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RISKS TO INDIVIDUALS IN NSW AND IN AUSTRALIA AS A WHOLE

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by

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ABSTRACT

Objective, quantitative estimates are made of some risks to which individual members of the general public are exposed in NSW and in Australia as a whole, in their private lives and ordinary activities. The risks are given as averages for the group of people exposed to each risk. In many cases, this is the whole population. Occupational risks and unusual risk-taking are excluded as far as possible from the study. Some of the estimates are based upon statistics on the causes of death. Others are based upon mathematical models, because specific evidence relating causes and effects is lacking.

The results of the study show that by far the highest risks of fatality are either voluntarily incurred or could be greatly reduced as a matter of choice by the risk-takers. Risks which come into these categories include smoking, some other causes of cancer, drinking alcohol and motor vehicle traffic accidents.

Risks to the general public from industrial accidents are comparatively low. These latter risks can be (and usually are) controlled to levels which, in a purely quantitative context, would generally not be perceived as significant.

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1 INTRODUCTION

With the increasing emphasis which is being placed upon probabilistic risk assessment of nuclear reactors and other potentially hazardous installations, there has been a great deal of information published on the levels of risks which people appear to find acceptable, e.g. risks to which they are exposed from industries which they accept and from activities in which they choose to participate [1-9]. This information, if accurate and used in a relevant context, may be useful in order to:

(i) demonstrate that no environment is free from risks;

(ii) place risks into perspective and perhaps indicate how efforts could best be directed to reducing the more significant risks; and

(iii) assist in defining reasonable objectives for safety, and criteria for the assessment of safety.

However, risk figures are often quoted without reference to their derivation, accuracy and possible limitations. The impression is often gained that authors are simply quoting each other and that they may have little idea whether the figures are accurate or relevant to a particular application. The significance of this is illustrated by the following example:

When using a figure for the risk of rail travel, it would be important to know -

(i) whether it is averaged over the whole population, the travelling population, regular rail travellers or perhaps some high risk group of travellers;

(ii) whether it refers to passengers only, or includes:-

  (a) railway employees, and/or

  (b) non-travellers involved in train accidents;

(iii) whether it refers to a particular district or the whole world;

(iv) when and how long was the period from which the data derived;

(v) how much the risk varies with time and place; and

(vi) who recorded the data and how?

Table 3 shows how misleading such figures could be, if quoted without this background information. There is an apparent range of more than 50:1 in the risk of rail travel, depending on how the risk is derived.

This study was therefore undertaken in order to provide specific, up to date estimates of mortality risks as a background to ANSTO safety assessments. It is not comprehensive, but concentrates to a large extent upon accidents and cancer as causes of death. Although no two risks are precisely comparable in all respects, the study uses a consistent measure of individual risk rate per year. The results provide a basis for direct quantitative comparisons between risks which are familiar to most (e.g. motor vehicle traffic accidents) and risks which many people may have difficulty in comprehending (e.g. radon in the air they breathe).

The study makes use of basic data and well documented studies by others, which are clearly referenced. It concentrates on risks to which members of the general public are ordinarily exposed. Occupational risks and extremes of untypical behaviour are excluded as far as possible.

Although the study is aimed chiefly at deriving estimates of risks to the people of NSW, risks based upon larger populations (although less specific) have greater statistical significance. Risks to Australians in general and (in some cases) to people in the US and UK are therefore shown for comparison, and are used for guidance when reliable specific estimates for NSW are not possible.

2 EVALUATION FROM STATISTICS

The average annual probability of death of individuals, due to a source of risk, is considered to be an objective, quantitative measure of that risk. It is not always the best measure of a particular risk (see 2.1 Transportation Accidents) but it provides a consistant basis on which most risks can be measured and compared one with another. For well established practices and clearly defined causes of death, this measure of the risk can often be evaluated from statistics on the causes of deaths in a known population. Tables 1 and 2 present statistics on accidental deaths in NSW [10, 11] and Australia as a whole [12]. Unless otherwise referenced, risks summarised in this section are derived from the data in Tables 1 and 2.

Risks are derived as the annual rate of fatalities per million people exposed to each risk. This is the average risk to an individual exposed to the risk, expressed as fatalities per million person-years. Except for cancer risks, the differences between rates for different age groups and between rates for males and females are not given (although they are quite large in some cases) because the study is concerned with average individuals. Differences are given in the case of general cancer incidence (Section 2.6 of the paper) because a particular significance to the trend is indicated.

TABLE 1
ACCIDENTAL DEATHS IN NEW SOUTH WALES [10,11]

Type of Accident	1975	1981	1982	1983	1984	1985	1986
Rail transport							
- total	32	31	33	27	26	33	37
- passengers only	26	4	11	7	12	10	18
Motor vehicle traffic							
- total	1318	1276	1283	924	935	1051	1023
- pedestrian	260	268	267	206	188	232	205
Water transport	46	25	20	34	32	31	28
Powered aircraft							
- total	6	12	25	10	11	11	22
- passengers only	5	6	23	10	10	11	19
Poisoning	63	106	94	94	110	90	90
Falls	391	355	343	286	255	325	320
Fires and flames	69	63	48	47	40	59	49
Venomous animals and plants	3	0	1	2	0	0	0
Lightning	3	0	0	0	0	1	2
Cataclysmic storms and floods	2	1	4	1	0	0	2
Drowning							
- total	155	106	123	113	93	112	98
- while swimming	55	38	35	39	30	30	33
Falling objects	19	28	19	13	11	11	13
Firearms	13	9	15	18	14	13	12
Electric current							
- total	27	37	26	21	19	26	23
- in industry	2	6	14	11	10	9	12
*Therapeutic use of drugs	n/a	3	4	8	19	9	14
*Homicide	62	115	102	96	109	112	98
Population of NSW (millions)	4.88	5.23	5.30	5.36	5.40	5.46	5.53

* Included in this table for convenience.

TABLE 2
ACCIDENTAL DEATHS IN AUSTRALIA [12]

Type of Accident	1975	1981	1982	1983	1984	1985	1986
Rail transport - total - passengers only	 74 26	 66 13	 72 15	 69 15	 75 16	 66 12	 65 25
Motor vehicle traffic - total - pedestrian	 3689 736	 3287 648	 3364 623	 2831 526	 2714 527	 2933 555	 2987 548
Water transport	127	89	79	114	79	104	68
Powered aircraft - total - passengers only	 45 40	 44 37	 61 42	 51 47	 40 28	 48 44	 56 52
Poisoning	116	196	184	219	217	216	159
Falls	1199	907	990	863	902	936	880
Fires and flames	168	145	183	228	119	152	127
Venomous animals and plants	11	6	3	6	5	3	5
Lightning	4	1	0	2	2	3	4
Cataclysmic storms and floods	**50	9	9	9	4	2	6
Drowning	435	334	320	328	272	294	269
Falling objects	76	70	67	53	61	53	40
Firearms	55	36	48	40	32	35	28
Electric current - total - in industry	 83 11	 85 31	 96 39	 72 36	 66 27	 68 23	 68 31
*Therapeutic use of drugs	n/a	20	16	23	33	23	32
*Homicide	224	28	289	294	299	314	315
Population of Australia (millions)	13.9	14.9	15.2	15.4	15.6	15.8	16.0

* Included in this table for convenience.

** It is assumed that this figure includes some of the effects of Cyclone Tracy, Dec. 25 1974: 50 deaths on land, 16 deaths at sea.

2.1 Transportation Accidents

Data on the numbers of deaths from transportation accidents and on the sizes of populations, are given in Tables 1 and 2, enabling the risks to be evaluated. Data on the total risks of fatality from transportation accidents, averaged over the whole populations, are available from the US [2,7] and UK [6,8,9].

Transportation risks vary significantly across the community, and are sometimes presented in the form of risk per journey or per person-kilometre for this reason. However, such a form of presentation would not be suitable for comparison with other risks in this study, and is therefore not adopted here.

2.1.1 Railway accidents

Data on the numbers of fatalities in railway accidents, averaged over the whole population, are shown in the first two lines of Table 3.

The total risk figures for railway accidents averaged over the whole populations of the UK and US are approximately 1 and 4 fatalities per million person-years respectively. The UK figure is increased to 18 if averaged over regular rail travellers only, which is comparable with the NSW figures.

The general public tends to be polarised into those who commute regularly by rail and those who rarely or never travel on the railways. Although there is a significant number of occasional rail travellers, figures from the State Rail Authority and Urban Transit Authority [13] indicate that some 45% of rail travel in NSW is undertaken by passengers with weekly, quarterly or annual tickets, making about twelve journeys per week, and that much of the remainder is by frequent suburban travellers using single or return tickets. It is therefore considered reasonable to represent the travelling public of NSW by the equivalent number of regular commuters (as shown in Table 4) in order to estimate the average risk from railway accidents to regular rail passengers (Table 3). Equivalent figures for the whole of Australia are not available (n/a).

TABLE 3
RISKS FROM RAILWAY ACCIDENTS
(fatalities per million person-years)

	Australia			NSW		
	1981	1986	1981-86	1981	1986	1981-86
Total (including rail employees) averaged over the whole population	4.4	4.1	4.5	5.9	6.7	5.8
Passengers only - averaged over the whole population	0.9	1.6	1.0	0.8	3.2	1.9
Passengers only - averaged for regular commuters	n/a	n/a	n/a	11	51	30

NOTES:

(i) Closer examination of the statistics shows that the risk to passengers varied in a random fashion over the period 1981-86, and that there was no evidence of a consistent upward trend.

(ii) The Granville disaster occurred in 1977 and is therefore not included in the period studied.

TABLE 4
RAIL TRAVEL IN NSW

Year	Passenger journeys	Equivalent commuters
1980-81	212,910,000	342,000
1981-82	220,837,000	354,000
1982-83	207,201,000	332,000
1983-84	202,253,000	325,000
1984-85	200,275,000	321,000
1985-86	218,581,000	350,000
1986-87	224,255,000	359,000

2.1.2 Motor vehicle traffic accidents

Total risk figures for motor vehicle traffic accidents are given in Table 5.

TABLE 5
RISKS FROM MOTOR VEHICLE TRAFFIC ACCIDENTS
(fatalities per million person-years)

	1960s	1972-75	1975	1982	1983-86
US	300				240
UK	150	140	120	104*	100
Australia		270	260	221	183
NSW			270	242	181

* Average for 1980-1984

The Australian and NSW figures are similar. The risk for NSW in particular dropped significantly in 1983, probably because of random breath testing of drivers. The figures for the US are consistently higher and for the UK are consistently lower.

UK data for 1975 [6] show pedestrians accounting for 31% of the total road fatality rate but US, Australian and NSW data show that pedestrians account for about 20% of deaths. The actual risks to pedestrians in NSW and the whole of Australia respectively were 38 and 34 fatalities per million person-years during 1983-86.

Most people in Australia probably use motor transport of some form quite frequently. Therefore, averages over the whole population is considered to be appropriate. The current risks in NSW and Australia as a whole are taken to be approximately the same at:

total risk	180 fatalities per million person-years
risk to pedestrians	35 " " " " "
travelling by motor vehicle	145 " " " " "

2.1.3 Aircraft accidents

Table 6 shows the risks from accidents to powered aircraft in Australia and NSW for the period 1981-86, averaged over whole populations and compared with figures available for the US and UK. There was no apparent trend to the Australian figures over this period.

TABLE 6
RISKS FROM AIRCRAFT ACCIDENTS
(fatalities per million person-years)

	Total	Passengers
Australia	3.2	2.8
NSW	2.8	2.5
US	9	
UK	1	

There has been no crash of a scheduled airline flight in Australia, or involving an Australian airline, for more than 25 years. This does not mean that this risk is zero. Airline accidents have occurred elsewhere in the world including the US and UK. This is a risk characterised by rare events, usually with large consequences, which would best be studied worldwide. The figures in Table 6 are merely indicative. However, it should be noted that one airline crash, averaged over the Australian population and the history of commercial aviation, would be unlikely to increase the risk by as much as 1 fatality per million person-years.

No estimate is available for the fraction of the Australian public which regularly uses air transport. Therefore no specific estimates can be made of the risks of travelling by air in Australia. However, it is assumed for this purpose that people in the UK travel significantly less by air than those in the US, with Australians somewhere in between. It has been estimated, for the UK, that the risk is about 10 fatalities per million person-years when averaged over the travelling public. The same figure for Australians would imply that about 30% of the Australian population use air transport, and is considered to be the correct order of magnitude.

There is no estimate immediately available of the risk to people on the ground from aircraft crashes in Australia. According to US data, the risk is about 0.1 fatalities per million person-years averaged over the whole population. However, this is not a very useful figure because people living near the ends of airport runways are at substantially higher risk from falling aircraft than the rest of the community.

2.1.4 Water transport accidents

The average risk from water transport accidents which can be derived from Tables 1 and 2 is approximately 5 fatalities per million person-years, averaged over the whole population. The method of collating causes of death does not make it possible to distinguish the fraction due to recreational boating or the fraction attributable to travel, as distinct objectives. Therefore, no attempt has been made to estimate the numbers of people undertaking either of these activities, or the risks of doing so.

2.2 Sporting Accidents

Deaths during sporting activities are likely to be quite clearly identified at the time of death although, in some cases:

(i) the sport may be only a contributory cause of death; and

(ii) deaths might not be recorded as being due to sporting accidents.

Greater uncertainty arises in defining the population at risk, e.g. because many people participate in sports casually and irregularly. A figure averaged over the whole population gives little indication of the risk from participation in a sporting activity.

2.2.1 Football accidents

The New South Wales Sporting Injuries Committee (SIC) provides specific information on risks from accidents during sports in NSW [14] in relation to the requirements of the Sporting Injuries Insurance Act. Football is selected for the purpose of the present study because it has a significant number of fatalities, and it is mainly played in teams run by recognised organisations which record the numbers of participants. Figures for the eleven year period ended 30 June 1987 are given in Table 7.

TABLE 7

RISKS FROM PLAYING FOOTBALL IN NSW, ELEVEN YEARS TO 1987 [14]

Sport	No. of fatalities	Focal population	Fatalities per million person-years
Australian Rules	1	15,154	6
Rugby Union	14	25,905	49
Rugby League	22	87,182	23
Soccer	1	40,995	2
Touch Football	2	4,899	37
Total	40	174,135	21
Total Rugby Football	36	113,087	29

The comparison between Rugby Union and League is interesting. Rugby League has the image of a brutal sport, because of the highly visible behaviour of professional players. However, on the basis of this record, Rugby Union is actually more dangerous. Hence, the inevitable inclusion of some occupational risk in the overall figures for football injuries may not be particularly significant.

The SIC believes it has access to most of the relevant information on Rugby Union and League in NSW, whereas it covers only a fraction of the other codes (perhaps a third of soccer players). Hence, the average figure of about 30 fatalities per million person-years for rugby football is the most reliable figure. This may be compared with the figure of 40 quoted for "football" (unspecified) in the UK [3], for which the derivation in unknown.

2.2.2 Swimming

The report of the Sporting Injuries Committee does not cover swimming, but data on drowning while swimming are available from another source [10]. It is assumed in the present study that drowning is the dominant risk while swimming, but the converse is not true - most deaths by drowning occur in other situations.

In the 1970's the total incidence of death by drowning in all situations was about 30 per year per million of the total population both for NSW and for Australia as a whole. This risk has now fallen to less than 20 per million person-years (see Tables 1 and 2). The incidence of drowning while swimming is recorded separately for NSW (see Table 1) and now averages about 6.7 per year per million of the total population.

Surveys carried out for the Australian Bureau of Statistics [15] and Department of Sport, Recreation and Tourism [16] indicate that about 6% to 13% of Australians engage more or less regularly in various swimming activities, rising temporarily to about 25% at the height of summer. Taking 13% as the rate of participation in swimming, a risk of about 50 fatalities per million person-years appears to be applicable to those who expose themselves to this risk.

2.3 Other Accidents

Risks from other accidents are derived from ABS data recorded in Tables 1 and 2 except where otherwise stated. The risks described in Sections 2.3.1 to 2.3.8 are averaged over the whole population.

2.3.1 Falls

Falls caused 59 fatalities per million person-years during the period 1981-86 in NSW and in Australia as a whole. Although there was no apparent trend during this period, the risk from falls had reduced approximately 40% since 1975.

2.3.2 Fires and burns

Fires and burns caused 10 fatalities per million person-years during the period 1981-86 in NSW and in Australia as a whole. No significant trend was apparent in this risk.

2.3.3 Falling objects

Falling objects caused 3 fatalities per million person-years during the period 1981-86 in NSW, and 4 in Australia as a whole. Both these risks had significantly reduced since 1975.

2.3.4 Poisoning

Accidental poisoning caused 18 fatalities per million person-years during 1981-86 in NSW, and 13 in Australia as a whole. Although there was no apparent trend during this period, both these risks had increased approximately 50% since 1975.

The therapeutic use of drugs caused 1.8 fatalities per million person-years during 1981-86 in NSW, and 1.6 in Australia as a whole. There appeared to be a slight upward trend in this risk during the period.

Poisoning by venomous animals and plants caused 0.1 fatalities per million person-years during 1981-86 in NSW, and 0.3 in Australia as a whole.

2.3.5 Electric current

Electric current caused 5 fatalities per million person-years during 1981-86 in NSW and in Australia as a whole. 40% of these deaths occurred in industry. Of the remaining 3 fatalities per million person-years, a significant fraction is likely to be occupational (e.g. tradesmen working on domestic installations). However, the method of collating causes of death does not make it possible to evaluate this fraction.

2.3.6 Lightning

Lightning strikes caused 0.09 fatalities per million person-years during 1981-86 in NSW and 0.13 in Australia as a whole.

2.3.7 Cataclysm

Cataclysmic storms and storm floods caused 0.2 fatalities per million person-years during 1981-86 in NSW, and 0.4 in Australia as a whole.

2.3.8 Homicide

20 fatalities per million person-years occurred during 1981-86 due to homicide in NSW and in Australia as a whole. This risk had increased substantially since 1975 and was nearly three times the current figure for the UK [9].

2.3.9 Firearms accidents

Accidents involving firearms caused 2.5 fatalities per million person-years during 1981-86 in NSW and in Australia as a whole, averaged over the whole population. This was ten times the figure for the UK [9].

Those who do not possess firearms are unlikely to be involved in such accidents. Therefore the above figure is considered to be misleading. The NSW Police firearms registry has estimated that there are approximately 250,000 firearms amongst approximately 5.5 million population of NSW, in addition to some 170,000 licences [17]. Assuming an average of one person at risk from every licensed and unlicensed firearm, this suggests that the average risk to those who possess firearms in NSW is approximately 30 fatalities per million person-years. However, allowing for the following factors:

(i) multiple ownership of firearms;

(ii) several persons in each household which possesses firearms;

(iii) the large uncertainty in any estimate of unlicensed firearms; and

(iv) considerable year to year variation in the accident rate;

the estimated risk is subject to a considerable factor of uncertainty but is probably within the range 10 to 100 fatalities per million person-years.

2.3.10 Accidents at home

Data on deaths from falls, fires, burns, falling objects and electrocution include many accidents in the workplace. Information on the location of accidents is not immediately available for deaths in NSW or Australia as a whole. However, in England and Wales, deaths due to all accidents at home averaged 106 per million person-years in 1971-75 [4] and 113 per million person-years in 1980-84 [9]. A similar level of risk has recently been quoted for the US [7]. A figure of 110 fatalities per million person-years is therefore taken as the approximate level of the risk of accidents at home in NSW.

2.4 Cigarette Smoking

Tobacco smoking causes and/or aggravates a wide range of potentially fatal diseases, including various forms of malignant neoplasms, cardiovascular diseases and ulcers [18]. Since these diseases have other causes and may be delayed by ten years or more, cause and effect cannot be correlated with certainty for specific cases. However, the relationships are well established by epidemiological data [5,19-21].

The health effects of smoking depend upon what is smoked and how much of it. Attention is directed here to cigarette smoking, and no account is taken of variations in tobacco.

Risks of fatality per unit consumption of cigarettes depend on age and rate of smoking, and generally appear to be lower for females than for males [5,19-21]. There are significant uncertainties in evaluation of the exact level of risk from statistics and in the application of average values to specific groups. At a smoking rate of 20 cigarettes per day, the average number of excess deaths per cigarette appears to be about one per million for males [19,20]. Other authorities have quoted a one per million probability of death as being equivalent to 0.75 cigarettes [22] and 1.5 cigarettes [1], averaged over all smokers. On this basis, 20 cigarettes per day is equivalent to a risk of about 5,000 to 10,000 fatalities per million person-years.

The annual death rate attributed to smoking in Australia, averaged over the whole population, has been about 1100 per million since 1977 [23]. "The proportion of males who smoke has been steadily decreasing since 1945, while until 1983, the proportion of females who smoke had been increasing". At present about a third of the Australian population smokes, suggesting that the risk to the average Australian smoker is currently about 3,300 fatalities per million person-years. This estimate is not linked to a specific rate of smoking. Figures for tobacco consumption in Australia [23] indicate that the risk from smoking 20 cigarettes per day is also about 3,300 fatalities per million person-years, if variations in the risk per cigarette are ignored. This estimate is subject to errors because of changes to population and smoking habits, and the periods of latency of the relevant diseases. Furthermore, the criteria for attributing deaths to smoking are not made clear in this report. However, it does suggest that 10,000 may be too high an estimate of the risk.

Reference [7] quotes the risk from smoking 20 cigarettes per day as 3,600 fatalities per million person-years in the US, within a factor of 3, but does not record how the uncertainty band was estimated. Reference [3] quotes a figure of 5,000 for the UK.

These figures represent the risk of death from all smoking related diseases. Other studies [5,21] suggest that at least 25% of this risk is due to cancers, about half of which are lung cancers. Hence the risks of death from smoking 20 cigarettes per day are considered to be of the following orders:

5,000 per million person-years from all effects
2,000 per million person-years from all cancers
1,000 per million person-years from lung cancer.

The figure for lung cancer is confirmed by reference [6].

Many people are also exposed involuntarily to the effects of tobacco smoke, as "passive smokers", even though they do not smoke themselves. There are two main groups of passive smokers:

(i) those who breath contaminated air and "sidestream" smoke, due to the smoking of others; and

(ii) unborn children, due to smoking by women during pregnancy.

Some physical effects of passive smoking have been clearly demonstrated [24]. In particular, a consistent pattern of moderately increased risk of lung cancer has emerged. However, the evidence so far is insufficient for reliable quantitative estimates of risk to be made.

2.5 Drinking Alcohol

Risks due to the consumption of alcohol are complex and not well documented in terms useful to the present study. It is often stated that modest consumption of alcohol is good for health. However, there appears to be no conclusive scientific proof of this [25-27]. On the other hand, no conclusive scientific proof has been found that modest consumption of alcohol (say 20 g per day) causes net damage to health as measured, for example, by a loss of life expectancy. The National Health and Medical Research Council [28] has concluded that:

> "To....recommend responsible levels and modes of drinking....is infinitely more complex than providing guidance regarding cigarette smoking. While it can be argued that no cigarette smoking is harmless from a health point of view, the evidence in regard to alcohol is more complex, suggesting that at very modest levels of consumption there may even be beneficial effects, at least in respect to certain bodily functions."

The Council recommends abstinence for women during pregnancy and for persons who intend to drive, operate machinery or undertake hazardous or potentially hazardous activities. For other situations, the Council recommends maximum consumption of two drinks (20g of alcohol) per day for women and four drinks (40 g of alcohol) per day for men, with more that four and six drinks per day respectively being considered harmful.

At higher levels of consumption, alcohol certainly has a variety of potentially fatal effects including cirrhosis of the liver, cancer, cardiovascular problems, increased likelihood of accidents and (in extreme cases) acute poisoning [18]. It is concluded that risks increase with consumption, above a possible threshold, but the form of correlation is not clear. There is no reason to assume that the correlation is linear, and there are some indications that risks are disproportionately high for heavy drinkers.

Reference [23] records that the annual death rate attributed to consumption of alcohol, averaged over the whole population of Australia, has fallen from about 260 per million in 1976-78 to about 210 per million in 1983-85. This has been mainly due to a fall in the number of road traffic accident deaths due to alcohol. Data now suggest that alcohol is a factor in only 40% of road deaths, compared with 50% prior to 1979. These percentages do not appear to include those who had not been drinking but were killed in accidents caused by drinkers. Therefore, it is not possible to draw any firm conclusion from these figures on the total number of road deaths caused by alcohol.

The total death rate attributed to alcohol in 1985 is broken down as follows:

alcoholism and alcoholic cirrhosis	30%
motor vehicle traffic accidents	43%
other alcohol related causes	27%

and the drinking pattern of the NSW population is classified approximately as:

non-drinkers	45%
light drinkers (average less than 5 drinks per day)	47%
moderate and heavy drinkers	8%

Assuming the risk rates due to alcohol in NSW are the same as for Australia as a whole, the risks averaged over all drinkers are therefore estimated to be approximately:

380 fatalities per million person-years from all effects

115 fatalities per million person-years from alcoholism and alcoholic cirrhosis.

If it were to be assumed that all the risk of alcoholism and alcoholic cirrhosis is borne by moderate and heavy drinkers, the figure for this risk would be increased to 790 fatalities per million person-years.

Reference [7] quotes the risk of alcohol to a light drinker in the US as 20 fatalities per million person-years, within a factor of 10, but does not record how the uncertainty band was estimated. Reference [3] quotes a risk of 75 fatalities per million person-years from drinking one bottle of wine per day, which is within the range described as "moderate" in reference [23]. It is assumed that neither of these figures includes the contribution of alcohol to motor vehicle traffic accidents. This being so, they could be consistent with the estimate for NSW if it is assumed that the risk per unit consumption of alcohol increases significantly with consumption.

2.6 Cancer (all causes)

Smoking is only one of the causes of cancer, albeit a large one. Many other environmental causes of this disease have been identified [29] including naturally occurring agents, constituents of man-made pollution, occupational causes and consumer products. However, adequate information is not available to quantify (or even completely identify) all such causes, particularly those due to non-radioactive agents. This Section of the paper therefore treats the total incidence of cancer mortality risk without reference to specific causes.

Data are available on the rates of cancer mortality in NSW [10] and Australia as a whole [12]. Data are also available from the US [30] and UK [6] for comparison. Risks which are recorded or evaluated from these data are given in Tables 8 and 9.

TABLE 8

CANCER RISKS - ALL MALIGNANT NEOPLASMS

		Fatalities per million person-years		
		1974/5	1982	1986
US [30]	- males	1,905		
	females	1,510		
	total	1,705		
UK [6]	- males	2,970		
	females	2,520		
	total	2,740	2,705*	
Australia [12]	- males	1,690	1,870	1,960
	females	1,310	1,410	1,520
	total	1,460	1,640	1,740
NSW [10]	- males	1,630	1,940	2.060
	females	1,150	1,470	1,600
	total	1,400	1,710	1,830

* Total neoplasms, average for 1980-84 [9]

TABLE 9

CANCER RISKS - MALIGNANT NEOPLASMS OF TRACHEA, BRONCHUS AND LUNG

		Fatalities per million person-years		
		1974/5	1982	1986
US [30]	- males	610		
	females	171		
	total	380		
UK [6]	- males	1,200		
	females	300		
	total	750		
Australia [12]	- males	500	560	540
	females	90	140	170
	total	290	350	360
NSW [10]	- males	530	590	580
	females	95	150	180
	total	310	370	380

The dependence of cancer fatality risks upon environment should be noted, e.g. the UK has more than twice Australia's rate of lung cancer fatality. The risks of cancer appear to be slightly higher in NSW than in the rest of Australia, and the following approximate figures are current for NSW:

1,800 fatalities per million person-years from all cancers
380 fatalities per million person-years from lung cancers

However, the cancer fatality rate is rising steadily. One reason for this appears to be the increasing rate of cigarette smoking by females. It is also attributable to the increasing average age of the population. Fig. 10 gives the age distribution (by percentage) of the total fatality rates for 1974/75 [12], showing that cancer death is predominantly a risk of old age.

TABLE 10
AGE DISTRIBUTION OF CANCER FATALITIES, 1974/75 [12]

Age group	Population distribution		All malignant neoplasms		Malignant neoplasms of the lung	
(years)	Australia	NSW	Australia	NSW	Australia	NSW
under 30	53.5	52.2	2.6	2.5	0.1	0.2
30-39	12.4	12.8	2.1	2.0	0.6	0.8
40-49	11.6	11.8	7.1	6.9	6.4	5.3
50-59	10.0	10.3	17.4	18.1	20.5	20.8
60-69	7.2	7.5	28.2	28.9	35.7	38.1
70-79	3.8	3.9	26.9	26.3	28.6	27.5
80 and over	1.5	1.5	15.7	15.3	8.1	7.3
Total	100.0	100.0	100.0	100.0	100.0	100.0

3 ESTIMATION FROM MATHEMATICAL MODELS

There are some sources of potential hazards to the general public for which it is difficult or impossible to evaluate the risks directly from death rate statistics. For example:

(i) the health effects of air pollution cannot be readily distinguished from similar effects with other causes;

(ii) some industries have the potential for accidents with major consequences outside the industries themselves (fires, explosions, releases of toxic materials), but these are rare events which may have made no contribution to a particular sample of statistics; and

(iii) cancer deaths from exposure to ionising radiation or chemical carcinogens may be delayed many years after the exposure, making it difficult or impossible to attribute the effect to the cause in individual cases.

These risks are nonetheless real and the control of them is important to society. Estimates of their size can often be made indirectly using mathematical models. However, because of the lack of clearly observable relationships between causes and effects, beliefs may be at least as important as estimates in moulding society's perceptions of such risks. Hence, some risks which are widely perceived to be important are found, on evaluation, to be small compared with other risks which do not cause as much concern.

In the sources of information on accident risks which are referenced below, the probabilities of unlikely major accidents are estimated (with the assistance of fault-tree/event-tree logic where appropriate) from global data on similar accidents and on faults and events which would contribute towards causing such accidents. The consequences of accidents, dispersions of airborne materials, and related health effects are estimated from mathematical models based upon theories, hypotheses and experiments, as well as the observed effects of actual events.

For the purpose of this study, the risk values which are synthesised using mathematical models are expressed in the same units (fatalities per million person-years) as statistically based risks. However, there may be significant differences between the two types of estimates.

First of all, particularly in the case of releases of potentially toxic materials, the model may involve an extrapolation from conditions under which fatal health effects have been observed to conditions under which there is no proof of fatal effects. Evaluations of risk often depend upon conservative assumptions concerning the relationships between health effects and exposures, e.g. the hypothesis that the probability of incurring cancer from exposure to ionising radiation is proportional to dose without threshold (the "linear hypothesis"). Thus, the actual risk may be zero and is likely to be between zero and the estimate which is quoted.

Furthermore, risk estimates may be based on the "critical group", i.e. the hypothetical group of persons in each case exposed to the most extreme level of risk. This is normal practice in radiation protection [31], and a similar approach is usually applied to risks from potential accidents (nuclear and non-nuclear), which are usually highest for persons near the source of risk. Therefore, the estimate is essentially a local value. There is no suggestion that a large fraction of the general population is exposed to these levels of risk, in contrast with statistically based risk estimates which are averaged over the whole population or the whole group of risk takers. In fact:

(i) by definition, the average risk to the population is much lower than the risk to the critical group; and

(ii) estimates of risks to hypothetical critical groups are not intended to indicate levels of risk which will necessarily be found in practice, and may significantly overestimate risks to real individuals.

Finally, there are inherent uncertainties in mathematical modelling, including those outlined above, which may be much greater than the uncertainties in statistically based risk evaluations. Environmental models, which are necessary for some estimates, are a particular source of uncertainty.

3.1 Chemical Plant Accidents

Chemical plants in and near urban areas of NSW contain potentially flammable, explosive, toxic, carcinogenic and mutagenic substances [32]. Routine effluents probably have potential long-term health effects, but estimates of risks from them are not immediately available. Chemical plant accidents capable of harming members of the general public are rare, but the accident at Bhopal in India (1985) clearly demonstrated that they are possible. Studies of potential major accidents at the Canvey Island petrochemical complex in the UK suggest that risks as high as 1,300 fatalities per million person-years may have been imposed on members of the general public in adjacent residential areas [33]. However, this was at a time when these risks were not fully understood and before they had been quantitatively estimated. Substantial modifications to the plants have now been made to reduce these risks to an estimated maximum figures of 67 and 54 fatalities per million person-years for the whole complex and for a single plant respectively. These studies [33] indicate that a maximum risk of the order of 10 to 50 fatalities per million person-years to members of the general public, would be typical of an existing chemical plant brought under regulatory controls which are considered to be appropriate. This is the figure for the direct effects of potential accidents (fire, explosion and acute toxicity) and does not include delayed fatality risks, although the latter may also exist.

The study of existing chemical plants at Canvey Island was a costly and difficult exercise, with major uncertainties regarding its risk estimates. New plants are more amenable to risk analysis, at the design stage, so that compliance with strict risk objectives can be more readily achieved and demonstrated. For new chemical plants situated in NSW, the Department of Planning has proposed that the risks to members of the general public should not exceed 1 fatality per million person-years [32]. This is within the range of safety objectives proposed by practitioners of probabilistic safety assessment worldwide, although few authorities intend to use such a figure as a rigid or legal requirement. It should be recognised that, for many existing chemical plants, compliance with such a standard could not be demonstrated.

The Netherlands Government, for its external safety policy [34], has adopted a requirement that individual risk from new chemical plants must not exceed 1 fatality per million person-years and should, if possible, be reduced to 0.01 fatality per million person-years. These criteria are generally considered to be extremely restrictive.

3.2 Electricity Generation

Risks to some members of the general public in NSW may exist due to the transportation of coal for electricity generating stations (insignificant in the case of a pit-head station) and potential failure of hydro-electricity dams. Estimates of these risks are not available.

There is also the possibility of a significant health risk due to air pollution from burning coal. Constituents of such pollution include:

(i) fly-ash, containing (inter alia) naturally occurring radioactive decay products of uranium and thorium: and

(ii) oxides of sulphur which become widely dispersed in the environment.

Using the approach which is taken to the assessment of routine effluent from nuclear reactors, the radiation dose to a member of the critical group from operation of a 2,000 MWe coal-fired station is estimated to be within the range 0.02 to 0.23 mSv per year [35,36]. Such exposures give rise to a hypothetical risk of cancer induction. On the basis of the recommended risk coefficient[1] this is equivalent to an individual risk within the range 0.4 to 5 fatalities per million person-years.

At low levels of exposure, the risks from chemical toxicity may be subject to even greater uncertainties than radiological risks. Estimates of the total risk to the whole population from air pollution, including chemical pollution, from the operation of coal-fired stations in the US and UK have been reported in the range 0.07 to 300 fatalities per 1,000 MWe per year [38-40]. The Electricity Commission of NSW, serving approximately 5 million people, generates approximately 5,000 MWe on average from burning coal [41]. Although NSW power stations are generally sited well away from centres of population, there are stations in the US which are also remotely sited. Hence, the average individual risk to the population of NSW from coal-burning appears likely to be in the range 0.07 to 300 fatalities per million person-years.

3.3 The Chernobyl Reactor Accident

Nuclear power is not used to generate electricity in Australia, but is widely used for this purpose overseas. Routine effluents from overseas nuclear power plants are controlled so as to cause only minor risks even to the local population, e.g. in accordance with the recommendations of the ICRP [31]. The only reactor accident known to have caused significant risks to individual members of the general public occurred at Chernobyl in the USSR in 1986. Even the Chernobyl accident did not cause acute health effects outside the reactor site.

The Chernobyl accident was also the only accident to a nuclear power plant serious enough to have caused significant exposures to radioactive material outside the country of origin. The collective effective dose equivalent commitment to European nations from the Chernobyl accident has been estimated from environmental monitoring data [42], permitting hypothetical risks to be estimated. The

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1 Note: The risk coefficient is the fatality risk per unit dose. It has recently been suggested that the ICRP recommended risk coefficient of 10^{-5} fatalities per mSv [31] should be revised upwards. All radiological risks in this study have therefore been doubled as an interim measure as recommended in ref.[37].

average individual dose commitment in the UK is approximately 0.05 mSv. The average for Europe as a whole is approximately 0.1 mSv and there is no record known of any individual dose greater than 10 mSv outside the USSR.

Averaging the dose commitment over the average life span of the population, or assuming that such an event occurs once in a lifetime, the risk from the Chernobyl accident is of the order of 0.01 fatalities per million person-years in the UK. Taking into account the attenuation of radioactivity in transfers from the Northern to the Southern Hemisphere, the risk in Australia is at least an order of magnitude less than the average risk in the UK.

3.4 Natural Sources of Ionising Radiation

There are many naturally occurring sources of ionising radiation in our environment, e.g.

(i) radon and thoron gases from the uranium and thorium decay chains;

(ii) cosmic radiation;

(iii) natural radionuclides in the human body; and

(iv) in some locations, e.g. near high concentrations of thorium minerals, doses received directly from the ground.

Except in the case of exposure of underground miners to radon, prior to the introduction of adequate protective measures, there is no evidence to prove that naturally occurring radiation has harmful effects [43]. Nevertheless, levels of radiation can be measured and their hypothetical effects can be estimated using the risk coefficients applied to artificial sources [31,37].

Radon and thoron tend to accumulate in the atmosphere inside buildings, causing exposure of the lungs of occupants, particularly when ventilation is poor. The risk may therefore be increased as a direct consequence of some energy conservation measures. Doses vary widely depending upon location, building construction and the life-style of occupants.

The average radon concentration measured inside homes in the UK is equivalent to about 20 Bq/m^3 of radioactivity in the air breathed, but there are variations up to at least 8,000 Bq/m^3 [44]. A preliminary survey of Australian homes indicates that the average is about the same as in the UK [44]. Commercially available data from the US yields an average of more than 100 Bq/m^3, but this is not the result of a statistically designed survey [45]. The highest value reported for a home in the US is 115,640 Bq/m^3 [45].

The estimated risk from 20 Bq/m^3 of radon in homes is of the order of 30 fatalities per million person-years, subject to at least a factor of 2 uncertainty due to variation of occupancy and other factors [43]. This estimate should be increased by about 20% for exposures in other buildings and about 10% for exposure to thoron [44]. Outdoors exposures to radon and thoron are negligible by comparison [44]. Hence the average estimated risk from exposures to radon and thoron in Australia is of the order of 40 fatalities per million person-years.

Not including exposure to radon, the average natural background dose to persons at sea level in Australia is approximately 1 mSv per year [46]. This is equivalent to 20 fatalities per million person-years.

The natural background dose rate varies considerably with location and is at least 10 mSv per year in some parts of the world. The component due to cosmic radiation could be increased by more than 0.2 mSv per year (+4 fatalities per million person-years) by living at a high altitude in a mountainous region [7]. Passengers on commercial airline flights are exposed to an average dose rate of 1.35×10^{-3} mSv/hr due to cosmic radiation [35]. Hence, hypothetical additional risks of the order of 1 fatality per million person-years would be incurred due to the additional radiation exposure on one flight round the world per year.

3.5 Medical Exposures to Ionising Radiation

The collective dose from medical exposures is dominated by the contribution from x-ray examinations. Estimates of effective dose equivalent range from less than 0.05 to about 10 mSv per full x-ray examination [35]. The average individual dose from all medical exposures is of the order of 1 mSv per person per year in Australia and other countries with similar medical practices [35, 48]. On the basis of the recommended risk coefficient [31,37] this is equivalent to 20 fatalities per million person-years.

3.6 Meteorite Strikes

A meteorite is a solid chunk of stone or iron which enters the earth's atmosphere from interplanetary space. A meteorite burns up as it passes through the atmosphere but, if it is large enough, a fragment may reach the earth's surface. About 1,500 meteorites with mass at impact greater than about 10kg reach the earth every year. The larger the meteorites the lower the frequency of impact. Many craters scattered over the earth's surface are attributed to the fall of large meteorites. One of the most famous, which is near Winslow in Arizona, has a diameter of 1.2 km and a depth of 175 m, and some even larger craters exist [49].

There is no know case of human death from a meteorite strike, although injuries, property damage and the death of animals have been confirmed [50]. However, meteorites capable of killing humans undoubtedly reach the earth's surface in large numbers [49,51]. The risk is therefore real, although it is very low even in a seemingly crowded world.

Since it appears that impacts are distributed randomly over the earth's surface, an individual's risk of death from being struck by a meteorite can be calculated [49,51]. The relationship between the size of meteorites and their frequency of impact on the earth's surface has been determined by analysis of observations, and the relationship between mass and the lethal area around the impact location has been estimated by Blake allowing for blast effects and the ejection of soil, rock and other missiles [51]. Hence, the risk from meteorite strikes can be estimated as being of the order of 0.001 fatalities per million person-years.

With a world population of 5000 million, an individual risk of 0.001 fatalities per million person-years leads to an estimate of 5 fatalities per year on average, which appears to be inconsistent with the lack of evidence of any such fatalities. However, the major contribution to the risk is from the very large, but very rare meteorites capable of causing enormous damage [51]. This can be demonstrated mathematically and there is no practical possibility of avoiding or significantly reducing this risk. An average of 5 fatalities per year is equivalent to 5000 fatalities every 1000 years. Therefore, the destruction of a metropolitan centre (such as the Sydney Central Business District) would put the death toll well ahead of the average for the next thousand years. Although this is extremely unlikely, it could happen at any time and virtually without warning. A thousand years ago, the world's population was much lower and the risk from meteorites was understood less fully than now.

4 DISCUSSION AND CONCLUSIONS

Tables 11 to 13 present objective, quantitative estimates of some risks to which individual members of the general public are exposed in their private lives and ordinary activities. Risks have been estimated for Australia as a whole and for NSW. Some differences are detailed in Table 14. Otherwise, the estimates are similar for both cases. It was not the purpose of this study to examine hazards in the work-place or extremes of individual behaviour within the community. Occupational risks and unusual risk-taking are therefore excluded as far as possible. The risks are given as averages for the group of people exposed to each risk. In many cases, this is the whole population. These estimates are intended to provide a better understanding of where the main risks lie and what they are, with the hope of assisting in the formulation of appropriate controls leading to a safer general environment.

Tables 11, 12 and 13 each presents essentially the same information in a different format. Table 11 compares individual risks of death on the basis of estimated magnitude alone. These risks all involve:

(i) accidents; and/or

(ii) latent health effects, principally cancer.

Because risks causing direct and delayed fatalities may be viewed differently by society, they are listed separately on Table 12. On Table 13 risks are grouped by the type of risk for comparison. Table 15 gives an abbreviated comparison of selected items in the spectrum of risks.

By far the greatest risks are those due to tobacco smoking and other unspecified environmental causes of cancer, followed by the consumption of alcohol. Risks to the general public from industrial accidents, including risks from nuclear reactor accidents, are towards the lower end of the spectrum. A risk objective of one fatality per million person-years for members of the general public (i.e. more than a thousand times lower than the risk of cancer from cigarette smoking) appears to be reasonably practicable for accidents to industrial plants. However, risks from existing chemical plants are sometimes significantly above this objective.

A range of risks of intermediate size exists due to various domestic, recreational and transportation accidents, which should be regarded as worthy of attention and precautions. However, with the possible exception of motor traffic accidents, these are not generally regarded as serious threats to society. There are also a number of hypothetical risks which may be significant or may be zero, depending upon the validity of the hypotheses upon which they are based. These include exposures to air pollution from burning coal to generate electricity, and exposures to naturally occurring radiation. The radiological risk in Australia from the Chernobyl reactor accident is estimated to be less than or comparable with the risk of being struck by a meteorite.

Reference on Tables 13 and 15 to a risk as "involuntary" means that the risk is not deliberately incurred. This does not mean that the risk is totally outside the control of the risk-taker. For example, risks of cancer are clearly influenced by deciding where and how one lives. This is not just a question of smoking. The large difference in cancer incidence between the UK and Australia demonstrates that there are other major factors. Many of these factors, such as components of air pollution and dietary factors, are well known and are either avoidable by individuals or potentially controllable by society.

REFERENCES

[1] Pochin, E.E. Occupational and other fatality rates. Community Health 6(1): 1974; 1-13.

[2] US Nuclear Regulatory Commission. Reactor Safety Study: An assessment of accident risks in US commercial nuclear power plants. USAEC Report WASH-1400 (NUREG 75/014), NTIS, October 1975.

[3] Kletz, T.A. What risks should we run? New Scientist, 12 May 1977; 320-325.

[4] Grist, D.R. Individual Risk - A compilation of recent British data. UK Atomic Energy Authority Report, SRD R125, August 1978.

[5] Cohen, B.L. and Lee, I-S. A catalog of risks. Health Physics 26; June 1979; 707-722.

[6] Commission of the European Communities, nuclear science and technology. Nuclear and non-nuclear risk - an exercise in comparability. EUR6417EN. Report prepared by Pollution Prevention (Consultants) Ltd., Crawley, England, 1980.

[7] Wilson, R. and Crouch, E.A.C. Risk assessment and comparisons: an introduction. Science, 236; 17 April 1987; 267-270.

[8] HM Health and Safety Executive. The tolerability of risk from nuclear power stations. London, UK, 1988.

[9] Fernandes-Russell, D. Individual Risk Statistics for Great Britain (1980-1984). Research Report No.2; School of Environmental Sciences, University of East Anglia, UK; February 1987.

[10] Australian Bureau of Statistics. New South Wales - Causes of Death 1975 and 1981 to 1986. Australian Bureau of Statistics, NSW Office, Sydney, NSW. (Some additional data has been obtained directly from ABS records).

[11] Official Year Book, New South Wales. Published annually. New South Wales Government, Sydney, NSW.

[12] Australian Bureau of Statistics. Causes of Death 1974, 1975, and 1981 to 1986. Australian Bureau of Statistics, Canberra, ACT (Some additional data has been obtained directly from the ABS records of its NSW office).

[13] Private communication from the statistical service of the State Rail Authority of NSW (1988)

[14] New South Wales Sporting Injuries Committee. Third Annual Report. Report for the year concluded 30 June 1987. SIC, Sydney, NSW.

[15] Australian Bureau of Statistics. General Social Survey: Leisure activities away from home, May 1975. Australian Bureau of Statistics, Canberra, ACT

[16] Department of Sport, Recreation and Tourism. Recreation participation surveys, 1985. Australian Government, Department of Sport, Recreation and Tourism, Canberra, ACT

[17] Private communication from the NSW Police (1988)

[18] Organisation for Economic Co-operation and Development. The Alcohol and Tobacco Issue, Offprint of articles published in "OECD Information" Nos 92-95 and 97 (1983-84).

[19] US Surgeon General. Smoking and health. Circa 1966.

[20] Royal College of Physicians. Smoking and health now. London, UK, 1971.

[21] Doll, R. and Peto, R. The causes of cancer: Quantitative estimates of avoidable risks of cancer in the United States today (Oxford Medical Publications). Oxford University Press; 1981.

[22] Marshall, W. Big nuclear accidents. Proceedings of an International Atomic Energy Agency Conference on Nuclear Power Experience; Volume 4, Nuclear Safety: 53-69; IAEA-CN-42/18; IAEA Vienna, 1983.

[23] Commonwealth Department of Health. Statistics on drug abuse in Australia. AGPS, Canberra, ACT; 1987.

[24] National Health and Medical Research Council. Report of the Working Party on the Effects of Passive Smoking on Health. Adopted at the 101st. Session of the Council in Brisbane, Queensland; June 1986.

[25] Ferrence, R.G., Truscott, S. and Whitehead, P.C. Drinking and the Prevention of Coronary Heart Disease: Findings, Issues and Public Health Policy. J of Studies on Alcohol 47(5) 1986; 394-407.

[26] Knupfer, G. Drinking for Health: the daily light drinker fiction. Brit. J of Addiction (1987) 82; 547-555.

[27] Shaper, A.G., Wannamethee, G. and Walker, M. Alcohol and Mortality in British Men: Explaining the U-Shaped Curve. The Lancet; p.1267; December 3, 1988. (See also the Editorial in the same issue, p.1292)

[28] National Health and Medical Research Council. Is there a safe level of daily consumption of alcohol for men and women? Report to the 102nd session of the Council in Canberra, ACT, December 1986.

[29] Epstein, S.S. The Politics of Cancer, Anchor Press/Doubleday, Garden City, New York, USA; 1978.

[30] US Department of Health and Human Services. Cancer mortality in the United States: 1950-1977. National Cancer Institute Monograph 59; April 1982. National Institute of Health Publication No. 92-2435.

[31] International Commission on Radiological Protection. Recommendations of the ICRP. ICRP Publication 26. Oxford: Pergamon Press; 1977.

[32] Department of Environment and Planning (now Department of Planning). A risk assessment study for the Botany/Randwick industrial complex and Port Botany. Government of NSW, Department of Planning, Sydney; 1985.

[33] Health and Safety Executive. Canvey: an investigation of potential hazards from operations in the Canvey Island/Thurrock Area; 1978. Canvey: a second report. A review of potential hazards from operations in the Canvey Island/Thurrock area three years after publication of the Canvey Report; 1981. London: Her Majesty's Stationary Office.

[34] Multiyear Environmental Plan for the Netherlands 1986-1990. Tweede Kamer den Staten Generaal, Vergaderjaar 1985-1986, 19204 nrs. 1-2. The Netherlands.

[35] United Nations Scientific Committee on the Effects of Atomic Radiation. Ionizing Radiation: Sources and Biological Effects; 1982. Report to the General Assembly, with annexes; UN, New York, 1982.

[36] Camplin, W.C. Coal-fired power stations - the radiological impact of effluent discharges to atmosphere. NRPB-R107. National Radiological Protection Board, Harwell, UK; 1980.

[37] National Radiological Protection Board. Interim Guidance on the implications of Recent Revisions of Risk Estimates and the ICRP 1987 Como Statement. NRPB-GS9, November 1987.

[38] AMA Council on Scientific Affairs. Health evaluation of energy-generating sources. Journal of the American Medical Association, 240(10); 1978. (A full report on this subject was presented by C. John Tupper as Report: C(A-78) and adopted by the AMA House of Delegates on June 21, 1978).

[39] Ferguson, R.A.D. Comparative risk of electricity generating fuel systems in the UK. The Energy Centre, University of Newcastle-Upon-Type, UK; 1982.

[40] Etnier, E.L. and Travis, C.C. Risk of energy technologies. Nuclear Safety, 24(5): September-October 1983; 671-677.

[41] The Electricity Commission of New South Wales. Annual Report 1986.

[42] Morrey, M., Brown, J., Williams, J.A., Crick, M.J., Simonds, J.R. and Hill, M.D. A preliminary assessment of the radiological impact of the Chernobyl reactor accident on the population of the European Community. National Radiological Protection Board: Commission of the European Communities, Health and Safety Directorate. Luxemburg; January 1987.

[43] Jacobi, W. Environmental Radioactivity and Man. The 1988 Sievert Lecture. Proceedings of the Seventh International Congress of the International Radiation Protection Association, Sydney, Australia, 10-17 April 1988; 1558-1572.

[44] Wrixon, A.D., Green, B.M.R. and Miles, J.C.H. Public Exposure to Radon Daughters. Ibid; 201-204.

[45] Solomon, S.B., Peggie, J.R., Wise, K.N. and Paix, D. Radon Levels in Australian Homes, Ibid; 215-218.

[46] Alter, H.W. and Oswald, R.A. Nationwide Distribution of Indoor Radon Measurements. Ibid; 209-213.

[47] Dwyer, L.J., Keam, D.W., Stevens, D.J. and Titterton, E.W. Search for Fallout in Australia from the Christmas Island Tests. The Australian Journal of Science, 20(2); August-September 1957; 39-41.

[48] Swindon, T.N., Morris, N.D. and Solomon, S.B. Contributions to the Genetic and Mean Bone-Marrow Doses of the Australian Population from Radiological Procedures. ARL/TRO17. A report prepared for the National Health and Medical Research Council by the Australian Radiation Laboratory; June 1980.

[49] Hawkins, G.S. The Physics and Astronomy of Meteors, Comets and Meteorites; McGraw-Hill, 1964.

[50] La Paz, L. The Effects of Meteorites Upon the Earth. Advances in Geophysics, Volume 4; Academic Press Inc., 1958; 217

[51] Blake, V.E. A Prediction of the Hazards from the Random Impact of Meteorites on the Earth's Surface. Sandia Laboratories; SC-RR-68-838; 1968.

RISKS TO INDIVIDUALS IN NEW SOUTH WALES

TABLE 11 - COMPARISON OF RISKS BY MAGNITUDE ONLY

	Chances of fatality per million person-years
Smoking (20 cigarettes per day)	
- all effects	5000
- all cancers	2000
- lung cancers	1000
*Cancers from all causes	
- total	1800
- lung	380
Drinking alcohol (average for all drinkers)	
- all effects	380
- alcoholism and alcoholic cirrhosis	115
+Burning coal to generate electricity	
- *total risk from air pollution	0.07 to 300
- maximum radiological risk	0.4 to 5
*Motor vehicle traffic accidents	
- total	180
- pedestrians only	35
*Being at home	
- accidents in the home	110
- +concentration of radon and thoron inside houses	33
*Accidental falls	60
Swimming	50
Maximum risk from potential accidents in chemical plants	
- existing plants	10 to 50
- objective for new plants	1
*+Natural background radiation	
- radon and thoron (total)	40
- other naturally occurring sources (sea level)	20
Playing rugby football	30
Travelling by train	30
Firearms accidents	30
*Homicide	20
*Drowning (all situations)	20
*+Medical exposures to radiation	20

cont next page

TABLE 11 CONT

*Accidental poisoning	
- total	18
- venomous animals and plants	0.1
*Fires and accidental burns	10
Travelling by aeroplane	
- accidents	10
- +cosmic radiation	1
*Electrocution	
- total	5
- non-industrial	3
*Falling objects	3
*Therapeutic use of drugs	2
*Cataclysmic storms and storm floods	0.2
*Lighting strikes	0.1
*Meteorite strikes	0.001
*+The Chernobyl reactor accident	less than 0.001

Notes:

*These risks are averaged over the whole population. Other risks are averaged over members of the group exposed to the risk.

+These are hypothetical risks of delayed fatalities. There is no direct or epidemiological evidence to prove that any risk exists from these causes in the situations which are, or would be, experienced by average individuals. Estimates of risk are based on the hypothesis that evidence can be extrapolated to these situations from conditions (e.g. high levels of exposure to radiation or toxic chemicals) under which harm has been observed.

RISKS TO INDIVIDUALS IN NEW SOUTH WALES

TABLE 12 - COMPARISON OF RISKS BY MAGNITUDE: DIRECT AND DELAYED FATALITIES CONSIDERED SEPARATELY

	Chances of fatality per million person-years
Fatalities Caused Directly by Accidents	
*Motor vehicle traffic accidents	
- total	180
- pedestrians only	35
*Accidents at home	110
*Accidental falls	60
Swimming	50
Maximum risk from potential accidents in chemical plants	
- existing plants	10 to 50
- objective for new plants	1
Playing rugby football	30
Travelling by train	30
Firearms accidents	30
*Drowning (all situations)	20
*Fires and accidental burns	10
*Accidental poisoning	
- total	18
- venomous animals and plants	0.1
Travelling by aeroplane	10
*Electrocution	
- total	5
- non-industrial	3
*Falling objects	3
*Cataclysmic storms and storm floods	0.2
*Lighting strikes	0.1
*Meteorite strikes	0.001
Delayed Fatalities through the Incidence of Diseases	
Risks based upon statistics	
Smoking (20 cigarettes per day)	
- all effects	5000
- all cancers	2000
- lung cancers	1000

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TABLE 12 CONT

*Cancers from all causes	
- total	1800
- lung	380
Alcoholism and alcoholic cirrhosis (average for moderate and heavy drinkers)	800
Delayed Fatalities through the Incidence of Diseases	
Hypothetical risks of delayed fatalities	
Burning coal to generate electricity	
- *total risk from air pollution	0.07 to 300
- maximum radiological risk	0.4 to 5
Natural background radiation	
- *radon and thoron (total)	40
- *radon and thoron (inside homes)	33
- *other naturally occurring sources (sea level)	20
- cosmic radiation (regular airline travellers)	1
*Medical exposures to radiation	20
*The Chernobyl reactor accident	less than 0.001

Note:

*These risks are averaged over the whole population. Other risks are averaged over members of the group exposed to the risk.

RISKS TO INDIVIDUALS IN NEW SOUTH WALES

TABLE 13 - COMPARISON OF RISKS BY TYPE OF RISK

	Chances of fatality per million person-years
Voluntary Risks (average to those who take the risks)	
Smoking (20 cigarettes per day)	
- all effects	5000
- all cancers	2000
- lung cancers	1000
Drinking alcohol (average for all drinkers)	
- all effects	380
- alcoholism and alcoholic cirrhosis	115
Swimming	50
Playing rugby football	30
Owning firearms	30
Transportation Risks (average to travellers)	
Travelling by motor vehicle	145
Travelling by train	30
Travelling by aeroplane	
- accidents	10
- +cosmic radiation	1
Risks Averaged over the Whole Population	
Cancers from all causes	
- total	1800
- lung	380
+Air pollution from burning coal to generate electricity	0.07 to 300
Being at home	
- accidents in the home	110
- +concentration of radon and thoron inside houses	33
Accidental falls	60
+Natural background radiation	
- radon and thoron (total)	40
- other naturally occurring sources (sea level)	20
Pedestrians being struck by motor vehicles	35
Homicide	20
+Medical exposures to radiation	20
Accidental poisoning	
- total	18
- venomous animals and plants	0.1

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TABLE 13 CONT

Fires and accidental burns	10
Electrocution (non-industrial)	3
Falling objects	3
Therapeutic use of drugs	2
Cataclysmic storms and storm floods	0.2
Lightning strikes	0.1
Meteorite strikes	0.001
+The Chernobyl reactor accident	less than 0.001
<u>Risks Imposed upon a Few People</u>	
Maximum risk from potential accidents in chemical plants	
- existing plants	10 to 50
- objective for new plants	1
+Maximum radiological risk from burning coal to generate electricity	0.4 to 5

Note:

+These are hypothetical risks of delayed fatalities. There is no direct or epidemiological evidence to prove that any risk exists from these causes in the situations which are, or would be, experienced by average individuals. Estimates of risk are based on the hypothesis that evidence can be extrapolated to these situations from conditions (e.g. high levels of exposure to radiation or toxic chemicals) under which harm has been observed.

TABLE 14 - DIFFERENCES BETWEEN RISKS AVERAGED OVER THE WHOLE POPULATIONS OF NSW AND AUSTRALIA

Source of Risk	Chances of fatality per million person-years	
	NSW	Australia
Cancers from all causes		
- total	1830	1740
- lung	380	360
Motor vehicle traffic accidents		
- total	181	183
- pedestrian only	34	38
Travelling by aeroplane	2.5	2.8
Travelling by rail	1.9	1.0
Accidental poisoning		
- total	18	13
- venomous animals and plants	0.1	0.3
Falling objects	3	4
Therapeutic use of drugs	1.8	1.6
Cataclysmic storms and storm floods	0.2	0.4
Lightning strikes	0.09	0.13

NOTE: Difference between the figures in Table 14 and in Tables 11,12 13 and 15 are due to:

(i) all risks in Table 14 being averaged over the whole population

(ii) some estimates in Table 14 being quoted with greater accuracy in order to assist the comparison.

RISKS TO INDIVIDUALS IN NEW SOUTH WALES

TABLE 15 - COMPARISON OF RISKS (ABBREVIATED TABLE)

	Chances of fatality per million person-years
Voluntary Risks	
Smoking (20 cigarettes per day)	5000
Drinking alcohol (average for all drinkers)	380
Playing rugby football	30
Transportation Accident Risks	
Travelling by motor vehicle	145
Travelling by train	30
Travelling by aeroplane	10
"Involuntary" Risks to the Whole Population	
Cancer from all causes	1800
+Air pollution from burning coal to generate electricity	0.07 to 300
Accidents at home	110
+Natural background radiation (sea level)	60
Pedestrians being struck by motor vehicles	35
Lightning strikes	0.1
Meteorite strikes	0.001
Other Risks Averaged over the Whole Population	
+Medical exposures to radiation	20
Electrocution (non-industrial)	3
Therapeutic use of drugs	2
Potential "Involuntary" Risks to a Few People	
Maximum risk from accidents in chemical plants	1 to 50
+Maximum radiological risk from burning coal to generate electricity	0.4 to 5

Note:

+These are hypothetical risks of delayed fatalities. See footnote + on Tables 11 and 13