HEALTH RISKS AND MOBILE PHONES

POST note 109 January 1998

POSTnotes are intended to give Members an overview of issues arising from science and technology. Members can obtain further details from the PARLIAMENTARY OFFICE OF SCIENCE AND TECHNOLOGY (extension 2840).

The rising market for mobile phones has been accompanied by concerns over their safety, especially that the radiofrequencies used to transmit signals may cause harm (most notably cancer). Such concerns relate both to the siting of the transmitter 'base' stations and the use of hand-held receivers.

This briefing note looks at the evidence behind such concerns, and the policy issues that arise.

BACKGROUND

Recent years have seen a massive growth in the market for mobile phones, with some 60M users worldwide (8M in the UK). The market continues to expand and a recent European Union (EU) estimate predicts 200M users worldwide by 2010. As detailed in **Box 1**, mobile phones are low power devices, that transmit and receive radio signals in the microwave range from local base stations. Several different systems compete in the UK market (**Table 1**); they include an estimated 2M analogue phones based on the Total Access Communication Standard (TACS) and some 4M digital handsets based on the Global System Mobile (GSM) standard operated by Cellnet and Vodafone, as well as a further 2M or so digital Personal Communication Network (PCN)-based phones operated by One2One and Orange. Each systems uses its own frequency to transmit (Table 1) but all lie between 800 and 1900 MHz.

It has long been known that microwaves generate heat when absorbed by biological tissues (Box 1), and that at sufficient power this can cause damage at the tissue, cellular and molecular levels. Restrictions on exposure advised by the National Radiological Protection Board (NRPB) in the UK and by other relevant national and international bodies - most notably the International Commission on Non-Ionizing Radiation Protection (ICNIRP) - are designed to avoid these so-called **thermal effects**. As described in **Box 2**, the recommended exposure limits for protecting the general public set by the two bodies differ by a factor of 5. Neither recommendation has legal force at present, although equipment is designed to comply with the standards.

Box 1 MICROWAVES AND THEIR EFFECTS

Mobile phones in the UK receive and transmit radio frequency (RF) signals, which fall in the microwave region of the **electromagnetic spectrum**, which ranges from the high frequency x-rays at one end to the very low frequency used in power transmission at the other.

The biological effect of radiation is related to its frequency (and wavelength) and its power. The shorter wavelength, high frequency radiation from x-rays can disrupt the bonds holding biological molecules together and are thus called ionising radiation. The RF radiation used in mobile phones is of much lower frequency (800-1900 MegaHertz -MHz) and is incapable of breaking chemical bonds (i.e. is **non ionising**). It can, however, disrupt biological processes through **thermal effects** (heating). For instance, 2450MHz is used in microwave ovens because water molecules absorb this frequency, turning the energy into heat, and similar thermal effects can occur with radiofrequencies down to around 1MHz, depending on the power of the signal used. A particular concern is that the wavelength of mobile phone signals may lead to localised energy deposition within tissue (often referred to as 'hotspots'). Signals of frequencies below ~0.1 MHz may also cause various (**non-thermal**) effects including 'perception' effects (caused by accumulating charge on the body) and effects on electrically excitable tissue such as nerves or muscle.

Table 1 UK MOBILE PHONE NETWORKS

Frequency (MHz)	*Standard*	*Approx No (M)*	*Examples*
900	**TACS**	**2**	**Vodafone, Cellnet**
900	**GSM**	**4**	**Vodafone, Cellnet**
1800	**PCN**	**2**	**One2One, Orange**

NEW QUESTIONS ON HEALTH EFFECTS

Recent research (summarised in **Box 3**) has led some scientists to question the assumption that radiowaves of the type used in mobile phones could only cause damage by heating tissue, and to ask whether low doses might be able to cause diseases through other, non-thermal, mechanisms. Cancer is the main concern, and some have questioned if mobile phones could be a factor contributing to an apparent increase in brain tumour rates among adults in some countries since the 1980s. To evaluate this possibility, research needs to answer the questions - do low (non-thermal) doses of RF microwaves:

- increase cancer rates in animal studies?
- directly damage DNA (and thus create a possible cause for cancer)?
- affect other biochemical processes (signalling pathways, immune processes) that might promote (rather than directly initiate) cancer?
- cause other harmful effects?

As outlined in Box 3, current scientific knowledge does not allow these questions to be answered unequivocally. The bulk of the available evidence suggests that RF microwaves do not cause such effects, but a few studies do report some adverse effects. The NRPB

Box 2 REGULATING THERMAL EFFECTS

The key factor determining the extent of thermal effects is the rate at which energy is absorbed - the **specific energy absorption rate** or SAR, measured in Watts per kilogram (W/kg) of tissue. The SAR depends on the characteristics of both signal and tissue. Research suggests that harm will only result if tissue temperatures are raised by 1°C or more, and such effects have only been seen at SARs above ~4W/kg (averaged over the whole body).

Both NRPB and ICNIRP reviewed the evidence on thermal effects and recommended exposure restrictions for RF microwaves used by mobile phones (see **Table**). Two main types of limit were recommended, one averaged over the whole body (relevant to exposure from base stations) and one averaged over a small mass (10g) of tissue in the head (relevant to exposure from handsets). NRPB recommended SARs of 0.4W/kg (whole body) and 0.1W absorbed in any 10g of tissue in the head. ICNIRP recommended the same limit for occupational exposure, but scaled in an additional safety factor of five for the general public (giving 0.08W/kg whole body and 0.02W in 10 g of tissue in the head, see Table).

Table NATIONAL AND INTERNATIONAL GUIDANCE ON EXPOSURE TO MOBILE PHONE FREQUENCIES

Organisation	*Exposure*	*Restriction*
NRPB	**Occupational and general public**	**0.4W/kg, whole body** **0.1W in 10g head / foetus** **1W in 100g neck / trunk** **2W in 100g limbs**
ICNIRP	**Occupational**	**0.4W/kg, whole body** **0.1W in 10g head**
	General public	**0.08W/kg, whole body** **0.02W in 10g head**

regards studies in this area as "*few and inconsistent*", and various features make interpretation difficult. Many of the studies used doses very much higher than those typically emitted by phones and base stations; few of them studied exactly the type of signals used by mobile phones; and there are difficulties in estimating exact exposures in test animals. Nor have the studies purporting to show adverse effects yet been replicated by independent researchers (and in some cases attempts to do so have failed). There are also difficulties in extrapolating from animal studies to humans because of doubt over how the biological systems of humans and animals compare in their response, as well as difficulties in making allowance for the very different physical shape and size of people and test animals. ICNIRP recently concluded that "*data from laboratory studies relevant to cancer do not provide a basis for limiting exposure to the fields associated with the use of hand-held radiotelephones and base transmitters*".

EPIDEMIOLOGICAL STUDIES

Searches for possible links between disease and exposure to RF microwaves have tended to focus on people exposed to signals from TV / radio transmitters rather than mobile phone base stations (which are relatively new). One study in a metropolitan area in Australia published in 1996, compared the incidence of leukaemia and brain tumours among people living in municipalities near TV broadcast towers, with those further away. Both total and childhood leukaemia were higher among those living near the towers, but there was no differences in rates of total or childhood brain tumours. No attempts were made to actually measure exposures, and the potential influence of other factors cannot be ruled out.

In another study conducted in the UK, researchers investigated cancer rates among people living near a high power FM / TV transmitter at Sutton Coldfield. They found that rates of adult leukaemia (and skin cancer) were 1.8 times higher within 2km of the transmitter, but these rates declined with distance from the transmitter. No other associations were found for other types of cancer (including lymphomas, breast cancer and brain tumours). On the basis of this finding, the research was extended to investigate cancer rates among people living close to 20 other high power FM / TV transmitters in the UK. The results of this larger study did not support the original findings and no increases in cancer rates were found near the transmitters. These studies are currently being considered by the NRPB's Advisory Group on Non-ionising Radiation (AGNIR).

With mobile phone use there is little hard evidence one way or the other. A number of cases are currently being pursued through courts in the USA and elsewhere, where mobile phone users are trying to claim compensation for illnesses (lymphomas, brain tumours, etc.) they claim to be linked to their mobile phones. No such claims have yet been successful. Reports have also surfaced in the media, where mobile phone use has been linked to a range of conditions from headaches to concentration and sleep difficulties, but such claims are based on anecdotal evidence. Both ICNIRP and NRPB have concluded that the published epidemiological studies do not form a basis for health hazard assessments and cannot be used for setting restrictions on human exposure.

ISSUES

Adequacy of Current Regulatory Restrictions

Operators of mobile telephone networks in the UK have to take account of a number of regulations and restrictions involving the regulatory / advisory bodies:

- **Department of Trade and Industry** (DTI) - primarily concerned with licensing (under the Telecommunications Act and the Wireless Telegraphy Act).
- **Department of Health** (DH) - which advises on certain health-related aspects of mobile telephones (e.g. interference with medical equipment) and is funding research in this area[1].

1. DH are funding one 3 year study (£180,000) on the effects of electromagnetic fields (including mobile phone frequencies) on cell cycle control mechanisms, and a one year (£113,000) project on effects on brain cells and behaviour in rats.

BOX 3 RESEARCH ON NON-THERMAL EFFECTS OF RF MICROWAVES

Cancer in Animal Studies. At least 8 studies during the 1990s exposed animals to low power (i.e. insufficient to cause tissue heating) RF microwaves to study the possibility that mobile phone signals might cause cancer:

- A significant increase in the risk of lymphoma was seen in one study conducted in Adelaide where 100 transgenic mice (genetically engineered to be predisposed to develop lymphomas) were exposed to RF microwaves (2X30 minutes each day to 900MHz for up to 18 months at 0.13-1.4W/kg) and compared to 100 identical non-exposed mice. Mice in the exposed group were more than twice as likely to develop lymphoma.
- Another study found slightly higher rates of cancer (all types) among normal rats exposed to microwaves (2450MHz at 0.15-0.4W/kg for 21.5 hours a day over 25 months) compared to non-exposed controls. While this result was statistically significant, the researchers were unsure as to its biological relevance (since no effects were observed on lifespan or cause of death, and cancer rates were unusually low in the control group).
- 6 further studies investigating the effects of lifetime exposure to RF microwaves (in the range 435-2450MHz at SARs between 0.1-10W/kg) on mice and rats, have all failed to show any increase in cancer rates.

Taken as a whole, the results are usually interpreted as showing that non-thermal doses of RF microwaves do not normally cause cancer in rodents. The results of the Adelaide study (the only study where a definite effect was seen) show that such signals can increase the risk of lymphoma in mice genetically engineered to be predisposed towards developing them in the first place, although the biological relevance of this to normal animals or to humans is unclear.

RF Microwaves and DNA. A recent study has reported that relatively low doses (~1.2W/kg) of microwaves (2450MHz) can cause rearrangement of chromosomes in mice (testes and brain) cells, and another that similar doses (0.6-1.2W/kg) of the same frequency causes breaks in DNA strands in the brain cells of rats. Such results remain equivocal, as neither study has been replicated (two subsequent attempts to replicate one of them in other laboratories have failed). Other recent studies have exposed cell cultures (mice blood cells, animal fibroblasts) to low power RF signals (2450MHz at 1W/kg and 836MHz at 0.015W/kg respectively) and found no sign of DNA damage. Finally, another recent study found that 954MHz at 1.5W/kg did not directly damage DNA in human blood cells, but did increase the amount of damage produced in these cells by a chemical carcinogen.

Other mechanisms. Other studies have shown that low power radiofrequencies may also have a range of other biological effects on cells, including affecting the flow of calcium and other ions across membranes in brain tissue, transient effects on behaviour, suppressing certain elements of the immune system, and having transient effects on levels of certain enzymes (protein kinases). The biological significance of such effects is unclear, although it has been suggested that RF microwaves might help promote (rather than directly initiate) cancer through subtle effects on the biochemical pathways controlling cell functions.

- **Health and Safety Commission/Executive (HSC/E)** - endorses the NRPB approach in developing its restrictions on human exposure to electro-magnetic fields and radiation, and expects employers to follow them in order to comply with statutory duties. HSE also provides the joint chair (with DH) and secretariat of a non-ionising radiation Liaison Group, and is helping fund a 5 year World Health Organisation project into effects of electromagnetic fields.
- **Standards and approvals bodies** - operator's licences require all equipment installed to be 'type approved' to national or European standards. Such specifications are laid down by the **European Telecommunications Standards Institute** (ETSI) and approvals are considered by the **British Approvals Board for Telecommunications** (BABT).
- **Local Authorities** have powers under the Town and Country Planning Act 1990 concerning planning approval for telecommunications masts.
- **NRPB, ICNIRP and other international advisory bodies** publish guidance on exposure limits. These are not enshrined in legislation *per se*, but form the basis on which equipment is approved prior to use.

As far as **base stations** are concerned, antennas operating at 800-900 MHz or at ~1800 MHz will both produce power densities in excess of guidelines, but only in the immediate vicinity. Power densities decline very rapidly and since both types of transmitters are usually mounted on rooftops or on towers, people at ground level (at least 15m from the antennae) typically receive exposures that are hundreds or thousands of times lower than the limits recommended by NRPB or ICNIRP.

Turning to the hand-held receivers, the concern here is that although these devices are low powered, the fact that they are held in close proximity to the head and neck may lead to localised absorption of energy by tissue in these areas, causing so-called 'hotspots'. It is not possible to directly measure the rate at which energy is absorbed by head tissues, and thus such concerns have to be investigated using computational modelling and measurements on 'phantoms' (physical models that are realistic representations of the main head tissues). One such UK study - the IBREHT[2] project developed such a computational model, and a series of physical 'phantoms' of the head, together with the sensitive probes needed to measure electric and magnetic fields.

The IBREHT computational model indicated that energy absorption rates in the human head would only exceed current NRPB guidelines with handsets producing mean radiated powers of more than ~4W at

2. The IBREHT - Interaction of the Body with the Radio Emissions from Handheld Transceivers - project was funded by the Engineering and Physical Sciences Research Council / Department of Trade and Industry (joint contribution £350,000) and 9 industrial partners (also jointly contributing £350,000). NRPB provided the scientific management of the project and published the final report.

900MHz and ~1.7W at 1800MHz. These results are in general agreement with those produced by measurements in phantoms - for instance the ICNIRP review notes one study that suggests limits of 3.2W and 2.2W (at 900 and 1800MHz respectively), below which the NRPB guidelines should not be exceeded. The same study also derived limits of 0.6W and 0.4W (900 and 1800MHz respectively) for not exceeding the stricter ICNIRP general public guidelines.

How do these figures relate to the power outputs from mobile telephones used in the UK? Unfortunately, this question is difficult to answer, since the power emitted by a handset varies greatly with the circumstances of use. For instance, digital phones adjust the power according to signal strength, so that one used in rural areas (i.e. a long way from a base station) may operate at a higher power than if used in an urban area. As noted previously, technical specifications for all mobile phone equipment used in the UK are set out by ETSI, which (*inter alia*) specifies **maximum** limits for the average radiated power outputs of the different types of handset. These vary from 0.6W for analogue TACS phones, through 0.25W for GSM, down to 0.125W for the latest digital (PCN) phones. **All are thus well within the limits that the computational models and phantom studies suggest are needed to meet the NRPB standards**.

With the stricter ICNIRP general public limits, however, there is less margin for error. Thus the maximum power output for a TACS phone operating at 800MHz is set at 0.6W by ETSI, exactly the same as the upper limit for compliance with ICNIRP suggested by phantom studies. However, phantom studies such as the IBREHT research represent the 'worst case scenario', where all the available power from the handset is radiated, whereas in practice this is unlikely to be the case. NRPB is thus confident that all mobile phones currently used in the UK comply with both sets of standards.

Scientific Uncertainty/ Research Priorities

While not disagreeing that equipment currently in use in the UK meets NRPB and probably ICNIRP guidelines, some scientists argue that the existing limits are based on preventing thermal effects and do not take into account the (albeit equivocal) suggestions from research that low doses of RF microwaves might cause other harmful effects. They also point to the differences between the national guidelines from NRPB and the lower ones from ICNIRP as underlining the degree of uncertainty involved in setting safety standards.

NRPB and other national and international bodies, however, emphasise the need to base standards on sound scientific evidence relating to established effects on human health, and point out that the research on non-thermal effects has yet to be scientifically validated (e.g. replicated). Such bodies thus see an urgent need for further research on non-thermal effects.

Box 4 RESEARCH PRIORITIES

Dosimetry/exposure systems: exposure systems for *in vitro* and *in vivo* experiments, exposure parameters, characterisation of tissue values of SAR (*in vivo*), use of exposure conditions that correspond to the use of mobile phones, human (volunteer) studies, and monitoring and control of environmental factors (e.g. external RF sources).

Biology: *in vitro* studies (effects of RF microwaves on membrane function and signalling pathways, on biochemical reactions at the gene and other levels, and on cell cycle and proliferation), *in vivo* studies in animals (effects of RF microwaves on genes/ chromosomes, on cancer, on the immune system and on the nervous system), and laboratory studies on humans (effects of acute exposure to handsets on volunteers, studies of people claiming neurological symptoms associated with mobile phones or transmitter bases, and research into sleep pattern disturbances).

Epidemiology: studies investigating links between exposure to RF microwaves and the risk of brain cancer in different countries, the risk of other types of cancer (acoustic neuroma, salivary gland tumours and leukaemia), cause-specific mortality and cancer incidence in a large (cohort) study.

Research priorities have been addressed recently by an Expert Group set up by the European Commission in 1996 (for which NRPB provided the Chairmanship and administration), comprising experts in a range of fields (e.g. biology, medicine, epidemiology, dosimetry, radiation protection and telecommunications) from 8 EU Member States. This Group made detailed research recommendations covering areas outlined in **Box 4.**

Technical 'Fixes'

The concerns above have led to some products being marketed to shield users from the RF emitted by mobile phones, as well as the development of a chip intended to minimise biological effects by rapidly fluctuating the phone signal. Currently the mobile phone industry (as represented by the Federation of Communication Services (FCS)) are dubious about the effectiveness of devices such as shields, pointing out that shielding the antennae of a digital phone will merely prompt it to increase the power output to try and restore signal strength. Another technical option would be to reduce the maximum power outputs specified by ETSI, although this would have implications for the number of base stations required, and also on the coverage of the various networks (particularly in rural areas). Finally, if future health research supports the need for lower exposure limits, the amount of energy absorbed by tissues in the head could be minimised by redesigning the phones and their antennas.