What Does the Research Tell Us About the Risk of Electromagnetic Radiation (EMR)?

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Abstract

The current regulation of the communications industry raises suspicion of the setting of Human Exposure limits. The question of conflict of interest can give bias in the setting of the radiation protection reference levels.

The Electromagnetic Radiation (EMR) Spectrum in the range from 3 kilohertz (kHz) to 300 gigahertz (GHz) is used for communications.

Bio-effect Research conducted in the area of radiofrequencies typically includes:

- *in-vivo* small animal studies;
- *in-vitro* studies;
- small and large statistical studies of epidemiological groups of specific diseases. (e.g. such as patients with various brain tumours, breast cancer etc.);
- clinical studies involving high levels of EMR exposure to workers (e.g. communication workers, medical MRI operators, radar workers in defence etc.);
- ecological epidemiological studies around mobile phone base stations and broadcast antennas;
- Digital Enhanced Cordless Telecommunications (DECT) cordless devices (phones & monitors).

ORSAA undertook an independent review of the research data using a novel classification system. The biological effects were assigned to metadata and stored in a relational database, which enable the cross-referencing of information as well as providing the basis for future analysis. Besides the novel classification assessment, this database also encompasses the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) classification criteria and the Bradford Hill Criteria as part of the assessment system. The research period encompasses a subset of studies performed from 2000-2016 and adds to the data of ARPANSA report Technical Report Series (TRS) 164. Some very interesting trends are revealed.

Key Words

Electromagnetic Radiation, EMR, EME, EMR, RF, Microwaves, WiFi, Mobile phones, Health, Cancer

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1. Introduction

The **Oceania Radiofrequency Scientific Advisory Association** (ORSAA) [www.orsaa.org] decided to conduct its own independent review of the scientific literature and to categorise the information in a relational database so that data could be easily retrieved, sorted and analysed.

Electromagnetic Radiation (EMR) encompasses the frequency bands shown in Table 1 below.

Table 1 Frequency Bands

Frequency Range (Hz)	Wave Length Range (m)	Description	Detailed Abbrev.	General Abbrev.
3 Hz- 30 Hz	100.000 km - 10.000 km	Extremely Low Frequency	ELF	ELF
30 Hz-300 Hz	10.000 km - 1.000 km	Super Low Frequency	SLF	
300 Hz-3 kHz	1.000 km - 100 km	Ultra Low Frequency	ULF	
3 kHz-30 kHz	100 km - 10 km	Very Low Frequency	VLF	VLF
30 kHz-300 kHz	10 km - 1 km	Low Frequency	LF	
300 kHz-3 MHz	1 km - 100 m	Medium Frequency	MF	
3 MHz-30 MHz	100 m - 10 m	High Frequency	HF	RF
30 MHz-300 MHz	10 m - 1 m	Very High Frequency	VHF	
300 MHz-3 GHz	1 m - 10 cm	Ultra High Frequency	UHF	RF or MW
3 GHz - 30 GHz	10 cm - 1 cm	Super High Frequency	SHF	

WHO definition of ELF is (3-30 Hz) | RF=Radio-frequency and MW=Microwave

The main focus of EMR health studies since 1990 has been towards the 50- 60 Hz ELF band used by commercial electricity power providers. High voltage power line studies and childhood leukaemia were the health research focus in the 1980's and 90's. VHF and HF radio frequency bands used by commercial TV broadcaster towers and cancer clusters near these broadcast towers were another focus for epidemiological studies in the last two decades. The UHF frequency bands (microwave bands) were not really exploited by the mobile communication companies until the 1990's and saturation was not achieved until the 2000's.

Figure 1 below illustrates the rapidly increasing use of the EMR spectrum over a number of decades [1]. EMR is now one of the major sources of pollution together with air pollution, water pollution and noise.

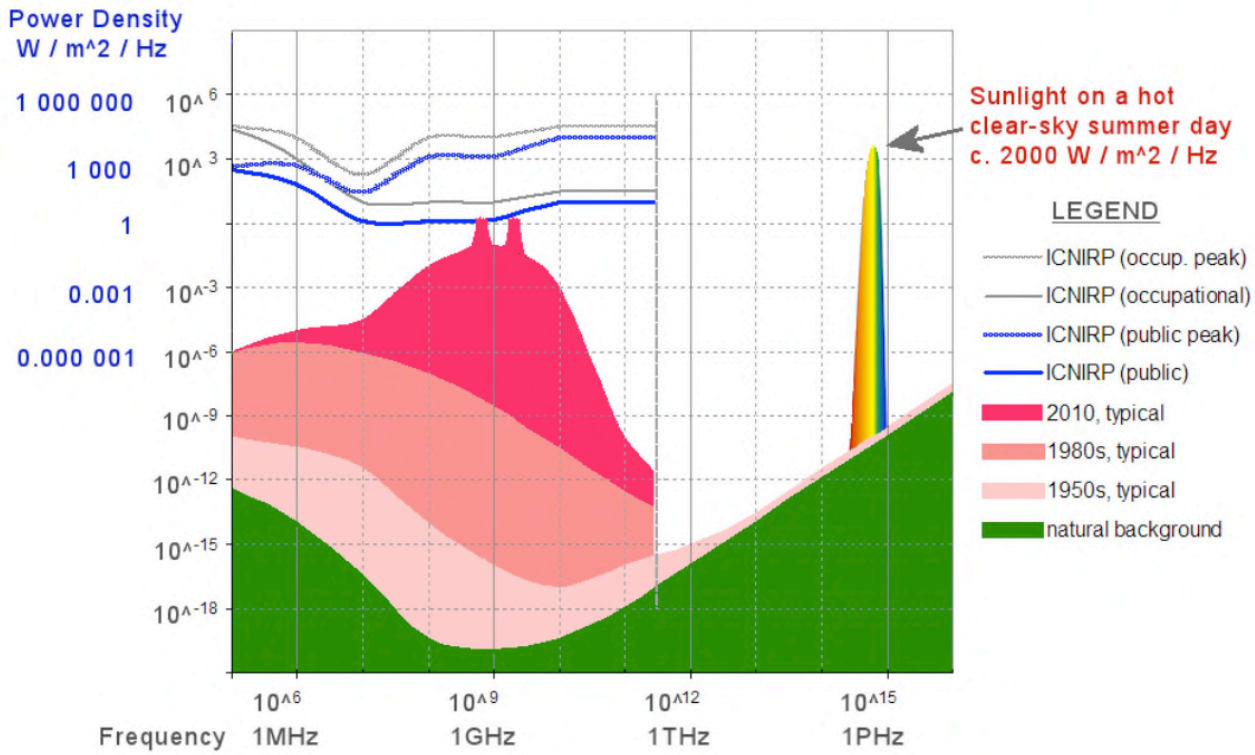

Figure 1 Increasing EMR spectrum use

Scientists have only recently begun to direct their attention to radiation emitted from Wi-Fi in the latter half of the first decade of the new 21st-century. The use of mobile phones and the close proximity to the brain has become a major focus of many recent research studies due to the extensive proliferation of these devices around the globe. The use of these microwave frequencies by mobile phones has as a consequence directly led to an increase in radiation levels around mobile phone base stations (MPBS) due to rising call and data volumes. With these increased levels of radiation exposure, the spotlight has been turned to population groups living in close proximity to MPBS as common symptoms are being reported, which can include headaches, tinnitus, sleeping problems, cognitive and behavioural effects etc. The recognition that people at home and work were being exposed to higher and higher intensities meant that peoples' health and well-being might also be affected. More recently with the rapid pace of technological advances, the types of frequencies and modulation patterns used by these communication devices continually evolves and has meant that earlier studies based on analogue signals have become less relevant as they have been largely replaced by digital pulsed signals.

2. Database Design

The two main sources used by ORSAA for accessing studies relating to non-ionising radiation (specifically ELF to RF frequencies) are PubMed and EMR-Portal. EMR-portal often provides additional details including the research aim and experimental method; something that is generally missing from the "abstract only" listing that is typically posted on PubMed.

Authors provide in their case studies or experiments on animals detailed information which is often presented as free flowing text or data in tables with a large number of unsearchable fields buried within. PubMed makes no attempt to categorise this information as it simply reproduces the study abstract. EMR-portal on the other hand often extracts the most important information and summarise it for the reader. We

believed that a simple screening tool to capture the author's important conclusions would be useful in helping to categorise the research findings. A simple overarching classification as to outcomes of the research was used as shown in Table 2.

Table 2 Simple Classification of Peer-Reviewed Paper Outcomes.

Result	Selection Criteria	Comment
Effect	Author highlights effect(s) in conclusions.	Effects were categorised as shown in Figure 4. Effects do not necessarily mean a health effect.
No Effect	Author sees no effect from experiment.	
Uncertain Effect	Author does not report clearly defined outcomes or is unsure of outcomes and qualifies conclusions.	These papers in the discussion and conclusions were read by a number of independent reviewers to ensure correct classification.
Non-Experimental Supporting Study (NESS)	These articles although of general interest have no experimentally derived data (e.g. standards documents or measurement studies or supporting information of national disease statistics).	
Effect Positive	An effect that have an unexpected positive effect	Only 8 papers in this category have been found at this time but may change as studies are being continually added to the database.

2.1. Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) Classification

Each paper stored in the ORSAA database was classified using a system adopted from ARPANSA's Technical Report Series (TRS) 164 [2]. This classification scheme has been further enhanced by the addition of extra fields to indicate whether the study was an animal ***in-vivo/in-vitro*** study as opposed to human study. The animal meta-tag allows for the selection of animal studies only. We have also added to the epidemiological studies an extra field to indicate if the study had been prospectively designed. Prospective design is a longitudinal cohort study that follows over time a group of similar individuals, for example brain cancer patients, who differ with respect to certain factors under study, to determine how these factors relate to disease development and health outcomes. Short-term epidemiological studies particularly with the study of long latency diseases, like brain cancer, we believe have limited value. We have also added another searchable field to indicate if the study was a meta-analysis study. Meta-analysis studies perform a systematic review and evaluation of multiple related scientific epidemiological studies to develop an overall conclusion.

We have also included a field to indicate whether a selected paper has been referenced by ARPANSA in their technical reports or monthly EMR literature research surveys. The funding source can be listed if known. We have noted that there are some major problems with funding declarations because they are often not disclosed [3]. The actual database screen is shown below in Figure 2.

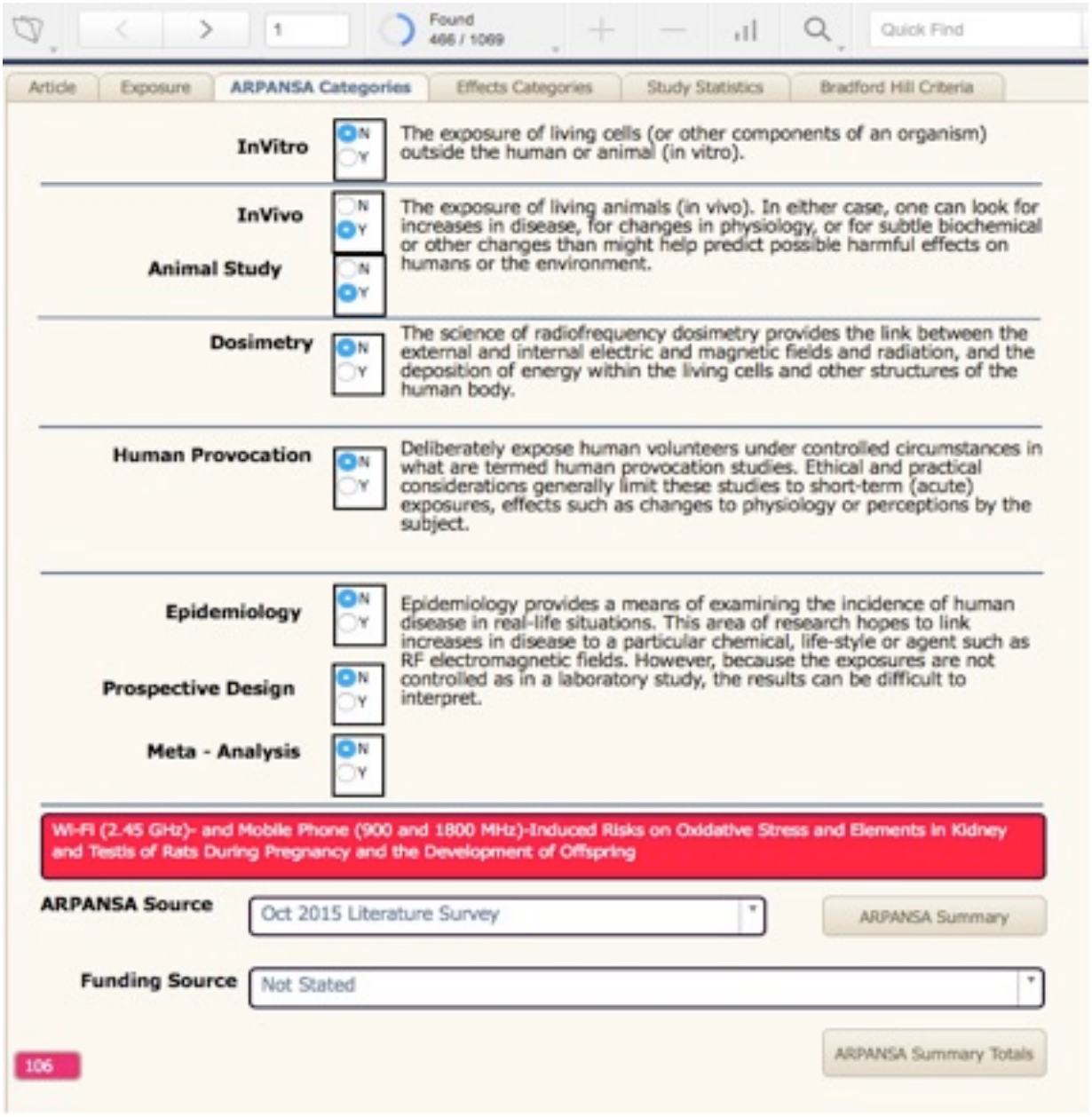

Figure 2 ARPANSA Categories – Actual data entry screen

2.2. Exposure Categories and Exposure Parameters

Each paper was classified into frequency of exposure categories as shown below in **Table 3**. Note that the frequency categories shown in **Table 1** are included.

Table 3 Exposure categories used in Database lookup table.

Abbreviation	Frequency band	Usage
ELF (3 Hz-100 Hz) studies	Extremely Low Frequency	Power Lines and domestic power. Magnetic field interaction with body
SLF (30 Hz-300 Hz) studies	Super Low Frequency	Radar & satellite communications
ULF (300 Hz-3 kHz) studies	Ultra Low Frequency	
VLF (3 kHz-30 kHz) studies	Very Low Frequency	

LF (30 kHz-300 kHz) studies	Low Frequency	
MF (300 kHz-3 MHz) studies	Medium Frequency	Radio stations
HF (3 MHz-30 MHz) studies	High Frequency	
VHF (30 MHz-300 MHz) studies	Very High Frequency	
UHF (300 MHz-3 GHz) studies	Ultra High Frequency	Microwave, Wi-Fi, Mobile Phones, DECT phones Cordless Devices, Bluetooth
SHF (3 GHz - 60 GHz) studies	Super High Frequency	
Categories with wider frequency range		
ELF - VHF (3Hz - 300 MHz) studies	ELF - VHF Frequency	
ELF- MF (3Hz - 3MHz) studies	ELF - MF Frequency	
ELF - VHF (3Hz - 300 MHz) Ecological	ELF - VHF Frequency	Broadcast towers (Radio / TV)
ELF - SHF (3 Hz - 60 GHz) workers	ELF - SHF Frequency	Power line, Welders, Plastic welders and communication workers
ELF - UHF (3 Hz - 3 GHz) workers	ELF - UHF Frequency	Power line, Welders, Plastic welders and communication workers
HF - VHF (3 MHz - 300 MHz) Ecological	HF - SHF Frequency	Broadcast towers (Radio / TV)
VHF - UHF (30 MHz - 3 GHz) studies	VHF - UHF Frequency	
VHF to SHF (30 MHz - 60 GHz) workers	VHF - SHF Frequency	
UHF (300 MHz-3 GHz) Ecological studies	Ultra High Frequency	Base Stations
UHF - SHF (300 MHz-60 GHz) studies	ULF - SHF Frequency	
UHF 300 MHz-3 GHz) workers	Ultra High Frequency	
WSMF studies	Weak Static Magnetic Fields	
Microwave - No Specific Frequency	MW	
Measurement Studies		
Standards, Regulations and Policies		
Supporting unrelated study - Non EMR study		

A detailed exposure screen is provided (Figure 3) in which the experimental data can be entered. Often a research paper might record a number of separate experiments on animals at different exposure frequencies, SAR ratings or power densities, which can be individually captured. Furthermore, the EMR exposure may be performed for different periods and durations. Studies may include **p-value** [4] for statistical testing of results and these values can be recorded. A small **p-value** (typically ≤ 0.05) indicates statically significant evidence against the null hypothesis, giving confidence that the observed effect is unlikely to be due to chance.

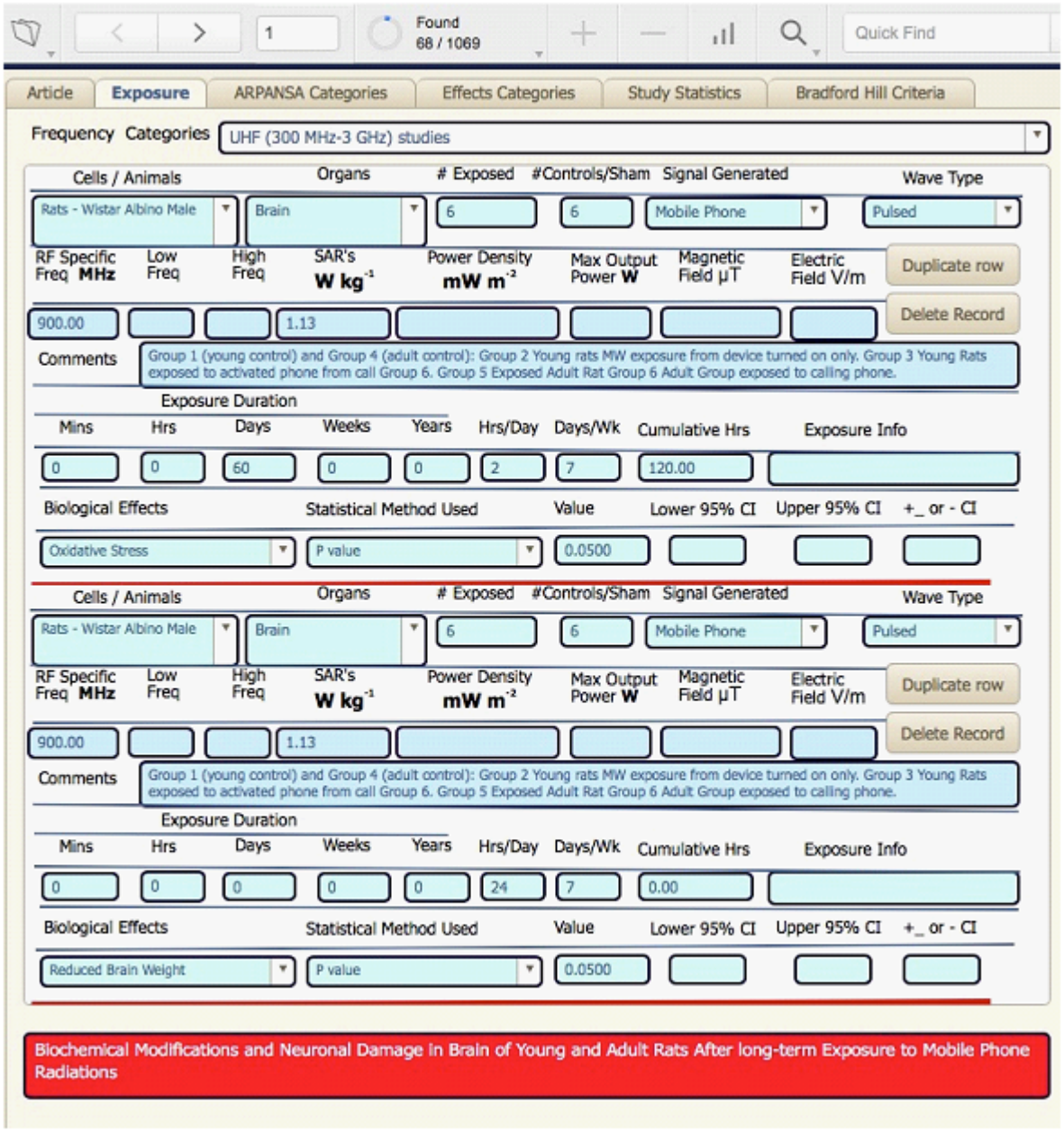

Figure 3 Exposure Details – actual data entry screen

2.3. Effects of Electromagnetic Radiation (EMR)

The most commonly reported **effects** in reviewed studies are categorised as shown below in **Figure 4**. Provision is provided to capture additional effects that are not covered in the defined list using free text (multiple effects can be added but must be separated by commas). Multiple effects can be selected with the Y/N radio buttons. Only effects that the study authors felt were statistically significant (typically this is represented by findings with a p-value ≤ 0.05) are captured here.

Figure 4 Effects categories – actual data entry screen

This categorisation allows for searching individual effects or combinations thereof. The search engine allows for "AND" and "OR" searches.

2.4. Statistical Summaries from Epidemiological Studies

The statistical information associated with epidemiological studies can be recorded as shown below in Figure 5. The Odds Ratio (OR) [5] and the associated 95% confidence intervals can be entered. Other statistical parameters like Relative Risk (RR) [6] and p-value are also available. Comprehensive search functionality is provided, for example, it is possible to select only those epidemiological studies with an "OR greater than 1 and the “Lower Confidence” level also greater than 1.

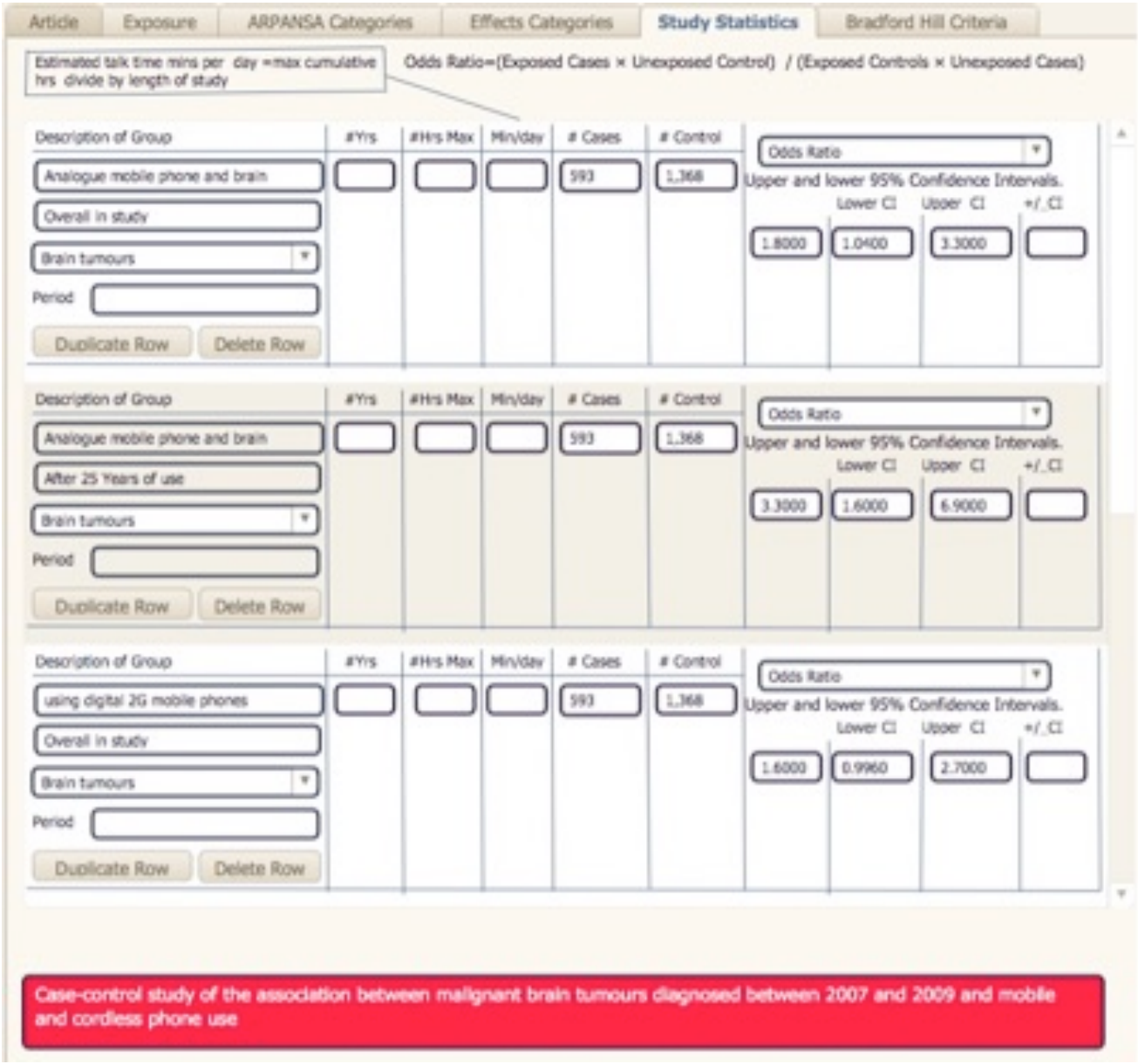

Figure 5 . Studies Statistics - actual data entry screen

2.5. Bradford Hill Criteria on Causation

Bradford Hill [7] criteria that are satisfied by this study can also be entered. Hill asked, “In what circumstances can [one] pass from [an] observed *association* to a verdict of *causation*?” He proceeded to propose nine “aspects of association” for evaluating traditional epidemiologic data. In the case of EMR, the analogue criterion is not relevant. Chemical substances that have similar structure can be used as analogues effects resulting in similar diseases being developed. As an example, analogous mechanistic hypothesis testing has been conducted on carbon nanotubes using the extensive literature on the mechanistic toxicity of asbestos fibers. Models based on molecular structure and physical–chemical characteristics such as aspect ratio predict a mechanism of action similar to that of asbestos [8].

EMR has no other similar analogues in adjacent parts of the electromagnetic spectrum. Therefore, only eight criteria are considered when dealing with EMR radiation [9].

Swaen G and van Amelsvoort L [10] examined 159 known carcinogenic agents and the Bradford Hill model correctly predicted 130 of the 159 (81.8%) agents as carcinogenic agents and is now widely accepted as a methodology for selection of potentially carcinogenic agents. If 6 of 9 criteria are met, then this is taken to be strong grounds for causation.

The criteria of strength, plausibility of the association and experimental evidence were the three criteria with the largest impact.

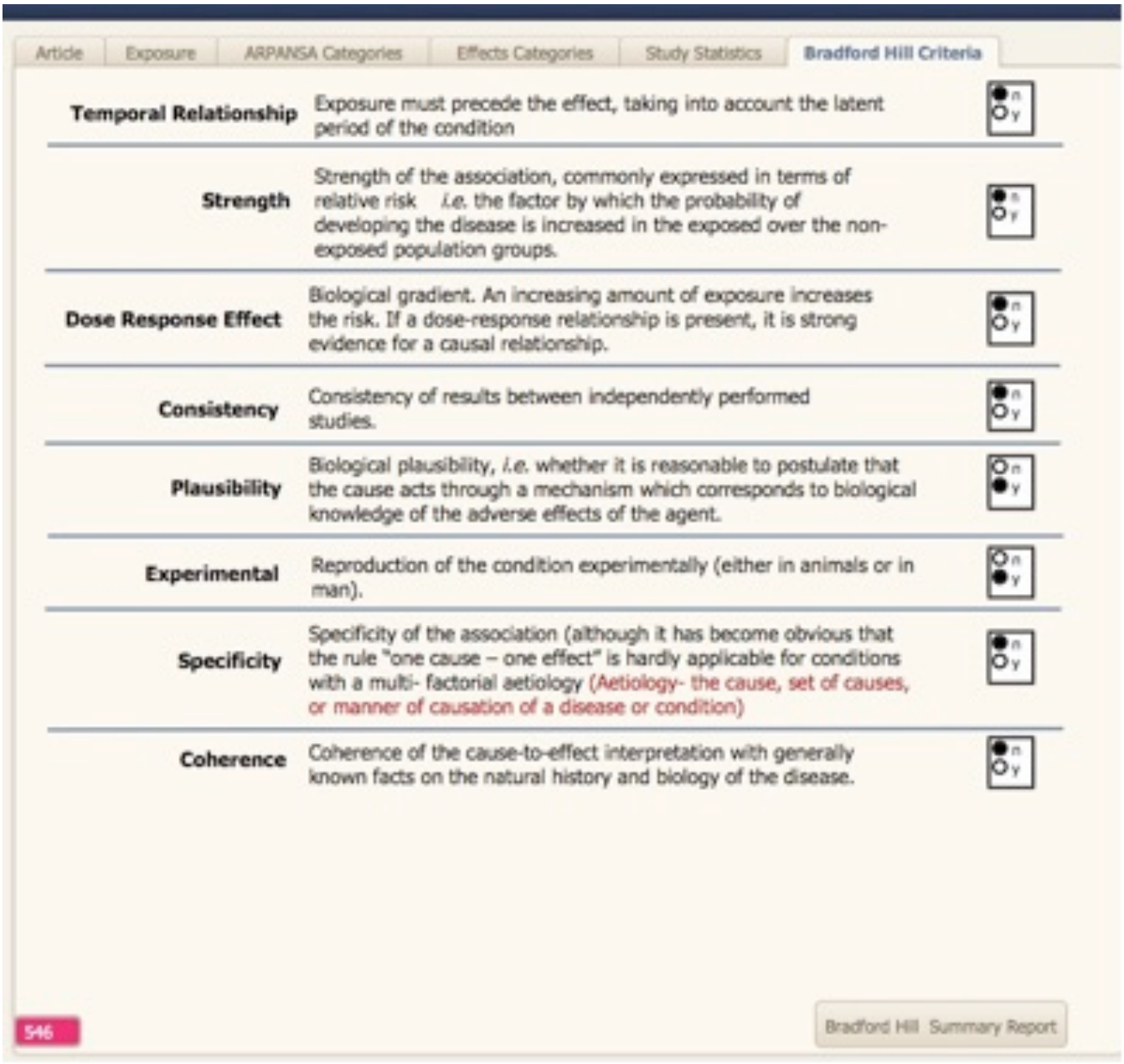

Figure 6 Bradford Hill Criteria - Actual data entry Screen

3. Summaries from All Studies

Firstly, we can examine the collection of 1070 papers (as of Aug 2016) currently in the database in terms of Effect/No Effect/Uncertain Effect as shown in Table 4.

Table 4 Number of Scientific papers that are in each category

	Effect		No Effect		Uncertain Effect		NESS	Positive Effects	Totals
	Animal Studies	Non-Animal	Animal Studies	Non-Animal	Animal Studies	Non-Animal			
Number	151	290	20	182	10	120	288	8	1070
Totals	[441]		[202]		[130]				
%	14%	27%	2%	17%	1%	11%			1
%	41%		19%		12%		27%	1%	100%

Table 4 contains 311 references from ARPANSA's Report "Technical Report Series (TRS) 164" and all the EMR literature survey reviews from January 2012 to March 2016 accounting for a sum total of 776 studies. Papers referenced in the TRS 164 report only contains references to epidemiological studies. Unfortunately, the ***in-vivo, in-vitro*** and **provocation** studies were not sighted in the references section of TRS 164. Some 61 papers are referenced in both TRS 164 and the EMR monthly literature surveys.

In-vivo non-animal studies are mainly human male volunteers (i.e. sperm testing) or human female volunteers (foetal and neonatal exposure) and some blood or saliva testing from provocation studies along with EEG or ECG testing. Table 5 shows the ARPANSA subset of the data provided in Table 4.

Table 5 Number of papers that are in each category from ARPANSA references

Source	Effect #		No Effect #		Uncertain Effect (#)		NESS	Positive Effects	Sub-total
	Animal Studies	Non-Animal	Animal Studies	Non-Animal	Animal Studies	Non-Animal			
TRS 164	0	117	0	69	0	66	60	0	311
EMR literature survey	45	79	16	114	8	46	154	3	465
Totals	45	195	16	183	8	113	214	3	776
	5.8%	25.1%	2.1%	23.5%	1.0%	14.5%			
Total (%)	31.0%		25.5%		15.5%		27.5%	0.5%	100%

There are always going to be accusations of "cherry-picking" data but Table 5 does not contain all the references used in TRS 164. ARPANSA claims to have a database of 1300 articles but these could not be found in the available ARPANSA literature.

What is clear is that there are more papers that show "Effects" than "No Effect". Both Table 4 and Table 5 do agree somewhat to the percentage of "Uncertain Effects" and the number of Non-Experimental Supporting Studies (NESS). Approximately 30% of all the literature on this subject doesn't contain any experimental data but are reviews of existing information, or standards documents, or measurement studies or supporting information of national disease statistics.

As the ***In-Vivo / In-Vitro*** studies and **Provocation** studies investigated by the study authors were not referenced in the TRS 164 report the actual number of animal studies could not be reflected in the table above.

3.1. Animal Studies (in-vivo)

The animal experiments are very varied and can be categorised into studies involving various frequencies as shown in Table 6 below. The focus of animal studies has typically been on mobile phone and Wi-Fi frequencies.

The animals used in experiments are typically rats and mice with the occasional hamsters and quail eggs being used. Larger animals such as primates or pigs have not been commonly used as we suspect ethics approval is more difficult to obtain. Life span might also be an issue with larger animals when you wish to study hereditary factors. However, some limited primate experiments have been performed showing neurological effects following exposure of monkeys to acute and chronic exposures [11].

Sometimes animal studies might involve ***in-vitro*** irradiation of cells before injecting in the host animal. It can be seen that the variety of exposures are often compared with other studies and only on a limited number of occasions are their repeated studies performed to exactly the same experimental protocols. Typically, new studies (original research) are far more likely to receive funding support than a repeated study.

Table 6 Number of Scientific papers that are in each exposure category for in-vivo studies

Frequency Category	Effect	No-Effect	Uncertain Effect	Comment
ELF - UHF (3Hz - 3GHz)	3			
ELF (3 Hz-100 Hz)	14			Mainly 50/60 Hz frequency range
ELF - VHF (3Hz - 300 MHz)	1			
ELF - VHF (3Hz - 300 MHz) Ecological	1			
ELF - SHF (3 Hz - 60 GHz) Ecological	1			
ELF - SHF (3 Hz - 60 GHz) workers	5			
ELF- MF (3Hz - 3MHz)	2			
VLF (3 kHz-30 kHz)	1			
LF (30 kHz-300 kHz)	1			
UHF - SHF (300 MHz- 60 GHz)	4			
UHF (300 MHz-3 GHz) Ecological	1			
UHF (300 MHz-3 GHz)	146	10	3	Frequency band used for communications
SHF (3 GHz - 60 GHz)	2			
Microwave - No Specific Frequency	4			
Weak Static Magnetic Fields (WSMF)			1	
Totals	186	10	4	

The numbers of **animal *in-vivo*** studies that show effect are 132 out of 186.

Figure 7 below shows the number of papers in our database that indicate certain categories of biological effects with the majority being found in the following areas:

- Oxidative Stress/ ROS/ Super Oxides/Free Radicals/Lipid Peroxidation
- Altered Enzyme Activity/Protein Damage/Altered Protein Levels
- Biochemical changes
- Cell Irregularities/ Cell Damage/Morphological changes
- DNA Damage/ Mutagenic/Genotoxic

Find Search Summary Totals

Peer Reviewed Studies Showing Biological Effects — **Number of records used :** 186

Auditory Dysfunction / Hearing loss / Tinnitus	3	Apoptosis (Programmed Cell Death)	15	Brain Tumours	0
Blood Brain Barrier Permeability Changes	9	Breast Cancer	1	Cellular Stress	6
Brain Development / Neuro Degeneration	10	Biochemical Changes	49	EEG changes / Brain Waves	6
Neuro Behavioural Effect / Cognitive Effects	22	Cell Irregularities/ Damage/ Morphological Changes	43	Effects on Mitochondria	9
Calcium Influx / Efflux	1	Fatigue	1	Altered Enzyme Activity / Protein Levels / Protein Damage	50
Circadian Rhythm Disruption	7	Altered Gene Expression	23	Headaches/Migraines	2
DNA Damage / Mutagenic / Genotoxic	28	Altered Glucose Metabolism	1	Inflammation	7
Endocrine / Hormone Effects	16	Cardiovascular Effects	4	Hepatic Effects (Liver)	7
Miscarriage / Spontaneous Abortion / Foetus Resorption	0	Immune System Effects	5	Impaired / Reduced Healing/ Bone Density Changes	2
Memory Impairment	14	Oxidative Stress / ROS/ Free Radicals	43	Speech Impairment	0
Sperm /Testicular Effects	19	Sleep Effects	6	Haematological Effects	2
Tumour Promotion	3	Glioma	0	Meningioma	0
Acoustic Neuroma (Vestibular Schwannoma)	1	Visual Disturbances/ Ocular Effects	2	Autism	2
Leukemia	1	Parotid Gland Malignancy	0	Neoplasis/ Hyperplasia (Abnormal Tissue Growth)	0
Depression	1	Induced Adaptive Response	2	Dizziness / Vertigo / Vestibular Effects	1

Figure 7 Summary of Biological Effects

In order to correctly interpret these effect findings, physiological expertise (endocrinologist or immunologist) would be recommended.'

3.2. Cell Studies (in-vitro)

The papers in the ***in-vitro*** category are summarised below in Table 7.

Table 7 Number of scientific papers that are in *in-vitro* category

Effect #			No Effect #		Uncertain Effect #	
Animal Studies	Human	Plant	Animal Studies	Human	Animal Studies	Human
19	37	1	2	10	3	4

The 37 human studies have been conducted on sperm samples, breast cells, hippocampal cells, different types of blood cells, protein, dermal, mitochondrial DNA, mucosa, brain tumour and cancerous cells.

Figure 8 show the categorisation of biological effects for the 37 papers that indicate effect on human cells. The most numerous categories are:

- Oxidative Stress/ ROS/ Super Oxides/Free Radicals Lipid Peroxidation
- Altered Enzyme Activity/Protein Damage/Altered Protein Levels
- Biochemical changes
- Cell Irregularities/ Cell Damage/Morphological change
- Sperm effects

Figure 8 Summaries of Biological Effects (Human Cells)

Interestingly, this shows agreement with the categories prominent for the ***in-vivo*** experiments.

By far the most interesting experiment was with low power Radiofrequency Implanted Devices (RFID) in the 100 to 200 kHz range used to treat cancer patients. RFID implants in patients and laboratory experiments show that cancerous cell development can be impeded and gives prospects for a new use in radiotherapy [12].

3.3. Epidemiological Studies

Epidemiological studies can be divided into short-term (less than 4 years) and long-term studies. Epidemiological studies that are designed with longer-term follow up of a cohort are referred to as studies that have **Prospective Design**. A prospective designed study looks for outcomes, such as the development of a disease, during the study period and relates this to other factors such as suspected risk or protection factor(s). These types of studies usually involve taking a cohort of subjects and watching them over a long period. Lung cancer studies amongst smokers followed people for 30 years to test the predicted incidence rates [13].

Often the studies combine a number of technologies into the one study, for example mobile phones and cordless (DECT) phones, but there can be other confounders, such as a large number of participants might have an allergic reaction to other chemicals that might not be absent from the control group.

Epidemiological studies associated with mobile phones show about equal studies between "Effect" and "No Effect" About 40% of the studies are short-term studies and prospective design was absent. Most of these studies are flawed in some respects [14].

However, just assessing brain cancer studies can be misleading as shown by Dobes [15] as it is specific brain cancer types like Glioblastoma Multiforme (GBM) that are associated with mobile phone usage and may not be evident by simply looking at brain cancer as a whole because there are approximately 130 different types of brain cancers [16]. Of the 32 association studies that show a statistically significant risk, 9 are associated with GBM. These studies showed increased risk with call time, particularly for those users with call durations of at least one hour per day. There were 31 studies that show no association but the user groups investigated were more casual users.

Table 8 Epidemiological Studies by Exposure Category

Study type / frequency category	Effect		No Effect		Uncertain Effects
	#	# Prospective Design	#	# Prospective Design	#
VHF (30 - MHz-300) MHz Radio and TV	1	0	1	0	
ELF - UHF (3 Hz - 3 GHz) workers.	6	1	16	10	6
ELF - UHF (3Hz - 3GHz) studies. RF exposures	7	1	5	3	0
ELF - VHF (3Hz - 300 MHz) Ecological. TV broadcast towers.	5	0	0	0	3
ELF (3 Hz-100 Hz) studies	17	4	20	9	10
ELF - SHF (3 Hz - 60 GHz) Ecological	0	0	0	0	2
ELF - SHF (3 Hz - 60 GHz) workers	4	0	1	0	4
HF - VHF (3 MHz - 300 MHz) Ecological	3	0	3	2	2
HF (3 MHz-30 MHz) studies.	1	0	1	0	
MF (300 kHz-3 MHz) studies	2	0	1	1	1
SHF (3 GHz - 60 GHz) studies. Radar	1	0	0	0	0
UHF - SHF (300 MHz- 60 GHz) studies. Base stations and Radar	18	1	2	1	7

Study type / frequency category	Effect		No Effect		Uncertain Effects
	#	# Prospective Design	#	# Prospective Design	#
UHF (300 MHz-3 GHz) Ecological studies. Base stations.	16	1	9	1	3
UHF (300 MHz-3 GHz) studies. Mobile Phone frequencies	69*	23	61*	27	50**
UHF (300 MHz-3 GHz) Epidemiological Mobile phones – All Brain Tumour studies	32	23	31	21	15
UHF (300 MHz-3 GHz) Epidemiological Mobile phones Glioblastoma Multiforme	9	4	15	5	5
UHF (300 MHz-3 GHz) Epidemiological case studies Mobile phones.	86*	29	68*	28	53
ULF (300 Hz-3 kHz)	0	0	2	0	0
VHF (30 MHz-300 MHz)	3	0	0	0	1
VHF to SHF (30 MHz – 60 GHz) workers	3	0	0	0	0

* Total of 9 of these studies are Meta-Analysis studies.
** Total of 6 of these studies are prospective design studies.

The most troubling aspect was the indicators of possible bias shown by some researchers when reporting their results as shown in Table 9 below. Researchers tend to be polarised into two groups and one only has to look at who the author is to guess the likely conclusion of a study. Only two researchers reported in both the "effects" and "no effects" categories being Hardell and Lonn.

Hardell and his group of researchers seem to be a major independent research group. Almost all their studies are done with prospective design, whereas the majority of other researchers that show no-effect are mainly short-term studies.

Table 9 Eight Epidemiological Studies by Author

Author	Effect		No Effect		Description
	# Studies	# Prospective Design	# Studies	# Prospective Design	
Hardell	18	13	2	0	Testicular Salivary Gland
Inskip	0		3	0	Brain Tumours
Christensen	0		2	0	Brain Tumours & acoustic neuroma
Lahkola	0		3	0	Meningioma & intracranial tumours. Low mobile phone usage study. One paper is a meta-analysis study
Lonn	1	1	3	1	Parotid gland, brain tumour & intra-cerebral tumours Two papers are meta-analysis studies

3.4. Bradford Hill Criteria

The Bradford Hill criteria for causation are a well-recognised and widely used framework when finding direct evidence is not possible. Each paper was reviewed with regard to these criteria. For animal studies the experimental and biological plausibility criteria were assessed. If the study was repeated and the same effects were observed, then the consistency criterion was satisfied and the dose response effect criteria and strength criteria were usually met.

There are 32 epidemiological studies that show statistically significant association with UHF (microwave frequencies) as shown in Table 8. When the Bradford Hill criteria is applied to these studies the following summary below in Figure 9 demonstrates that 5 out of the 8 criteria are met with some degree of certainty.

Hardell and Carlberg [17] observed that coherence between studies from different countries have shown increases in particular types of tumours glioma (e.g. Glioblastoma Multiforme) in the most exposed parts of the brain (temporal and adjacent lobes) and they contend that this data alone should see a more precautionary stand being taken by the regulators.

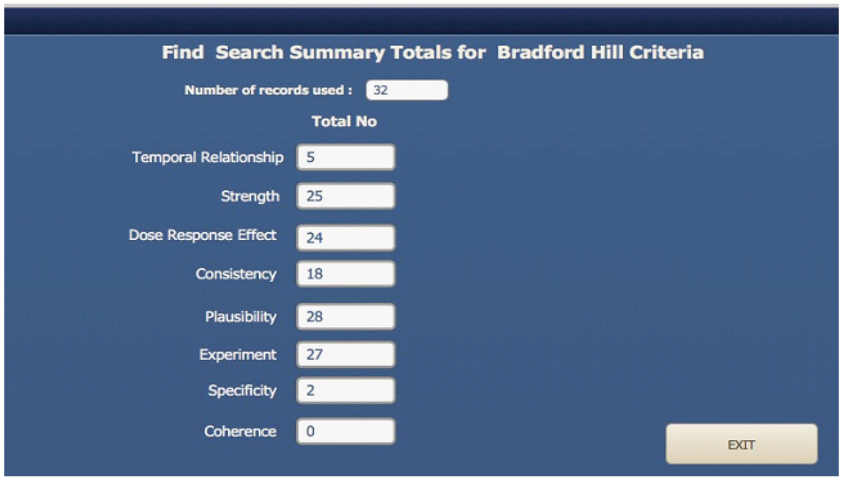

Figure 9 Summary Totals for Epidemiology studies reviewing Brain Cancer using the Bradford Hill Criteria

3.5. Electromagnetic Hypersensitivity (EHS) Individuals

There have been a number of papers on Electromagnetic Hypersensitivity (EHS). Some of the research has been using provocation studies while others have been carried out using epidemiological surveys, sometimes combining data in a meta-analysis study. Table 10 summarise the studies.

Table 10 Summary of studies looking at subjective symptoms in ORSAA Database.

Frequency Category	Effect			No Effect			Uncertain Effect		
	No	Pro	Epi	No	Pro	Epi	No	Pro	Epi
ELF (3 Hz-100 Hz)	5	5	0	2	2	0	3	2	1
ELF - UHF (3 Hz - 3 GHz)	5	1	4	1	1	0	2	1	1
ELF to SHF (3 Hz - 60 GHz)	4	0	4	1	1	0	4	0	4
ELF - VHF (3Hz - 300 MHz)	1	1	0	0	0	0			
UHF (300 MHz - 3 GHz)	36	10	26	18	15	3	9	7	2
UHF – SHF (300 MHz- 60 GHz)	1	0	1	0	0	0			
VHF to SHF (30 MHz - 60 GHz)	2	0	2	0	0	0			
Totals	**54**	**17**	**37**	**22**	**19**	**3**	**18**	**10**	**8**

Pro means Provocation | **Epi** means Epidemiology

Reviewing the data in Table 10 shows "no effect" determination as being almost exclusively limited to provocation based studies. The majority of provocation studies are typically acute short-term exposure studies.

So what constitutes a fair test for hypersensitivity when undertaking provocation testing? The testing must ensure that the follow-up time after exposure must be sufficient to allow the individual's symptoms to develop and be noted. This symptom development time may vary between individuals. The ambient EMF levels within the testing room may be sufficient to trigger symptoms and so could confound the test – shielding may be necessary. The trigger levels might be different for different individuals. Where the participant is tested multiple times, the intervals between exposures must be such that the effects from the last test do not carry over into the next test. The intervals between testing and the EMF levels need to be tailored for each individual. The volunteers tested are normally health individuals, which may not be the case for those suffering from EHS. Individuals who may have other health issues are typically excluded from such test so it is not possible to see if these people are more vulnerable when exposed to RF.

We have a number of EHS cases following accidental exposure at EMR levels well below the thermal limit. In the case of an occupational exposure, a worker developed a scalp condition called Dysaesthesiae, which can be associated with an unpleasant burning sensation and pain [26]. The condition may start a few minutes after using a mobile phone or some hours later and the effect can diminish shortly after the phone call or could continue on for several hours later. The occupational exposed person experienced effects well below the thermal threshold and the symptoms diminished with time resulting in a full recovery being achieved after 6 months. However, a study of some 40 EHS respondents to a survey showed a great deal of variability but did include a common theme of temple pain, ear pain, occipital pain, often dull pain, heating and visual effects [27].

Of great interest is the common findings between low exposure events, as described above, and clinical studies investigating "over exposure" scenarios. We see the same common types of symptoms such as headache, numbness, parasthesiae, malaise, dysaesthesiae etc. leading one clinician to suggest "*The effects of exposure to radiofrequency radiation, particularly those on the nervous system, appear to be greater than would be expected from tissue heating*." [28] Although symptoms for many cases can be considered to be transient, for some, full recovery is not always a certainty with some effects becoming persistent with little or no change years later. [28] [29] [30].

4. Conclusions

A review of non-ionising radiation ***in-vivo*** and ***in-vitro*** studies shows an increased risk of adverse health effects. Cell studies are not direct evidence of human biological effects. However, thermal effects cannot explain the biological effects that exist at low power and various frequencies.

Thermal effects are evident at high-power and non-thermal effects are present at low-power [20] [21]. Microwave radiation can interact with the organism to create a range of biological effects that involve the central nervous, endocrine, cardiovascular, immune, reproductive, hepatic and hematopoietic systems.

The most direct human evidence comes from young women who have chosen to store mobile phones in their bras for greater than 6 years and the risk of developing breast cancer [18]. RF Implanted Devices (RFID) using low-power (143 kHz) has been used to disrupt cancer progression in terminal ill patients, which shows clear targeting of cancerous cells compared to non-cancerous cells [12].

The epidemiological case-studies with mobile and cordless phone exposure show strongest evidence for effect when it comes to the brain cancer types Glioblastoma Multiforme and meningioma, particularly amongst the heavy users (more than one hour per day) while no association or risk is found amongst casual users.

It is also clear that the industry-sponsored research has been used as a tool to obfuscate these effects and confuse the public [2]. But despite their attempts, the public remains skeptical of assertions of safety as many have the experience of tobacco and asbestos as the yardstick for behavior when profits are the only

motivator. Statistical association studies do not necessarily imply increased disease or risk of disease but it does point to a potential risk and there is enough evidence to suggest we take a precautionary approach with respect to these wireless devices and to use them in a safe manner.

5. ORSAA Recommendations

Safe use should constitute:

- Use of hands free for mobile phone calls where possible;
- Do not store against the body when switched on (non-airplane mode);
- Do not use wireless devices on your lap for long periods;
- Use mobile phones like answering machines for those employed in non-emergency roles rather than keeping them on;
- Use wired connections rather than Wi-Fi connections in your home;
- Do not leave active wireless devices near to where you sleep.

It is well known that both ionising and non-ionising radiations show serious biological effects at high exposures levels that exceed safety limits. At low levels for both forms of radiation there is uncertainty when it comes to biological effects and their implications to health. From a regulatory stand point, there is an inconsistency in how each form of radiation is managed. For low-level ionising radiation, the radiation protection exposure standards take a precautionary approach in setting radiation dose limits, that is the principle of "As Low As Reasonably Achievable" (ALARA) is applied. When it comes to non-ionising radiation limits, where the effects are also uncertain at low-power and the biological mechanism for cell damage is not directly known, but is present all the same, there is no precaution being applied. Unfortunately, the ALARA radiation protection philosophy is totally absent for non-ionising radiation exposure.

The Australian Communications Media Authority (ACMA) is responsible for implementing the Radiocommunications Act (1992) [22] is not only the promoter of wireless spectrum usage but the health regulator [23]. ACMA maintains that a precautionary approach or similar instrument adds additional safety factors and should only be adopted on a voluntary basis [22].

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