The Effects of Microwave Radiation From Telecommunication Base Stations

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Introduction

Network Rail have plans to roll out a GSM communications system throughout their network. Upon the announcement that a GSM base station and transmitter was to be located at Yeoford station, the whole community had deep concerns about the visual impact on the environment and on the effects of the transmitter on the health of those living nearby. Several people have asked me to write a discussion of the latest research on health problems associated with base stations. This is of particular concern to Devon people because of the highly publicised cancer clusters around the Orange transmitter in Crediton and the shared transmitter in Pennsylvania, Exeter.

Mobile phones and GSM in particular are relatively new technologies, so there are few long term epidemiological studies that show statistically significant results, that is where results are unlikely to be due to chance. However, there is a growing body of research and anecdotal evidence that should not be ignored.

This is not an exhaustive study. It is a review of some of the published literature on the effects of microwaves, radio waves (RF) and electo-magnetic fields (EMF). Evidence is presented that emissions from microwave base stations do have effects on those living nearby. Studies on animals that demonstrate possible mechanisms for those effects are also discussed. Evidence is also presented that indicates similar effects from long term low level exposure and short term higher level exposure. Most of the papers are from peer reviewed journals, where the work is scrutinised by other academics before being accepted for publication.

The GSM-R Railway Communications System

The GSM-R system is similar to other GSM microwave systems. It is based on two way radio communication between a mobile handset in the train and the nearest base station. Each base station can serve a line length of up to 4km. in each direction, dependent upon the topography. Information received from Network Rail indicates that the main beam's dispersion angle is between 25 and 65 degrees, dependent upon local topographic requirements. Commercial GSM base stations may have many transmitters to cover 360 degrees. Several GSM companies may share a particular mast, which increases the total microwave radiation emanating from that mast. There seems to be very little published literature on the effects of mast sharing. Network Rail have indicated that there are no plans to share masts with commercial GSM system providers, but there is evidence that the O2 company has applied for planning permission to share Network Rail masts and that Ultramast, (a subsidiary of Network Rail), is actively promoting the railway network as

suitable for shared communications masts. Commercial pressure and current instructions to local councils make it likely that planning permission for mast sharing may be granted.

The GSM-R system uses a carrier frequency close to 900MHz, with a frame repetition rate of 217Hz. The frames are transmitted in groups of 25, with the 26th frame missing, which results in additional low frequency wave pulsing of 8.34Hz, Hyland (2000). There is an additional pulsing at 2Hz in discontinuous transmission mode when there is no communication between transmitter and receiver. These frequencies correspond to signals within the human brain.

Safety Levels

In this country the relevant "safety" limit is laid down by the NRPB (National Radiological Protection Board) who have adopted the international (ICNIRP) maximum power standard of 0.4 mW/cm-sq for frequencies in the region of those used by GSM technology. This standard, although international, is not universally adopted. In Australia the limit is 0.2 mW/cm-sq, Switzerland 0.0042mW/cm-sq and Italy 0.01 mW/cm-sq (and regionally enforced standards of 0.0025 mW/cm-sq). The UK "safe" level of radiation is therefore 160 times higher (ie. less stringent) than the regional Italian level. The reason that our limit is much higher than other parts of the world is that in other countries these limits are based on possible effects from electric and magnetic fields, and the heating effects of energy transfer to water molecules. The NRPB guidelines are based on heating effects only (see below). The NRPB guidelines for exposure to electromagnetic fields (for example from high tension power lines) are similarly lax (1600 microtesla) compared with those in Italy (0.2 microtesla), Sweden (0.2 microtesla) and Australia (0.4 microtesla), (Henshaw (2002)).

The Effects of Microwave Emissions on Living Organisms

Water based animals (humans, birds, mammals) act effectively as aerials to electromagnetic waves. This is analogous to the effect of radio waves on a crystal radio receiver, generating minute electrical currents in the aerial. It is these currents that are believed to be responsible for the effects described in the scientific papers discussed below.

The effects are divided into heating and non-heating effects.

Heating Effects

The heating effect is identical to that seen in a microwave oven. The microwave energy is absorbed by the water content of food, which is why food gets hot and plates don't. Heating effects become insignificant when distance from a microwave transmitter exceeds a few metres. This is why exclusion zones around mobile phone base stations are relatively small. However a bird perching on a phone transmitter would feel the heating effect very quickly. (It is of interest that the British Trust for Ornithology is investigating the effects of base station emissions on urban bird populations.) The main danger from heating effects is in using a mobile phone receiver. There have been many recent studies on these effects, eg. Frey 1998, who reported on potential causes of headaches associated with mobile phone

use. Other studies have reported interrupted sleep, fatigue, warmth behind the ear and burning skin (Coghill (1998) cited by Trower (2001)). Mobile phone use is usually in short bursts of relatively high power emissions. This contrasts with exposure to base stations where emissions are of a much lower intensity but can be continuous.

Non-Heating Effects

Research on the effects of mobile communication technology is in its infancy, but the hazards of microwave, radio frequency (RF) and electromagnetic field (EMF) emissions on living systems have been known since the Second World War. The use of microwaves as a weapon has been exploited by the Russians and Americans. Simon Best (2001), writing about microwave crowd control weapons: "after 20 years of rumours and speculation the Pentagon has finally confirmed that it has developed a device as part of its joint non-lethal weapons programme …". He continues, "in the UK many of the women protestors at Greenham Common in the 1980s experienced symptoms that they attributed to being zapped by microwave weapons from the US base". There was a scandal when US Embassy personnel and dependants in Moscow had been showered with up to 18 $\mu W/cm^2$ of microwave radiation for up to 18 h/day as part of an espionage effort. There is evidence that two ambassadors developed leukaemia.

Many laboratory studies have looked at the effect of pulsed microwave radiation on rodents. They are simple to work with and can produce many generations in a short time. Most studies look at the short term effects, some of which have produced negative results (Chagnaud *et al.* (1999), Heikkinen *et al.* (2001)). Such studies are worthwhile in that they contribute to our total knowledge of the subject, but they only demonstrate that under a particular experimental regime, no effect was discovered. These should be viewed in the context of the many studies that show a significant result. For example:

Fesenko *et al.* (1999) reported that irradiation with pulsed microwaves (8.15-18 GHz, 1 Hz within, 1 microW/cm2) increases the cytotoxic activity of natural killer cells of rat spleen. In mice exposed for 24-72 h, the activity of natural killer cells increased by 130-150%, the increased level of activity persisting within 24 h after the cessation of treatment.

French *et al.* (1997) found that 835 MHz radiation at low power density may be affecting a signal transduction pathway involved in cell proliferation.

Changes to thymidine incorporation in rat brains have been induced by exposure to base station levels of GSM type waves (Stagg *et al.* (1997)).

Imaida *et al.* (1998) reported significant decreases in melatonin levels in rats when exposed to both 900 MHz and 1.5 GHz microwaves. They postulate that changes of serum melatonin levels may modify the development of preneoplastic lesions in the livers of rats so exposed.

The following article appeared in the New Scientist on 24/10/2002 reporting the effects of low level emissions (only 2.5 times higher than the NRPB safety level for base station emissions) on cancer cells:

Cancer cell study revives cellphone safety fears

The safety of cellphones has been brought into question once again by research that suggests radio waves from the devices could promote the growth of tumours. Paradoxically, the study suggests that the radiation makes tumours grow more aggressively by initially killing off cancer cells.

Cell biologist Fiorenzo Marinelli and his team at the National Research Council in Bologna, Italy, decided to investigate whether radio waves had any effect on leukaemia cells after previous studies indicated that the disease might be more common among mobile phone users. The life cycle of leukaemia cells is well understood, making it relatively easy to spot changes in behaviour.

The team exposed leukaemia cells in the lab to 900-megahertz radio waves at a power level of 1 milliwatt, and then looked at the activity of a gene that triggers cell suicide. Many European mobile networks operate at 900 megahertz, and maximum power outputs are typically 2 watts, although they regularly use only one-tenth of this power.

After 24 hours of continuous exposure to the radio waves, the suicide genes were turned on in far more leukaemia cells than in a control population that had not been exposed. What is more, 20 per cent more exposed cells had died than in the controls.

But after 48 hours exposure, the apparently lethal effect of the radiation went into reverse. Rather than more cells dying, Marinelli found that a survival mechanism kicked in. Three genes that trigger cells to multiply were turned on in a high proportion of the surviving cells, making them replicate ferociously. The cancer, although briefly beaten back, had become more aggressive.

Thus it may be seen that GSM emissions may promote cancerous growth.

The significance of these studies is that there was a biological change to tissue structure or function when exposed to non-heating levels of pulsed microwaves.

Field studies are more disturbing. Most studies before the advent of GSM technology relate to radio frequency (RF) transmitters. It is reasonable to include such studies in this review because GSM900 is close to the RF band and the observed effects are similar. Eg.

Kolodynski and Kolodynska (1996), who presented the results of experiments on school children living in the area of the Skrunda Radio Location Station (RLS) in Latvia. "*Motor function, memory and attention significantly differed between the exposed and control groups. Children living in front of the RLS had less developed memory and attention, their reaction time was slower and their neuromuscular apparatus endurance was decreased*."

Michelozzi *et al.* (1998) investigated a leukaemia cluster near a radio-transmitter in Rome. The leukaemia mortality within 3.5 km was significantly higher than expected. The risk declined with distance from the transmitter.

Dolk *et al.* (1997(i)) investigated a reported leukaemia and lymphoma cluster near a high-power FM/TV broadcast antenna at Sutton Coldfield in the UK. They found that the incidence of adult leukaemia and skin cancer was elevated within 2 km of the antenna.

Hocking *et al.* (1997) and Hocking *et al.* (2000) in Australia, who reported that "There was an association between proximity to the TV towers and decreased survival, among cases of childhood leukaemia".

Selvin *et al.* (1992) ran a statistical study of exposure to RF from the Sutra Tower (for radio and TV transmission) in the San Francisco City area. There was a large concentration of all childhood cancers, primarily brain tumour, within 1 km of the tower. Outside this there was a ring with low cancer rates and then a ring with higher cancer rates. This study ignored local topography, so the statistical fit between distance from the transmitter and cancer rate was poor.

Cherry (2000) re-analysed Selvin's data to find "*the spatial data when related to actual radial radiation exposure patterns forms significant linear dose-response relationships, with All Cancer and Brain Tumour having extremely significant dose-response relationships.*" This means that exposure was not only related to distance from the tower but also the topography of the land. There was a highly significant correlation between actual exposure to RF and cancer rates. Hillsides facing the tower showed more instance of disease than those facing away. This becomes obvious when viewed in graphical form (Figure 1).

As with laboratory studies, some epidemiological studies have not shown significant results eg. Dolk *et al.* (1977(ii)). Such papers are publicised by the mobile phone industry to back up their assertion that there is no "conclusive proof" of harmful biological effects from their products. However, in an important paper in the *The Lancet*, Rothman (2000) summarised the difficulties with this type of research:

> "individual exposure from base station exposure is difficult to assess … Buildings reflect and scatter the beam, the intensity of which varies over time according to the telephone traffic. The few studies to date of populations near microwave, radio, and television towers have produced no consistent finding(s) …, but these studies typically exhibit problems with exposure assessment or geography-related confounding. The epidemiological study of base-station exposure is a formidable problem."

Each study must therefore be looked at on its own merits. If a study does not show significant results, it means that evidence of effects was not discovered in that study. It does not mean that evidence from studies that show an effect should be discounted. Further studies, as outlined below, show that there is evidence from field studies on RF and GSM type emissions for the threat to the health of those close to the base stations or in the direct path of the beams to be taken seriously. Conclusive proof has been demanded by scientists defending their positions and decisions after they have pronounced the following to be safe: thalidomide; asbestos; BSE; smoking; sheep dip. Is there need to add GSM to the list?

Two studies (Santini and Santini (2001), Santini *et al.* (2002)) surveyed people living up to 300m from GSM base stations. There were statistically significant correlations between distance from the base stations and health problems. Tiredness up to 300m; headache, sleep disruption, "discomfort" up to 200m; depression, memory loss, dizziness, visual perturbations up to 100m. Women were more susceptible than men. They conclude that base stations should be sited more than 300m from dwellings.

The biological effect of proximity to a base station is reinforced by a study off fecundity in mice near a mobile phone "*antenna park*" Magras and Xenos (1997):

> "RF power densities between 168 nW/cm2 and 1053 nW/cm2 were measured. Twelve pairs of mice, divided in two groups, were placed in locations of different power densities and were repeatedly mated five times. One hundred eighteen newborns were collected. They were measured, weighed, and examined macro- and microscopically. A progressive decrease in the number of newborns per dam was observed, which ended in irreversible infertility. "

Of particular interest is a much cited study of cattle, Loscher and Kas (1998), which when kept close to a base station, recorded reduced milk yields, emaciation, spontaneous abortions, abnormal behaviour patterns, conjunctivitis, heart failure and still births. When cattle were moved away from the base station, their condition and milk yields improved. The severe symptoms reappeared when the cattle were moved back to their original field beside the base station. The symptoms only appeared when microwave transmitters were added to an existing television transmitter. Loscher and Kas also report the profound effects experienced by the farmer and his family since the microwave transmitters were installed. Similar cases of health effects induced by electromagnetic field exposure were cited. Loscher postulates that the effects are connected to changes in melatonin levels.

Other studies have shown the effects of RF and microwaves on melatonin secretion. Abelin (1999) looked at Adult Sleep Disturbance with RF exposure at Schwarzenburg, Switzerland. Alpeter *et al.* (1995) tested bovine salivary melatonin at the same location. Turning the transmitter off revealed significant rises in bovine melatonin and human sleep quality. The human subjects exposed to a mean RF signal of less than 0.1mW/cm^2 experienced highly significant sleep disturbance and reduced melatonin. Human melatonin increased significantly when the tower was turned off permanently. Cherry (2000), cites a further fourteen studies that show that EMR across the spectrum from ELF to RF/microwave reduces melatonin in people.

> "It is believed that during the daytime light going through our eyes passes a message to the pineal glands in the brain which slows down the production of melatonin. At night when no light goes through our eyes the production of melatonin is speeded up. Melatonin is believed to scavenge cancer cells and impurities in our bodies and boost the immune system…. microwave radiation is believed to act on the pineal gland and suppress the night-time melatonin to daytime levels; hence the good work of the melatonin at night will be restricted leading to suppression of the immune system."
>
> Trower (2001)

Its ability to inhibit the promotion of some types of cancer has been shown in animals and it has been shown to suppress the growth of breast cancer cells. So with reduced levels of melatonin, cancer will not be inhibited. Reduced levels of melatonin in the body have also been associated with depression. Similar symptoms have been demonstrated in cases of EMF exposure, Davis *et al.* (2001) and Levallois *et al.* (2001).

Other studies have shown disruption to sleep patterns. Mann and Roschke (1996) found changes to the pattern of rapid eye movement sleep:

> "… a REM suppressive effect with reduction of duration and percentage of REM sleep was found. Moreover, spectral analysis revealed qualitative alterations of the EEG signal during REM sleep with an increased spectral power density. Knowing the relevance of REM sleep for adequate information processing in the brain, especially concerning amnestic functions and learning processes, the results emphasize the necessity to carry out further investigations on the interaction of this type of electromagnetic fields and the human organism."

This is particularly disturbing because of its potential effect on cognitive response, and may explain the results of Kolodynski and Kolodynska (1996).

One common theme in epidemiological studies on health effects caused by RF and microwaves is headache. There has been a considerable body of research on the effects of emissions on the blood brain barrier (BBB). Headache is consistent with the effects of radiation on the dopamine-opiate system of the brain and permeability of the BBB, Frey (1994) and Frey (1998). The blood brain barrier protects the brain from toxins and allows toxins to be expelled from within the brain. The blood brain barrier is rather like a one way sieve. If the permeability is disrupted, toxins may affect the brain.

Other studies have shown effects on human resting blood pressure, Hyland (2000), which increased when exposed to RF. Hyland states that although the monitored field strength was higher than that which would be expected from a base station, the information content of the base station emissions is the same, and therefore "*these results are not irrelevant to any consideration associated with chronic exposure to base station radiation.*" Indeed there is evidence that RF and microwave effects are cumulative, so that prolonged exposure to low level emissions is as harmful as short term exposure to higher non-heating levels, Grigor'ev *et al.* (1995), Neshev NN, Kirilova EI (1996).

The papers cited above are just a few examples of the vast body of research on the effects of RF and microwave emissions. Further papers are cited by Hyland (2000) in a much cited paper in the The Lancet. Professor Hyland is one of the foremost experts in this field. Of particular concern is the 8.34Hz pulsing of GSM frame carriers which is within the range of human brain alpha waves. Their effect will be greatest in preadolescent children because the absorption of GSM waves is greatest in an object the size of a child's head. Any degradation of the immune system will also be most pronounced in children, where their systems are less robust than in adulthood. Hyland stresses the importance of animal studies where there can be no claim that measured symptoms are psychosomatic.

In 1999, Hyland made a submission to the Select Committee on Science and Technology (Appendix 15), commenting on the paucity of the current safety regulations and explaining some lack of experimental reproducibility*:*

> "Attention is drawn to the inadequacy of existing safety guide-lines governing the exposure of the public to radiation of the kind used in mobile telephony, and to the fact that the philosophy underlying the formulation of these guide-lines is fundamentally flawed….. Thereby excluded, however, are possible adverse health effects provoked by the ability of living organisms—and only living ones—to

respond in an non-thermal way to aspects of this radiation other than its intensity—specifically its frequency—both the microwave carrier and the lower frequency amplitude modulations that characterise the digital signals employed by the GSM system. The dependence of these effects on the "aliveness" of the organism necessarily means that they cannot enjoy the same degree of reproducibility, as do those that are not so dependent. This does not mean, however, that they do not exist, or that they should be excluded from the formulation of safety guidelines; indeed, the very real possibility that they might trigger adverse health effects must be seriously considered. The empirical fact that such radiation is known to have deleterious effects on both the neurological and immunological functioning of living organisms—including humans—is consistent with this possibility." [In the same way, not all people who smoke will die from cancer, but the risk of doing so is increased.]

Hyland continues with recommendations:

"Meanwhile, several courses of action can be identified that would go some way to ameliorating the (unnecessarily) hazardous situation currently obtaining in the case of base stations:

(i) Ensure that the field strengths to which the public is so indiscriminately and involuntarily exposed are kept well below the threshold values referred to above, which are 1,000 times lower than thermal levels, being of the order of microwatts/cm^2 (=μW/cm^2).

This will, of course, also lower the energy in each pulse, and can be achieved either by locating the antennae on much higher masts, or by introducing an exclusion zone, such as the one of 500 metres recommended (but not legally enforceable) by the Association of Local Governments of New South Wales (NSW), Australia; clearly, mast height can be traded against the extent of any exclusion zone.

It may be noted, in connection with NSW, that the safety limits there recommended (but again not legally enforceable) are the most stringent in the world—being 1,000 times lower than 1μW/cm^2. By comparison, the NRPB value of 3,300μW/cm^2 is one million times higher! Furthermore, the NRPB value is more than seven times higher than that (450μW/cm^2) of the International Commission on Non-Ionising Radiation Protection (ICNIRP [1]) who advise the World Health Organisation, whilst the EU has recently recommended a value of 10μW/cm^2.

(ii) Prevent localised areas of unnecessarily high fields by prohibiting the future erection of clusters of masts in the same vicinity, and requiring that existing clusters be replaced by a single tall mast serving the various companies. In considering Planning Applications, attention should be given to the proposed site of a mast in relation to the local topography, so as to ensure that in hilly terrain, for example, there are no homes, schools, hospitals or any other public buildings that are occupied for any appreciable period of time on a level with the emitting antennae. Furthermore, the antennae distribution on the mast should be such that the highest

possible emission in any direction (taking into account the maximum call traffic) is, in publicly accessible areas, well below the 1 microwatt/cm^2 threshold value.

Remove from the digital signal any low frequency (amplitude) modulations that fall in the range of the human brainwaves.

The Stewart Report

A group of independent experts led by Sir William Stewart has investigated possible health effects posed by mobile phone technology including base stations, on behalf of the Government. The group looked at recent research, took evidence from scientists, and listened to the views of the public at open meetings around the UK. Their report was published in May 2000.

Gaps in scientific knowledge led the Stewart Group to recommend a precautionary approach to the use of mobile phones and base stations until more research findings become available. They added that in some cases people's well-being may be adversely affected by insensitive siting of base stations.

Further research is now being set up to keep pace with developments in mobile phone technology. However, the largest experiment is the installation of GSM base stations around the country, using the general population as unwitting experimental subjects. It is clear from the above that evidence for the effects is emerging, but it may be many years before there is enough "proof" to overcome the commercial pressure for mobile communication. By that time it will be too late for many people.

How Does This Affect Yeoford

Evidence is presented above that there are measurable effects from GSM base stations at distances of 300m. John E Moulder (Professor of Radiation Oncology, Medical College of Wisconsin) has stated on his web site that "*the ground level power density does not drop with distance in any regular manner until you get at least several hundred meters away from a base station. Horizontal distance from a base station is less of a factor in ground level power density than antenna height, the antenna power and antenna pattern*". Certainly a taller mast creates lower emissions at ground level. At the proposed location, the dwellings clustered around the station will be within this distance. A significant part of the southern half of the village will be within 500m (the minimum exclusion zone recommended in Australia). There are locations between Yeoford and Salmonhutch where a mast can be located at more than 500m from a dwelling and greater distances from dwellings within the 25 degree beam. If Network Rail owns suitable land at these locations, or takes steps to acquire it, the problem may be solved. If Network Rail continues with their plan to allow 3G phone operators to use their masts, the whole of Yeoford would become an "electrosmog" hot spot if either of the currently proposed locations is used. For the sake of our children, we need to ensure that any emissions are below the threshold of reported biological effects. Microwaves radiate from transmitters over a wide area: from 3 to 9 miles. However, the radiation drops off quickly after 500-600m., and distance is the ally of safety. If taller masts allow the base

stations to be sited further away from habitation, the reduced visual amenity within the landscape is far outweighed by the reduced risk to health.

Conclusions:

Over the last ten years more than 40 peer reviewed studies have shown adverse biological or human health effects specifically from cell phone, base station and RF radiation. It is reasonable to group RF and microwave research because the effects are the same. These research results to date clearly show that cell phones and cell phone radiation are a strong risk factor for all of the adverse health effects identified for electromagnetic radiation because they share the same biological mechanisms. The greatest risk is to cell phone users because of the high exposure to their heads and the great sensitivity of brain tissue and brain processes, but there is also risk from long term low level exposure, as from base stations. These effects include

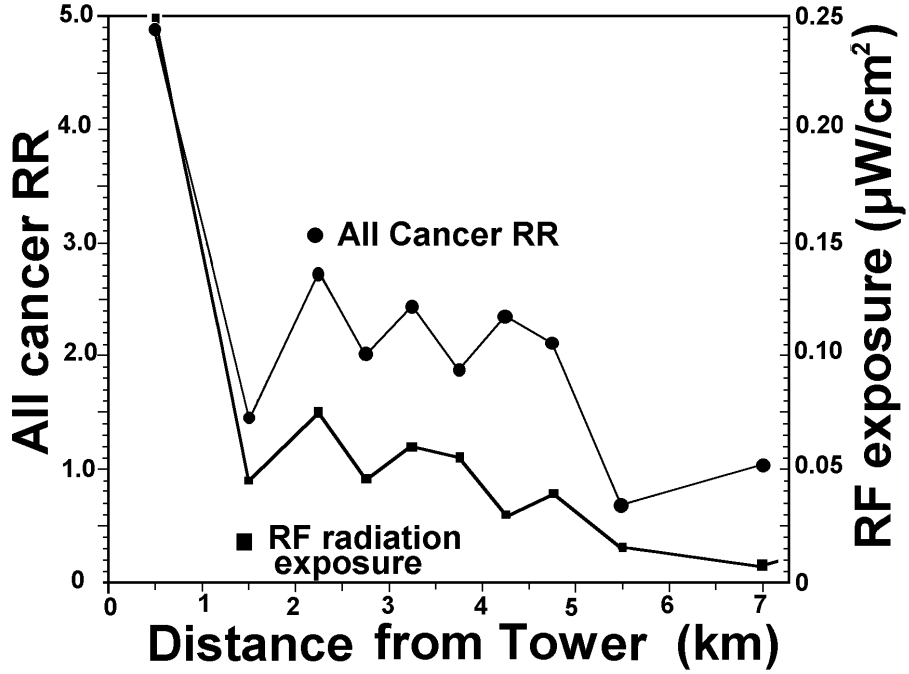
- Cancer, especially brain tumour and leukaemia, but all other cancers also.
- Cardiovascular problems, fluctuations in blood pressure.
- Neurological effects, including sleep disturbance, learning difficulties, depression, headache.
- Reproductive effects, especially miscarriage have been shown in rodents and cattle.
- Viral and infectious diseases because of reduce immune system competency as associated with reduced melatonin.

Dr Barry Trower in his report to the Police Federation summarised the effects:

> "If you think of a cell in our body, be it a brain cell, bone cell etc, as having a positive and negative charge on the outside and the inside similar to a battery the difference in these charges will draw the chemical into the cell or draw poisonous substances out of the cell. If the charge is changed on the outside of the cell, then necessary chemicals may not go in or poisonous chemicals may not go out. An analogy to that would be – think of your house as a cell in your body. Essential things like food, water and fuel come into the house and poisonous things like waste and gases leave the house. In fact a house is very similar in many ways to a cell in our body. Now, if we had a blockage and waste could not leave the house or sometimes food or electricity did not come into the house, over a short period of time we would survive this, but continual disruption over many years will probably have a knock-on effect on the health of the inhabitants particularly if they are young or frail. This is my explanation of how electromagnetic waves affect our cells….. When you suppress the immune system, you tend to have more colds, more coughs, longer colds, longer coughs, longer illnesses, depression, anxiety, or taken to its ultimate – leukaemia."
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> Professor Lawrie Challis, the new chairman of the expert Stewart Committee, said in a recent interview with the Exeter Express and Echo: "*We cannot say there is no risk. You could never say that. All you can do is take measures to reduce those risks.*

"The Government doesn't want to hear that message. They want us to say that masts are completely safe and aren't dangerous, but we can't say that."

Figure 1: The radial All Cancer Risk Ratio and the mean residential RF exposure as given in Table 15. Following a complex radial pattern shows a causal effect. (After Cherry 2000)



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