio stations are several orders of magnitude lower than those from GSM (Global System for Mobile communications) handsets. The average exposure from DECT (Digital Enhanced Cordless Telecommunications) phones is around five times lower than that measured for GSM phones, and third-generation (3G) phones emit, on average, about 100 times less RF energy than second-generation GSM phones, when signals are strong. Similarly, the average output power of Bluetooth wireless hands-free kits is estimated to be around 100 times lower than that of mobile phones. In occupational settings, exposure to high-power sources may involve higher cumulative deposition of RF energy in the body than with exposure to mobile phones, but the energy deposited locally in the brain is generally less.

Epidemiological evidence of an association between RF radiation and cancer comes from time-trend, cohort, and case-control studies. The populations in these studies were exposed to RF radiation in occupational settings, from sources in the general environment, and from use of wireless (mobile and cordless) phones. Two sets of data from case-control studies were considered by the Working Group as the principal and most informative basis for their evaluation of the human evidence, i.e. the INTERPHONE study and the Swedish case-control studies; both sets of data focused on brain tumours among mobile-phone users.

The Working Group recognized not only the rapid increase worldwide in the use of wireless communication systems – both in number of users and in duration of use – but also the considerable technological developments in this area, with the introduction of third- and fourth-generation (3G and 4G) devices during the past decade. It is of interest to note that the key epidemiological studies mentioned above were conducted in the late 1990s and the early 2000s. In the INTERPHONE study, all participating countries in Europe had GSM networks. It is worth mentioning that the 3G and 4G