HEALTH WATCH

The Australian Institute of Petroleum Health Surveillance Program

Twelfth Report

2005

The University of Adelaide
Department of Public Health

This Twelfth Report contains an analysis of deaths occurring up to the end of 2001, and cancers registered up to the end of 2000.

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Message from the Executive Director, Australian Institute of Petroleum

For the past 25 years, the Australian Institute of Petroleum has sponsored the independent Health Watch study to monitor the health of petroleum industry employees.

Health Watch follows the long-term health of employees, through a detailed analysis of job types, workplace practices, lifestyle influences, and illness and causes of death. The health and well being of petroleum industry employees is then compared with data for the Australian community. The study provides valuable insights into the influences on the health of employees, such as, the relationship between the incidence of various cancers and working in the industry, and the measurable effect of lifestyle in improving the health of employees.

In the past, the Health Watch research program has been conducted by the University of Melbourne, Deakin University and most recently the University of Adelaide. With the retirement of Dr Richie Gun, the principal researcher at University of Adelaide, the study will now be conducted by Monash University. AIP welcomes Associate Professor Malcolm Sim of Monash University to the Health Watch study and is certain its fine traditions will be maintained.

AIP sincerely thanks Dr Gun for his dedicated service to the Health Watch study since 1999 and wishes him all the very best in his new endeavours. The tireless efforts of Dr Gun and his co-researchers have ensured Health Watch has maintained its professional standing and international credibility.

Health Watch provides valuable information to participating companies and to the Australian community generally. Findings of the study assist in developing policies and programs that are providing safe and healthy working environments for employees.

AIP is pleased to receive the Twelfth Report.

Dr John Tilley

Executive Director

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AUSTRALIAN INSTITUTE OF PETROLEUM

COMPANIES WITH EMPLOYEES PARTICIPATING IN *HEALTH WATCH*

Caltex Oil Australia (incorporating Total, Ampol Australia and Australian Petroleum Pty Ltd
BP Australia Limited (incorporating Amoco)
ExxonMobil Australia Ltd (formerly Esso Australia Ltd and Mobil Oil Australia Limited)
Santos Ltd
The Shell Company of Australia Limited
Chevron Australia (formerly West Australian Petroleum Pty Limited (WAPET))
Woodside Offshore Petroleum Pty Ltd
Airport Fuel Services
Castrol Australia Pty Ltd (up to 30/6/94)

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The *Health Watch* cohort study was designed by Professor David Christie.

The study team gratefully acknowledges the advice and assistance of Dr A Robert Schnatter, of ExxonMobil Biomedical Sciences, New Jersey, USA in the conduct of the *Health Watch* study.

We are indebted to the contact persons in each of the participating companies. *Health Watch* is dependent on them for follow-up information.

We thank the Australian Institute of Health and Welfare for its ongoing co-operation which has made it possible for *Health Watch* to report on the occurrence of cancer and mortality. We also thank the staff of State death and cancer registries for confirmation of information, the Australian Electoral Commission, the Health Insurance Commission, the Department of Immigration, Multicultural and Indigenous Affairs, and the New Zealand Office of Health Statistics.

The method of treating follow-up time of persons lost to contact (Section 2.4.1) was adapted from a methodology developed by the Australian Institute of Health and Welfare.

Finally we wish to thank the many employees who participated and assisted the team.

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PREFACE

Health Watch is an epidemiological health surveillance program established by the Australian Institute of Petroleum.

Health Watch consists of a prospective cohort study of all-cause mortality and cancer incidence and a case-control study of leukaemia and benzene exposure. The cohort study was carried out by the University of Melbourne from 1980 to 1998, and by the University of Adelaide since 1999. Researchers from Monash and Deakin Universities took over responsibility for the case-control study in 1999.

Health Watch covers those petroleum industry employees from all major oil and gas companies who voluntarily joined the program at their work sites across Australia. About 95% of the industry's employees approached to participate, from refineries, gas plants, distribution terminals, and production sites, onshore and offshore, have joined *Health Watch*.

Employees in the industry were enrolled in the study by participating in one or more of four industry surveys over the 1980s and 1990s, using a detailed job and health questionnaire. This process obtains information on job tasks, on lifestyle factors including smoking and alcohol, and on health status. An employee is taken into the cohort analysis following a survey interview or after having served five years in the industry, whichever is later, and remains in the *Health Watch* cohort for life. Employees who have left employment with participating companies are contacted periodically to obtain an update of their employment and their health status. The cohort is now closed to further entry.

The employing companies maintain the flow of information on entrants, job changes and retirements. Contact with cohort members is maintained until death. Death registrations and cancer registrations are obtained from the Australian Institute of Health and Welfare, which compiles the National Death Index and the National Cancer Statistics Clearing House on behalf of all State Death and Cancer Registries.

The main output of the study is analysis of mortality and cancer incidence. These are carried out by comparing the rates of deaths and cancers in the *Health Watch* cohort with the rates in the general Australian population. Deaths and cancers in the *Health Watch* cohort are obtained by matching the *Health Watch* data with State and national registries. For the first time, this report also includes information based on self-reports from *Health Watch* members on conditions related to asbestos exposure.

Results have been published in periodic *Health Watch* reports and in scientific medical journals. The findings from the previous (11th) *Health Watch* Report have been published in the February 2004 issue of the journal Occupational and Environmental Medicine.[37] Results are also published on the websites of the University of Adelaide and the Australian Institute of Petroleum. Summary reports are distributed to all employees and former employees in the *Health Watch* cohort.

SUMMARY OF *HEALTH WATCH* RESULTS TO DECEMBER 2001

This update of the *Health Watch* cohort is based on national mortality data to 31 December 2001 and cancer incidence data to 31 December 2000. 16547 men and 1356 women are included in this analysis. 1147 men and 27 women in the cohort had died by the end of 2001.

The age-adjusted death rate in men is significantly less than in the general Australian male population. Death rates in all major disease categories - heart disease, cancer, respiratory disease, diseases of the digestive system, and external causes (accidents, violence etc) – are also significantly less than the corresponding rates for the male population.

The chance of getting most types of cancer is the same for men in this industry as for all Australians. However some cancers – mesothelioma, melanoma and prostatic cancer - have been occurring at significantly higher rates than in the general population, and there is a raised rate of bladder cancer of borderline significance. On the other hand the lung cancer rate, and the death rate from lung cancer, is lower than in the general population.

18 mesotheliomas have occurred in the cohort, 15 in refinery maintenance workers and operators. It is likely that several of these cancers are related to asbestos exposure in refineries, mostly before the 1970s, although some are likely to have resulted from asbestos exposure occurring prior to entering the oil industry. In addition 37 cohort members have reported other non-cancer conditions arising from asbestos exposure. Only one cohort member has died from asbestosis.

Asbestos exposure can also cause lung cancer. Some overseas studies have reported a higher rate of lung cancer in refinery maintenance workers compared with other refinery workers. An analysis in the *Health Watch* cohort has shown that maintenance workers have the same lung cancer rates as non-maintenance workers, although that analysis was based on small numbers. This suggests that very few, if any, asbestos-related lung cancers have occurred from working in the Australian petroleum industry, particularly so since the overall lung cancer rate in the *Health Watch* cohort is so low.

There is a statistically significant increase in the incidence of melanoma in males. The rate does not increase with increasing duration of employment or with increasing exposure to hydrocarbons. Similarly, prostatic cancer shows no association with duration of employment or increasing hydrocarbon exposure. On this basis and from what is known of the causation of these two cancers, it is therefore unlikely that either is caused by a factor in the workplace in this industry.

Although an increased incidence of bladder cancer was reported in the previous *Health Watch* report, this updated analysis shows only a small elevation in incidence which is not statistically significant. There was no evidence to suggest a bladder cancer risk in this industry. However the analysis confirmed the known association between bladder cancer and smoking.

Contrary to findings in previous *Health Watch* reports, there is no significant excess of leukaemia. Acute non-lymphocytic leukaemia (ANLL), which is the leukaemia most likely to be causally associated with benzene exposure, is not present in significant excess. There are too few of these leukaemias for statistical analysis according to duration of employment or increasing hydrocarbon exposure, but all cases were clustered in the medium to higher exposure categories, ie none of the 11 cases occurred in subjects in the 3 lowest exposure categories. Although workers in this industry have no greater probability of developing ANLL than others in the general population, it is still unclear whether benzene exposures, particularly past levels of exposure, have been high enough to cause leukaemia.

Health Watch continues to show a strong association between smoking and cancer, particularly lung cancer and bladder cancer, and dying from heart disease. Altogether smoking is estimated to have contributed to over one third of all male deaths in the cohort.

Health Watch carries out analyses of members in some particular occupational groups, and a small but marginally significant cancer excess was found in tanker drivers. However when examining the specific cancer types, the only cancer with a significantly raised rate in drivers was cancer of the kidney (12 cases compared with 6 expected on the basis of population rates). Evidence of an association between hydrocarbon exposure and cancer of the kidney from other studies is inconclusive, and the number of cases in drivers in *Health Watch* is too low to do any meaningful analysis of any work-related cause. The possibility of a causal relationship between cancer of the kidney and hydrocarbon exposure warrants further study.

Of the 27 female cohort members who have died, 18 were from cancer. This high proportion of deaths from cancer is in fact due to very low death rates from other causes. The standardised death rate from cancer in females is no different from that of the Australian female population in general.

47 cancers have occurred in women. As with men, the chance of getting most types of cancer is the same for women in this industry as for the general female population. No cancer type has occurred in a statistically significant excess.

The proportion of women in the *Health Watch* program remains very small and this prevents much detailed analysis. Women in the industry have death rates which are lower than that of women in Australia generally. No cancer type has occurred in a statistically significant excess, but the numbers of individual cancer types is too low for meaningful analysis.

1 INTRODUCTION

1.1 Industry Background

The petroleum industry became established in Australia in the first decade of the twentieth century when international companies began importing fuels and lubricants. Refineries were built from 1910 onwards and nationwide distribution networks were set up, with the distances involved leading to considerable cooperation between the competing companies which were servicing a relatively small, scattered population. World War II was followed by a period of rapid population expansion. Refinery and associated petrochemical plant development took place with major refineries in three States coming on-stream during the 1950s. Technological development has continued to date in line with the worldwide oil and gas industry. Australian refineries and terminals are technologically advanced although relatively small in capacity. Environmental legislation and emission controls are amongst the most stringent in the world, and this has resulted in changes in technology, eg introduction of bottom loading of road and rail tankers and hydrocarbon vapour recovery systems.

Local production of both oil and gas has grown, and from the 1970s the production of light crude oil and of natural gas made Australia a net energy exporter. Although development of new and existing fields continues around the continent and overall production continues to grow, Australian petroleum requirements are now partly met from imports. Moreover in the last ten years the industry has undergone considerable reorganisation leading to refinery operations becoming less labour-intensive, with a significant proportion of work now being undertaken by contractors. Consequently fewer people are employed by the petroleum companies than when *Health Watch* was established, especially in the refining sector.

The petroleum industry is represented by the Australian Institute of Petroleum (AIP) which was founded in 1975. AIP established a Health Committee in the same year.

1.2 Development and Design of the *Health Watch* Surveillance Program

In 1980 the Australian Institute of Petroleum contracted the Department of Community Medicine (now Department of General Practice and Public Health) at the University of Melbourne to establish an epidemiological health surveillance program to monitor major health outcomes of employees in the industry. The program, called *Health Watch,* has been running continuously since that time, monitoring major health outcomes in the **cohort**[†] of people who work in the industry. As Australia's oil and gas development has expanded, new companies and projects entered the program. Entry to the cohort has now closed.

In 1987 an overall excess of lymphohaematopoietic cancers (all leukaemias, multiple myeloma and all lymphomas except Hodgkin's disease) was seen in the cohort. To evaluate the relationship between workplace exposures (specifically benzene) and the excess of these cancers, a nested case-control study was commenced within the cohort in 1988.

In 1999 the University of Melbourne relinquished responsibility for *Health Watch*, and the AIP contracted the University of Adelaide to continue the cohort study. Responsibility for the case-control study was passed to a consortium at Monash University and Deakin University. With the approval of the University of Adelaide Ethics Committee, information for conduct of the case-control study was provided to the consortium.

Although all the major petroleum companies joined the *Health Watch* program of the AIP, participation by individual employees is voluntary. The health outcomes monitored are deaths from any cause and the incidence of cancer. These measures provide a broad view of

[†] A **cohort** was originally a group of Roman soldiers who marched together. The *Health Watch* cohort is made up of people working in the industry who are marching together through time.

the health experience of people working in the participating companies over the past five decades. Cancer Registry data available since about 1970 has allowed cancer incidence to be recorded and analysed.

Figure 1 is a representation of the *Health Watch* cohort structure.

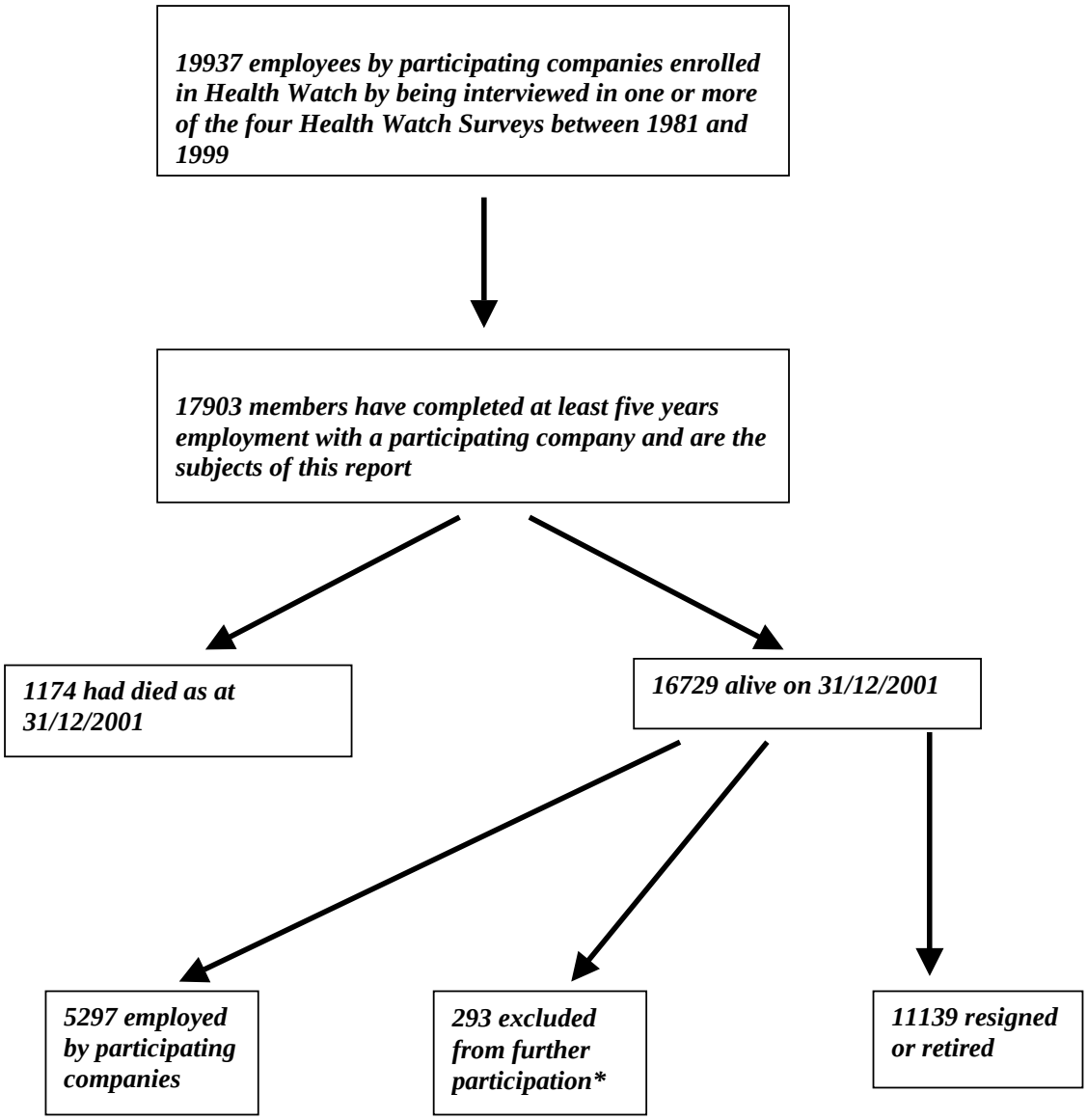

Figure 1: *Health Watch cohort structure*

* Exclusion due to withdrawal of Castrol from AIP in 1994

1.3 Reporting Results

Results are reported to the *Health Watch* Advisory Committee comprising:

- representatives of the Executive Director of AIP
- representatives of member companies of the petroleum industry
- persons appointed by the ACTU representing trade unions in the industry
- representatives from the research team at The University of Adelaide.

Results are published in this report, and in leaflets which are provided to all *Health Watch* sites for distribution to employees, and sent by post to all individuals who have resigned or retired.

Publications for medical and scientific journals are prepared on parts or the whole of this research program. A paper on the previous update (the basis of the 11th *Health Watch* Report) was published in the journal Occupational and Environmental Medicine in February 2004.[36] The leaflets are prepared by the *Health Watch* project team and set out the purpose, methods and results in straightforward language.

1.4 Consent and Confidentiality

1.4.1 Confidentiality

All information is kept at the University of Adelaide and results are published in such a way that no individual member of the cohort is identifiable. The University's Guidelines on Confidentiality of Research are followed and only members of the *Health Watch* team have access to the data. Under the terms of the contract between the AIP and the University, all members of the team are bound by formal confidentiality agreements.

All *Health Watch* approaches to cohort members are assessed and approved by the Advisory Committee. Project team members are aware of the need to avoid distress in their dealings with individuals or their families. Medically confidential matters relating to individual members of the cohort are handled within the project by the Director who is a medical practitioner.

Health Watch obtains information from subjects, their next-of-kin, families, relatives, employers, and the Australian Institute of Health and Welfare, which maintains the National Death Index and the National Cancer Statistics Clearing House on behalf of State registries. Information is also obtained direct from State cancer registries. Signed consent was obtained from subjects at the time of initial interview to obtain relevant information, and specifically to search cancer registries and to approach employers for job histories. Continuity of consent was obtained at each subsequent survey. Information regarding the consent and its implications was provided to potential entrants at briefing sessions on site, in writing, and at the time of interview. A small number of cohort members declined to give consent: these subjects are still cohort members but are not included in cancer registry searches (unless deceased).

1.4.2 Ethics committee approval

The *Health Watch* program deals with matters relating to medical and human research ethics, informed consent, and confidentiality. The work of the *Health Watch* cohort study has been approved by the Human Research Ethics Committee of the University of Adelaide.

To obtain identifiable cancer records it has also been necessary to obtain approval from ethics committees of the Australian Institute of Health and Welfare, and from individual State cancer registries. Fortunately this has not been difficult to obtain because written consent was obtained from subjects at the time of recruitment into *Health Watch*. Nevertheless privacy laws still present several obstacles to the efficient conduct of research, resulting in inadequate

data in some circumstances, as well as a great deal of time and effort applying and responding to ethics committees of State and national data repositories.

1.5 Present Work

This report is based on the work carried out in the *Health Watch* program in the period 2001-2004. The 11th *Health Watch* Report gave the results on the state of the cohort as at 31 December 1998. Since the publication of the 11th Report the vital status of each subject (ie whether living or deceased) on the cutoff date of 31 December 2001 has been ascertained as far as possible, and mortality rates compared with national rates. Registration of all cancers takes longer than death registration, so that at the time of analysis national cancer rates are only available for comparison up to 31 December 2000. Accordingly the analysis of cancer rates covers the period up to that date.

2 METHODS

2.1 Study design

The overall design of the *Health Watch* program is that of a prospective cohort study. Subjects recruited in successive surveys are followed up by periodic searches of death registry and cancer registry data. Vital status (whether subjects are living or dead) is checked from information from cohort members and next of kin, and sources such as the Australian Electoral Commission. Death rates by cause and cancer rates by site (eg lung cancer) are periodically compared with national death rates and cancer rates. The current report gives the results of cancer rates in the cohort compared with national cancer rates as at the end of 2000, and of death rates in the cohort compared with national death rates as at the end of 2001.

Within the cohort there has also been a case-control study of the association between benzene exposure and certain cancers of the blood, bone marrow and lymphatic systems. The past benzene exposure of cohort members with these cancers is estimated, and compared with the estimated exposure of a sample of cohort members who do not have these cancers. The comparison enables an estimation to be made of any association between these cancers and exposure to benzene. This aspect of the study has been carried out by a consortium from Monash and Deakin Universities, and was concluded in 2000. The report can be accessed on the AIP website (www.aip.com.au).

2.2 Formation and maintenance of the cohort

2.2.1 Recruitment

Recruitment to the cohort has been by participation in an interview carried out in four successive surveys.

All employees of petroleum companies operating in Australia working in refineries, storage and distribution terminals, offshore and onshore production facilities and airports were eligible to become members of the *Health Watch* cohort. For reasons of cost, employees working in capital city offices and sites with fewer than 10 employees were excluded.

Altogether four surveys were carried out before the cohort was closed to further entry in 2000. The First *Health Watch* Survey was carried out in 1981-83. The Second *Health Watch* Survey in 1986-87, the Third *Health Watch* Survey in 1991-93 and the Fourth *Health Watch* Survey in 1996-2000. The repeated surveys allowed updating of information for each member of the cohort population still employed, and the recruitment onto the cohort register of new employees in the industry.

Site rolls were provided by the participating companies, and these were used to make contact with each employee to offer the opportunity to participate in the survey interview.

During the periodic surveys, entry to the *Health Watch* cohort register was gained through voluntary attendance on site for personal interview with a project team interviewer. Full and informed consent procedures were undertaken for each employee during pre-interview briefings to employees in groups and individually at the time of interview. The major purpose of the briefings during surveys was to explain the nature of the program, the implications of entry and the consent procedures, and to provide feedback to existing and prospective cohort participants.

Surveys have used almost identical questionnaires and the methodologies have remained comparable, although some changes in technology have occurred. Most of the fourth survey was conducted by the University of Melbourne using direct input to portable notebook computers. Interviewers were trained in the application of the questionnaire. The interviewer had access to all the previous job history of current members and could accept potential

corrections to previous data. Not all sites were visited for the Fourth Survey, but further questionnaire responses were obtained by mail and by telephone.

2.2.2 Entry to the cohort

Subjects were admitted to the cohort after completing a survey interview or upon completion of five years of employment with a participating company, whichever was later. Thus subjects who had already completed five years of employment at the time of interview were admitted to the cohort immediately.

2.2.3 Information collected at survey interviews

Demographic information collected included name, sex and date and country of birth.

Employment information was obtained in some detail. Subjects were asked their occupation, the area they worked in, and all tasks performed and the proportion of the working week spent in each.

During the first two surveys, as decided at the outset of the program, details were collected by interview on the current job held by each participant. Although some history of jobs prior to entering the petroleum industry was collected, the jobs carried out in the petroleum industry prior to the current job were only sought for up to five years prior to the first interview.

By 1990 it was apparent that more complete job histories were required for the purposes of a nested case-control study within the cohort. This study was needed to investigate the excess which had appeared in the cohort of certain cancers of the blood and bone marrow, and it was important to investigate the likelihood that the excess was related to occupational exposure to benzene. Accordingly in 1991-3, during the third survey, all participants were asked at interview about all jobs held during their employment in the petroleum industry. The complete job histories were collected from nearly all current employees who participated. In a few cases, where complete employment histories were not obtained, or later proved to be incomplete, the computerisation of the fourth survey allowed gaps in the information to be more easily identified and corrections to be made at the time of re-interview. By this time 4000 men and 250 women had left the industry after having had at least 5 years experience in it. Their complete job histories had to be collected by including questions relating to this in the annual health letter sent to all retirees. This was done in 1994-5. Retirees were generally longer serving employees than those still employed, and therefore had longer gaps in the job histories previously collected. For many reasons, their complete job histories are likely to be less certain than those still employed and interviewed in the third survey. The response rate from retirees to requests for complete job histories was about 80%. Some job history information for deceased members was completed by surviving partners or family. These more complete job histories were used to assess benzene exposures in the case-control study, which was the subject of a separate report by a consortium from Monash and Deakin Universities.

Lifestyle information was also obtained. Standard questions on present and past smoking habit were asked of each participant, and a lifetime smoking history obtained.

Information on alcohol consumption was collected during the survey interview. Each cohort member interviewed was asked: "In an average week, on how many days would you have a drink?" and "How many drinks would you usually have on those days?" A drink is defined as a standard measure as served in a hotel or bar. The average number of drinks taken weekly can then be estimated.

Health information, related to current or significant past health problems, was also collected.

2.2.4 Information from participating companies

Participating companies have periodically provided lists of new employees, transfers, resignations and retirements. Following the decision to close the cohort to further entry in 2000, companies have continued to provide lists of transfers, resignations and retirements annually. This information from companies is used to compute the date of termination of employment of all subjects.

2.2.5 Coding of employment data for assigning estimates of hydrocarbon exposure

Exposure to hydrocarbons is one obvious measure of exposure to be considered for this industry. Petroleum industry occupational hygienists have considered exposure to hydrocarbons to be low, relative to Occupational Exposure Standards prevailing at various epochs, in all jobs and workplaces.

Direct measurements of exposure for particular jobs, eg, in "parts per million in air, time weighted average" are generally unavailable for the several decades of interest to *Health Watch*. In the absence of such information from companies, estimates of exposure have been derived from the job details provided at the survey interviews.

A precise *job description code* is used as the principal exposure index for the cohort analyses, based on collection of a job history from each participant.

The job classification developed for the American Petroleum Institute is used[1,2] and this has been modified on the advice of occupational hygienists in the industry where additional Australian job categories were required. This classification, referred to as the Dictionary of AIP Jobcodes, enables an employee in the cohort to be categorised by the processes on which they work and can act as a link to exposure information.

Each employee's job history was recorded at a survey interview for any of the 50 processes in the Job Dictionary. Categorisation for analysis is on the process where most working time is spent as recorded at the first interview, and this is identified as the "AIP Jobcode". Where a person worked on more than six processes concurrently, they were coded as "multiprocess"; this code also applies where the employee is rotated routinely around a number of processes.

To obtain some exposure classification, the processes or operating units used in the AIP Jobcodes have been classified by a committee of petroleum industry occupational hygienists into seven categories representing increasing potential for exposure to total hydrocarbons. This ranking represents the exposure situation in the early 1980s. During 1994-6 the previously used total hydrocarbon rankings were reviewed and amended in the light of additional job history information. The total hydrocarbon categorisation is still regarded as a crude measure of exposure. Distribution of *Health Watch* person-years across these categories is unequal, with many jobs being placed in the default category, category 4 in the middle of the range. A more rigorous, quantitative methodology for assessing benzene exposure as been developed for the *Health Watch* case-control study. However the assessment has been applied to only 474 cohort members, and cannot therefore be applied to the cohort analysis. The complete report of the *Health Watch* case-control study can be accessed at the Australian Petroleum Industry website (www.aip.com.au).

2.2.6 Participation rates in *Health Watch* Surveys

For the first two surveys a record was compiled of the proportion of subjects interviewed. In both surveys 93% of employees on the site rolls agreed to participate. A similar figure is not available for the third survey. However an estimate has been made based on two figures: (i) the number of subjects employed at the time of the Third Survey but who were not recruited until the Fourth Survey, and (ii) the number of subjects participating in either or both of the

First and Second Surveys who were not interviewed for the Third Survey although according to company records were still employed. On this basis it is estimated that 84% of eligible employees were interviewed in the Third Survey. In the Fourth Survey not all worksites were visited. Further contact was made by mailing out questionnaires and by telephone, but the response rate was not as high as that obtained by on-site interview. 73% of *Health Watch* members still employed were re-interviewed in the Fourth Survey, and in addition 1479 new subjects were recruited. The numbers and proportions of subjects recruited in each survey are shown in Table 1, and it can be seen that the incompleteness of the Fourth Survey affected recruitment from offshore production.

Table 1: Recruitment by Workplace type and by survey

Workplace Type	Recruited in: Survey 1		Survey 2		Survey 3		Survey 4		Total
	N	%	N	%	N	%	N	%	N
Refinery	4807	41.6	931	25.9	1239	37.6	704	47.6	7681
Terminal	5097	44.1	1238	34.4	1101	33.4	429	29.0	7865
Airport	426	3.7	104	2.9	57	1.7	47	3.2	634
Onshore Production	833	7.2	1094	30.4	795	24.1	295	19.9	3017
Off Shore Production	398	3.4	233	6.5	105	3.2	4	0.3	740
Total	11561	100.0	3600	100.0	3297	100.0	1479	100.0	19937

2.2.7 Follow-up

Efforts are made to maintain contact with all *Health Watch* subjects. This is of importance in updating personal information; in particular it is one of the main means of determining subjects' vital status. In addition subjects are sent periodic reports of the progress and findings of *Health Watch*. A report of the findings in the 11th *Health Watch* Report was sent to all subjects in early 2002.

Although the cohort has been closed and no further surveys are planned, a questionnaire was sent in 2003 to all subjects still employed by participating companies. The questionnaire sought information on current tasks, health problems and current smoking history. Of 4950 personally addressed questionnaires sent out through companies, 1950 (40%) replied.

Subjects who were no longer employed by participating companies were sent a reply-paid questionnaire with their 2002 letter. This was a continuation of the longstanding practice of sending out a periodical Health Letter to members who have retired or resigned. The questionnaire seeks information on current employment, any health problems and an update of smoking history (whether smokers have quit and when).

Altogether 11968 questionnaires were sent out and 7399 replies (62%) received. 1091 questionnaires were returned unopened and there was no reply from 3478.

Further efforts were made to contact the non-respondents by telephone. McGregor Tan Health Research was provided with a list of 3927 subjects and obtained 1439 responses (37%).

The names of non-respondents including those "Returned to Sender, and of retired members for whom no mailing address was known, was submitted to the Australian Electoral

Commission for matching with the electoral roll. Of 6019 names submitted, 3866 were matched. (The Commission will only supply names of close matches.)

The names of those still not contactable were submitted to the Health Insurance Commission (HIC), which retains records of Medicare services for each quarter for the last 5 years. The HIC was not willing to provide addresses to *Health Watch*, but was able to provide the names of close matches of subjects who had had a Medicare service in the previous five years, and the quarter in which the service was provided (but with no information on the nature of the service). Of 3163 names submitted, matches were obtained of 1841 *Health Watch* subjects.

The New Zealand Office of Health Statistics was sent a list of 77 subjects lost to contact who had been born in New Zealand. The Office identified 39 matches, but only 9 replied to a questionnaire sent to the given address: in fact some of the non-respondents to this letter in fact had had recent Medicare services in Australia.

A request to the UK Office of National Statistics to provide similar information was refused.

A list of remaining subjects lost to contact was submitted to the Department of Immigration, Indigenous and Aboriginal Affairs (DIMIA), which maintains a record of movements in and out of Australia. Of 731 subjects, 223 were identified: the most recent movement of 159 was entry into Australia, and of 64 it was departure.

In early 2004 a check of data from companies revealed names of several subjects apparently still employed but who had not been contacted for some years, some in fact not since the First *Health Watch* Survey. (According to the data, one subject was apparently still employed at the age of 84!) Therefore the names of all subjects recruited in any of the first three surveys and listed as still employed were submitted to the companies for review. As a result of the further checking 359 names were found to be no longer employed by a participating company. Of these, 195 were identified in a further search of the electoral roll, 95 of the remainder were found to have had a Medicare service in the last five years, and of the remainder, 51 were found in movement records of DIMIA.

2.3 Health Outcomes

Health Watch subjects provided information on their health in the successive *Health Watch* Surveys and in questionnaires sent to subjects no longer employed by participating companies. The only health outcomes statistically analysed are cause-specific death rates and cancer rates. These analyses are based not on information supplied by subjects, but from national mortality and cancer records. However health information supplied by subjects is useful in verifying matches with official records. For example, if there is uncertainty as to whether a name appearing in a cancer registry is the same individual as a person with the same name in the *Health Watch* cohort, identification is assisted if the person has notified *Health Watch* of that cancer.

Also, for the first time, this *Health Watch* report presents details of conditions caused by asbestos exposure based on self-reports from subjects. Although such notification is likely to be incomplete, it has provided a valuable insight into this important public health issue.

2.3.1 Mortality records

Consideration of all causes of death can provide a broad picture of major health patterns, as these are directly linked to death outcomes. Some medical conditions, where death is not a consequence, eg, *osteoarthritis*, cannot be analysed by *Health Watch*, since there is no population registry of diseases other than cancer. Others, where there is a link between number of deaths and overall morbidity (ill-health), such as *ischaemic heart disease* and *accidents*, can be reliably explored using *Health Watch* information.

For the purpose of mortality analyses, death records are obtained from the National Death Index (NDI), maintained by the Australian Institute of Health and Welfare (AIHW). The NDI

is compiled from death records from State Registries of Births, Deaths and Marriages, and causes of death, coded by The Australian Bureau of Statistics (ABS). ICD-9 coding was used for deaths occurring up to 1996. Deaths occurring since 1996 are coded in ICD-10. The coded deaths by cause are used to compile national annual cause of death statistics (mortality rates).

Periodic searches are made of the National Death Index (NDI) by submitting the list of *Health Watch* members, with dates of birth, to the AIHW, which uses a matching program to identify likely and possible matches. These are supplied to *Health Watch* for decision on which names on the list are to be accepted as true matches. Matching is sometimes made difficult because many State death certificates gave only the age (in years) of the person at death, rather than the date of birth. Final decisions on doubtful matches are based on information already held by *Health Watch*, such as information on deaths from next of kin or from companies. Sometimes it is necessary to obtain a copy of the death certificate, where certain items of information (eg occupation, place of birth) can be compared with information held by *Health Watch.*

The coded deaths identified as true matches are used for comparison with Australian statistics resulting in the calculation of a comparative index called the Standardised Mortality Ratio (see section 2.4.2). The analysis is updated to the time when the NDI is considered to be complete. At the time of this analysis the NDI is considered to have a record of all deaths up to 31 December 2001, which has therefore been determined as the cutoff date.

2.3.2 Validation of mortality records

As discussed in the previous section, mortality analysis is carried out by comparing death rates in the *Health Watch* cohort with national rates. For such an analysis to be valid the data sets must be comparable. This means that all deaths in *Health Watch* subjects must be included in the data set from which national mortality tables are computed. To ensure that this is so, it is necessary to ensure that all deaths known to *Health Watch* are located in the NDI.

Health Watch does not rely solely on NDI searching to learn of deaths. Notification of deaths in currently employed members of the *Health Watch* population is supplied by the employer, and deaths of members who have left the industry may be notified by next of kin in response to the mail contact. As a quality control measure, deaths notified from these sources are checked to ensure that they are all found in the NDI search. Where the death has not been found in the search, State death registries are consulted to assist in the search. If a match is found, the matter is referred back to the NDI. If a match is then found, the explanation is that the matching program failed to detect the death in the first instance, and the death is then confirmed. In some instances deaths are found to have occurred overseas: such deaths are excluded from the mortality analysis, as they are not included in the NDI from which national mortality tables are derived. All deaths reported by employers or next of kin have been confirmed except one, where NDI data were conflicting. This death, and the person-years of follow-up time of the subject, have been omitted from the analysis.

However it is not possible to be sure that all deceased subjects are identified in the matching program. For example, when subjects have changed their name (eg females after marriage or divorce) it is likely that their deaths will never be detected. Therefore absence of a person's name from the NDI does not necessarily mean that he/she is alive. Subjects not found on the NDI or in any of the other data bases are classified as "vital status unknown". (As discussed in the section 2.4.1, the follow-up time of such a subject ceases from the date of last contact or the cutoff date of 31 December 2001, whichever is the sooner.)

2.3.3 Cancer incidence

Data on cancer *deaths* have been available for many years, based on information on medical certificates of cause of death. However, the major question for studies of the effects of occupational (or other) exposure is how many people develop cancer, which is fortunately not the same as how many people die of cancer. For most cancers, treatment prevents death from the cancer, or prolongs life considerably. Since the death rate from cancer is so strongly related to the effectiveness of treatment, cancer incidence (ie the occurrence of cancer) is more important in determination cancer causation.

A distinguishing feature of the *Health Watch* program, amongst most cohort studies in the petroleum industry around the world (or indeed any industry), is its ability to consider the occurrence or incidence of cancer which is not necessarily fatal. This is made possible by the existence of population-based Cancer Registries in all Australian States. Cancer is a notifiable disease in all States and Territories and all cancers, except non-melanotic skin cancer, and all deaths are legally notifiable in Australia. Cancer registration has been universal in Australia and complete since 1982. Written consent has been obtained from most subjects to search for their names in cancer registry data.

Until the mid-1990s, *Health Watch* obtained information on cancer incidence by submitting the names and dates of birth of all subjects to State cancer registries. Since then matching has been made by matching with the National Cancer Statistics Clearing House (NCSCH), a compilation of data from all State and Territory registries, from which national cancer incidence tables are generated. Information from South Australia and Victoria is obtained direct from the State registries because of privacy provisions applying in those States.

The analysis is updated to the latest time at which the NCSCH is considered to be complete. In this report the cutoff date is 31 December 2000. (Complete enumeration of cancers takes longer than enumeration of deaths.)

Incidence is regarded as the first known occurrence of a primary cancer. To conform to the rules of the Cancer Registries, only cancers with a C coding in the International Classification of Diseases Revision 10 (ICD-10) manual are regarded as "cancers" for incidence purposes. Non-melanotic skin cancers are not generally recorded by the Cancer Registries, so that for the analyses comparing skin cancer rates in the *Health Watch* cohort with national rates, only melanomas are included.

2.3.4 Cancer Incidence Validation

The 2004 search of the National Cancer Statistics Clearing House revealed a number of inconsistencies between identified cancers and cancers already in the *Health Watch* database. In several cases cancers previously notified direct by State registries were missing from the NCSCH. The missing cancers were resubmitted for a repeat search in the AIHW, and all but 23 cases were identified. Each of the 23 cases was referred to the relevant State registry, and 9 of the cancers were identified. Some of the 14 cancers not found in the State registry had been reclassified as non-invasive, or had occurred overseas, but in others the absence of the cancer registration was unexplained. The 9 cases confirmed by the State registries were again submitted to the NCSCH, but only 2 were identified. Cancers not found in the NCSCH were excluded from the analysis, since for a valid comparison of cancer incidence with the general population, cancer registrations in the *Health Watch* cohort must also appear in the NCSCH data (from which national cancer incidence tables are derived).

It was not possible to test for registrations in the Victorian and South Australian registries that had not propagated to the NCSCH, as privacy provisions prevent searching the NCSCH for registrations from those States.

The absence from the NCSCH of some cancers previously notified by State registries raised concern that there may be other cancers missed in more recent searches, since responsibility

for matching had been transferred from the States to the AIHW: in other words, whether some State registrations had not propagated to the NCSCH. To test for this possibility the entire data set was submitted to the Western Australian Cancer Registry for matching. This revealed 4 cancers not found in the 2004 search of NCSCH. On submitting these 4 cases to NCSCH, only one was confirmed. In view of the low yield from this exercise, it was decided that submitting the entire data set to NSW, Queensland and Tasmania would not be worthwhile. (As explained in the previous section, the complete data set had already been submitted to the Victorian and South Australian registries.)

Health Watch also learns of cancer cases by direct notification from subjects. Of these self-notifications, all but12 were identified in the 2004 search of NCSCH. A search was made for them in State cancer registries, and 3 of the 12 were found. These 3 cancers were submitted to the NCSCH, and 2 were found.

Another source of cancer notification is death registrations where cancer is given as the cause of death. All but 16 cancers identified in this way were found in the 2004 search of the NCSCH. Each of the 16 not found was referred to the relevant State Cancer registry. This subsequent search identified 13 cancers which were diagnosed and registered after the cutoff date of 31 December 2000, and were therefore not included in the analysis. Of the other three, one cancer was found to have been diagnosed before the subject had entered the cohort and therefore excluded, one was not found at all, and the other was found in the State registry and then confirmed in the NCSCH. Only the last of these was included in the analysis.

2.4 Analysis

The basic analysis in *Health Watch* is to compare the death and cancer rates of the *Health Watch* cohort with the corresponding rates in the general population. The rates are expressed as the number of deaths as a proportion of the person-time of follow-up.

The total person-time is the total of the follow-up time of each individual. For example if 20 people are each followed up for 10 years, the total person-time would be 200 person-years. If 2 cancers occurred in these 10 people over that time, the cancer rate would be 2 per 200 person-years.

2.4.1 Follow-up time

The definition of subjects' follow-up time (usually expressed in person-years) is therefore critical.

Follow-up time commences on admission to the cohort, which as described in Section 2.2.2 occurs on the date of initial Survey interview or on completion of five years of employment in the industry, whichever is the later.

Follow-up time stops on the date of death or the cutoff date (31/12/01 for mortality, 31/12/00 for cancer) or the date of emigration, whichever occurs sooner. Subjects who have emigrated cease to be followed up after leaving Australia: if they die or develop cancer while outside Australia their death or cancer does not appear in the data on which national death and mortality tables are based: since such deaths or cancers will not be included in the analysis, the person's corresponding follow-up time is excluded from the denominator.

Some subjects' vital status is unknown on the cutoff date and the subject is therefore deemed to be lost to contact. There are a number of possible explanations:

- Emigration
- The subject may have died in Australia but the name was not detected in the matching program. This is particularly likely if the person has had a name change
- The subject may be alive and living in Australia but not on the electoral roll or on Medicare records

- The subject may be on the electoral roll and/or Medicare records but not detected in the matching program. This is quite likely as the Australian Electoral Commission and the Health Insurance Commission will not supply information if the match is not close.

For subjects lost to contact on the cutoff date, follow-up time ceases from the date of the last contact. This may be the date of matching the subject on the electoral roll, the last recorded quarter on which a Medicare service was rendered, or entry into Australia on the DIMIA search. (If the subject's last entry on the DIMIA entry is a departure, he/she is classified as having emigrated on that date). Alternatively it may be the date when the employer advised that the person had left the company, or when a reply had last been received to the questionnaire.

It will be seen that there are two categories of subjects lost to contact: those who will be found on the NDI when they die and those who will not. For example a subject who is not on the electoral roll or had a Medicare service in the last 5 years may nevertheless be living in Australia and be found in the NDI when he dies. On the other hand a person who has emigrated and remains overseas will never appear in the NDI, and a woman who has changed her name may be on the NDI under her changed name, and a match with the NDI will never be found.

In previous *Health Watch* reports subjects not found to be deceased were treated as living, and all had their follow-up time extended to the cutoff date. To the extent that the total person-time includes subjects lost to contact who would never be located in the NDI the total person-years is over-enumerated, leading to an *underestimate* of the mortality (or cancer incidence) rate relative to the national rate.

An alternative is for the person-time of subjects lost to contact before the cutoff date to be censored on the date of last contact. To the extent that the total person-time includes some subjects who will be found on the NDI when they die, the total-person-years of follow-up is under-enumerated, leading to an *overestimate* of the mortality (or cancer incidence) rate relative to the national rate.

Thus the *true* rate, relative to the national rate, lies between the estimates made by these two methods. As will be shown in the next chapter (Tables 5 and 6) the difference between the two estimates is so small as to be insignificant, due to the very small proportion of person-years lost to follow-up. Therefore for all other analyses only the latter method, ie censoring from date of last contact, is used.

The foregoing method for computing follow-up time applies only to subjects no longer employed by participating companies. Those still employed by participating companies are assumed to be alive on the cutoff date.

2.4.2 Measures of Comparison: the SMR and SIR

Health Watch compares death and cancer rates in the petroleum industry with the national rates to produce measures called the *standardised mortality ratio (SMR) and the standardised incidence ratio (SIR).*

The SMR is a measure of the death rate occurring in the *Health Watch* cohort population compared with the death rate occurring in the national population. This ratio can be measured for the whole cohort population or any subset, for any particular cause of death, or for all causes. The SMR tabulations show the number of deaths "observed" in the *Health Watch* population and the calculated "expected" number which would arise in a group of the same age and sex in the Australian national population.

When epidemiological analysis is carried out on death rates, comparison is made between the group of workers and the national or other reference population from which they come. Comparison of the "observed" number of deaths recorded by *Health Watch*, to the "expected"

number, as shown in the tables, produces the SMR. If the deaths in the *Health Watch* cohort are occurring at the same rate as they do in the national population, then the SMR will be 1.0. If the SMR is greater than 1.0 then deaths in the cohort are occurring more frequently than would be expected if national death rates applied to the *Health Watch* population. If the SMR is less than 1.0 then deaths in the cohort are occurring less frequently than they do in the national population. Thus the SMR forms a measure of the risk of death in the *Health Watch* cohort compared to Australians as a whole, with age and sex taken into account.

The expected number is computed from the national rates (by age, sex and year of occurrence) and the number of person-years spent by cohort members in each age, sex and year-of-occurrence stratum. The standard rates used for deaths which occurred up to the end of 1985 are the average national rates across 1981-5; those used for deaths in 1986-1990 are the average rates for 1986-90; deaths in 1991-1995 are the average rates for 1991-95, and those used for deaths in 1996-2000 are the average rates for 1996-2000 and for 2001 for rates for that year.

For measuring the risk of developing cancer the standardised incidence ratio (SIR) is calculated. Incidence measures cancer as it arises as opposed to when it causes death. All cases of cancer except non-melanotic skin cancers are reported to the relevant State Cancer Registry by the treating medical specialist. Providing that cancer registration is reliable, as it is in Australia, cancer incidence measures are a more valid indicator of cancer risk than are cancer mortality measures. This is because many persons who get cancer do not die from their cancer, but from other causes. The SIR is calculated in a similar way to the SMR and is age-standardised. To calculate SIRs, calculation of "expected" numbers, from national cancer incidence is required. The national data are derived from the NCSCH.

The SMR and SIR are accompanied by 95% confidence intervals. The SMR or SIR as shown is actually a statistical estimate of the "true" ratio. However, the true ratio cannot be known exactly, and the best we can do is to calculate a spread of estimates of the SMR or SIR within which we can be 95% certain that the "true" figure will lie. This spread is called the confidence interval.

The choice of 95% confidence intervals is commonly used in health studies, and simply means that the certainty of the result is such that the odds of the true figure lying outside the confidence interval are about 1 in 20.

The importance of this lies in the interpretation of the SMR or SIR in terms of risk appraisal. Where a ratio is higher than 1.0 then a risk may be present, but if the lower end of the confidence interval extends below 1.0 then it is possible that the real ratio is 1.0 or less and no risk is present. However, when the lower end of a confidence interval is above 1.0 then we can say with some certainty that a risk does exist. This is often described as being a statistically significant result.

2.4.3 Analysis by Workplace Type

In addition to comparing the overall *Health Watch* cohort with national rates, separate analyses have been performed on different categories of workplace: five types of workplace are in this Report, namely: Refinery, Terminal, Airport, Onshore production and Offshore production. Where a subject has worked in more than one workplace type, he/she is assigned to the workplace worked most recently.

2.4.4 Analysis by Job Type

Analysis of health outcomes for specific categories of job (single AIP Jobcode) is dependent on there being sufficient members of the cohort who carry out this particular job. Using the data available up to 2001 for reliable analysis on other AIP job codes allows for analysis of the jobs with the largest numbers of employees in the industry, these being "Driver, Refinery

Operator, Terminal Operative and Maintenance (terminal or refinery)". The latter two categories are composite groups brought together to allow for job type analysis.

2.4.5 Confounding Variables

Confounding variables are other factors (aside from occupational exposure) which may be operating in members of the cohort population in ways which affect the health outcomes being studied. Where these factors can have large influences on outcomes, such as with smoking and cancer, it is necessary to account for these factors. Even small differences in exposure to tobacco smoke can cause large differences in lung cancer rates. To cause confounding a variable has to be a cause of the disease in its own right, and to be unequally distributed between the different groups being compared.

What is a confounder?

A confounder is a term used in epidemiological studies in which a group with a particular exposure history is compared with a group without the exposure. A confounder is a variable which can lead to a misleading result. To cause confounding a variable has to be a cause of the disease in its own right, and to be unequally distributed between the different groups being compared.

For example the lung cancer rate in a group of workers exposed to a carcinogen (say asbestos) may be compared with the rate in a group of workers not exposed. Since smoking can cause lung cancer, smoking prevalence is a potential confounder in this analysis. If the group exposed to asbestos happens to have a higher proportion of smokers than the comparison group, an excess of lung cancer in the former may be incorrectly attributed to the asbestos, whereas it may be partly or wholly due to the difference in smoking. In such a case the variable "smoking prevalence" is a confounder.

Differences in risk between various exposure groups could therefore be masked or falsely calculated if confounding variables are not allowed for.

In the SMR and SIR estimates, adjustment is made for confounding by age and calendar year. These confounding variables were used, as they are known to have major effects in the Australian population. For example, in the case of calendar year, the incidence rate and mortality rates of many cancers have undergone marked changes over the period since *Health Watch* began. Confounding by sex is avoided by separate analyses of males and females.

Adjustment for tobacco smoking is more difficult. Although *Health Watch* has obtained good smoking data on its subjects, comparable data are not readily available for the general population. Data on smoking prevalence in the Australian population by age group in the mid-1990s are available,[3] and by comparing this with the smoking prevalence of the *Health Watch* cohort, and by using information on the strength of any association between smoking and a particular disease, it is possible to estimate the likelihood that a particular outcome is smoking-related. Another indirect method of estimating whether the smoking prevalence differs from the general population is to examine the cancer rate or death rate from diseases almost exclusively due to smoking, such as emphysema and laryngeal cancer.

2.4.6 Other measures of comparison – the RMR and RIR

Health Watch uses internal comparisons to look at the health effects of working in the petroleum industry. Where a measure or ranking of exposure can be obtained a *relative mortality ratio (RMR) or relative incidence ratio (RIR)* can be calculated, comparing those who have less exposure to those who have more. (SMRs and SIRs are generally unsuitable

for comparing different categories of exposure.) Generally, we would expect that if the exposure is causing the effect, then those with more exposure, in time or intensity, would suffer more effect on their health, and this would show up in the health outcomes. This is known to apply, for example, for the number of cigarettes smoked and its outcome in terms of risk of getting lung cancer. It applies for most exposures which create risks to health.

For any particular exposure or category, a baseline group is chosen, and represented as having a risk of 1.0. All other exposure groups or ranks are then calculated for risk in comparison with the baseline. The measures of these comparisons are the relative mortality ratio (RMR) when death is the outcome or relative incidence ratio (RIR) when a case of cancer is the outcome.

As discussed in Section 2.2.5, to obtain some exposure classification, the processes or operating units used in the AIP Jobcodes were classified by a committee of petroleum industry occupational hygienists into seven categories representing increasing potential for exposure to total hydrocarbons. Category 1 are those with no exposure, and category 7 those with the highest exposure rankings.

The "baseline" category for these analyses is usually the least exposed group. For smoking it is people who have never smoked. For hydrocarbon exposures it is Category 1, who are office and service workers. If the RMR or RIR for any group in *Health Watch* is 1.0 then deaths or cancers, respectively, are occurring at the same rate as they do in the baseline group. If the RMR or RIR is greater than 1.0 then deaths or cancers are occurring more frequently than they do in the baseline group. If the RMR or RIR is less than 1.0 then deaths or cancers are occurring less frequently than they do in the baseline group.

The RMR and RIR analyses are done using Poisson regression models. All analyses are adjusted for age and calendar period of follow-up. Where smoking is a possible cause of an outcome an adjustment is also made for smoking by categorising the cohort subjects into ever smoked or never smoked.

2.4.7 Time-related Variables

RMRs and RIRs are used to examine three time-related variables which might throw light on any occupational cause for excess death rates or cancer rates. These are:

- period of first employment in the industry
- duration of employment in the industry
- time from first employment in the industry.

Period of first employment analyses may provide clues as to whether exposures in particular calendar periods may have had risks attached to them. Because technology and work procedures, and therefore exposure, have been constantly changing in the industry over the past decades, health outcomes must be explored to ascertain whether they are related to historical exposures or reflect current risks. If hazardous exposures were present in higher concentrations in the 1950s than in the 1960s, and if some cancer types occurred at a higher rate in the former period, it could be inferred that the exposure may be a cause of that type of cancer.

The analyses for ***duration of employment*** in the industry help in investigation of whether an excess death rate or cancer rate may be work-related, even though the specific causal agent in the workplace is not known. It may be expected that total or cumulative exposure will increase with increasing duration of employment. Therefore if the workforce is divided into different categories according to duration of employment the death or disease rate will, if related to an exposure at work, increase with increasing employment duration. Where a subject leaves and later returns to work with a participating company, the time away is deducted from the total duration.

Consideration of elapsed ***time from first employment*** to diagnosis of cancer or death is an attempt to explore what latency periods might be involved with the development of disease, particularly cancer.

"Employment" here refers to employment with one of the participating companies. The date of commencement was obtained from subjects in the survey interviews. Termination dates are obtained from companies. (NB Duration of employment should not be confused with follow-up time, which continues after subjects cease working for participating companies.)

2.4.8 The special case of drivers

In recent years most participating companies have outsourced tanker drivers' duties to transport contractors. Many tanker drivers who formerly worked for participating companies now work for contractors but perform identical duties to those previously performed. Although the contractors are not members of the Australian Institute of Petroleum, it has been possible to identify many such tanker drivers from their responses to the health questionnaire. In such cases the drivers have been classified as still "employed".

Numerous other *Health Watch* members have continued to work in the industry for nonmember companies of AIP. However they perform a variety of tasks not readily assigned to the API job coding system, so their duration of employment is treated in the standard manner.

2.4.9 Analysis by Hydrocarbon Exposure

RIRs are also compared between categories of hydrocarbon exposure. The coding of jobs and assignment of hydrocarbon exposure ranking are described in section 2.2.5.

For the RIRs, two measures of hydrocarbon ranking are used: highest hydrocarbon ranking job ever held, and hydrocarbon ranking of the job held longest.

2.4.10 Adjusting for confounding by smoking

The confounding effect of smoking is more readily dealt with in RIR analyses, since unlike SIR analyses, no reference to national smoking rates is required. Therefore direct adjustment has been made for the confounding effect of smoking in estimating relative rates for cancers related to smoking. For the purposes of these adjustments, smokers are categorised into two categories – ever smoked *vs* never smoked.

2.5 Deletion of subjects

Twelve cohort members have indicated that they do not wish to participate further in *Health Watch.* Their follow-up time has been excluded retrospectively ie back to their enrolment, and they have been excluded from the analyses.

3 GENERAL RESULTS FOR THE COHORT

Results are reported for cause of death (mortality) and cancer incidence, for men and women in the cohort. Because of the small number of women, analyses cannot be reliably done to the same level of detail as for men.

The results come from analyses of various occupational factors and categories, smoking and alcohol. Account is taken of age through standardisation. Diseases and cancer types are grouped into major categories for which comparisons are made with national mortality and cancer incidence data obtained from the Australian Institute of Health and Welfare.

3.1 The Cohort Population

3.1.1 Description of Cohort Population at 31 December 2001

There are 16547 males and 1356 females in the *Health Watch* cohort population included in the current analysis. This reflects the preponderant employment of males in the industry. The cohort was closed in 2000 at the end of the Fourth *Health Watch* Survey. However since entry into the cohort starts from the date of the first interview or on completion of five years of service, whichever is the later, there is still a small number of subjects interviewed who have not yet been admitted to the cohort. These are subjects who were recruited in the Fourth Survey 1996-2000 but who had not yet completed 5 years of service at the cutoff date of December 2001.

The state of the cohort as at 31/12/2001 is shown in Table 2.

Table 2: State of the cohort as at 31/12/2001

	Male	Female	Total
Died in Australia	1147	27	1174
Still employed	4976	321	5297
Excluded from further participation[a]	220	73	293
Retired from industry	10204	935	11139
Lost to contact as at 31/12/2001	*608*	*124*	*732*
Emigrated[b]	*12*	*3*	*15*
Overseas Deaths before 31/12/2001[c]	*11*	*0*	*11*
Total	16547	1356	17903

a Exclusion due to withdrawal of one company from AIP and a small number of subjects who withdrew
b Follow-up time of subjects known to have emigrated ceases from estimated departure date
c Overseas deaths are not included in the estimates of mortality rates

The table shows that 732 cohort members (4.1%) were lost to contact on the cutoff date – 608 males (3.6%) and 124 females (9.1%). The relatively high rate of loss to contact for female subjects is due to their greater likelihood of change of name. If a subject changes her name without the knowledge of *Health Watch*, it is not possible to match her in the National Death Index, the electoral roll, Health Insurance Commission records or in Cancer Registries.

The age of the cohort is indicated in Table 3, which shows the distribution of year of birth of the cohort.

Table 3: Distribution of year of birth

Year of Birth	Males		Females		Total	
	N	%	N	%	N	%
1900-1919	78	0.5	1	0.1	79	0.4
1920-1929	1674	10.1	53	3.9	1727	9.6
1930-1939	2881	17.4	144	10.6	3025	16.9
1940-1949	4826	29.2	270	19.9	5096	28.5
1950-1959	4819	29.1	398	29.4	5217	29.1
1960-1969	2055	12.4	396	29.2	2451	13.7
1970-1979	214	1.3	94	6.9	308	1.7
Total	16547	100.0	1356	100.0	17903	100.0

Because the number of new entrants is now relatively small in relation to the whole cohort, the age distribution is moving towards an older population. This factor strongly influences the death rate from most non-infectious diseases, as well as increasing the incidence (rate of occurrence in the population) of cancer. Consequently, when estimates are made of the risk of death or disease from any particular cause in the *Health Watch* population compared with the general population, allowance must be made for the fact that the increasing age of the *Health Watch* cohort itself will increase the probability of death or disease such as cancer.

3.1.2 Person-years of observation in the cohort

With each succeeding calendar year, the number of years of observation increases for each surviving member of the cohort population. Each subject completes a person-year of observation for each year since entry into the cohort until death. The number of person-years of observation of the cohort is the sum of the person-years contributed by each cohort member. *Health Watch* has now accumulated 242367 person-years of observation in men and 14904 person-years in women. The accumulation of person-years by calendar period is shown in Table 4. The calendar periods listed in this table are used in the standardisation of mortality rates against the Australian death rates.

Table 4: Person-years of observation

Sex	Number of subjects	1981-1985	1986-1990	1991-1995	1996-2000	2001	Total
Males	16547	29326	56378	68,368	73037	15258	242367
Females	1356	1323	2951	4253	5202	1176	14904

Subjects are classified as lost to contact if their vital status on the cutoff date of 31/12/2001 is not known. In fact many of these had been located a short time before the cutoff date, and relatively few have remained untraced for a long time. Consequently, although 4% of the cohort has been lost to contact as of the cutoff date, the percentage loss of observation time from loss of contact is only 1.3% in men and 4.9% in women.

3.2 All-cause mortality

Up to the 31st December 2001, 1147 deaths had occurred in males and 27 in females.

In estimating the mortality rate of the *Health Watch* population relative to the Australian population (the Standardised Mortality Rate or SMR), there is a degree of uncertainty due to lack of knowledge on whether subjects lost to contact are actually alive and living in Australia. As explained in the previous chapter (Section 2.4.1), since some of those lost to contact are undoubtedly alive and living in Australia, their death, when it occurs, will be recorded in the NDI. This means that their person-years of follow-up should be included in the total follow-up time. Since it is not known how many subjects lost to contact are alive and living in Australia, there is uncertainty as to how many of the subjects should be included in the calculation of the total person-years of follow-up. Therefore two methods of estimating person-years have been used. In the first, the follow-up time of all subjects lost to contact is excluded from the date of last contact; so that it is assumed that none of the subjects lost to contact will ever be identified in the National Death Index. In the second, the follow-up time is extended to the cutoff date of 31/12/2001, so that it is assumed that *all* of the subjects lost to contact will in time be found in the National Death Index. The true follow-up time lies between these two extremes. These estimates of follow-up time are used to calculate the SMR. Thus there are two estimates of SMR, with the true SMR lying somewhere between the two estimates.

The SMR estimate with follow-up time of subjects lost to contact excluded from the date of last contact, is shown in Table 5.

Table 5: All-cause mortality by sex, standardised for age and calendar period of follow-up – estimated upper limit of SMR

Sex	Person-Years	Observed	Expected	SMR	95% C.I.
Male	242367*	1147	1584.96	0.72	0.68 - 0.77
Female	14906*	27	37.62	0.72	0.47 - 1.04

* Follow-up time of subjects lost to contact ceases from date of last contact.

The SMR estimate with follow-up time of subjects lost to contact included up to the cutoff date of 31/12/2001 is shown in Table 6.

Table 6: All-cause mortality by sex, standardised for age and calendar period of follow-up – estimated lower limit of SMR

Sex	Person-Years	Observed	Expected	SMR	95% C.I.
Male	245597*	1147	1607.35	0.71	0.67 - 0.76
Female	15673*	27	38.83	0.70	0.46 - 1.01

* Follow-up time of subjects lost to contact is included up to cutoff date 31/12/2001

Comparison of Tables 5 and 6 shows that whether or not the follow-up time of subjects lost to contact is included makes very little difference to the result – in males the estimate varies by 0.01 (ie 1%) and in females by 0.02 (2%). The reason is that only a very small percentage of follow-up time is unaccounted for in the tracing of subjects. In fact the variation between the two estimates is less than the random error indicated from the confidence intervals.

Therefore for all subsequent analyses in this report only one method of estimating SMR (and SIRs for cancer) is used, ie the method used in deriving Table 5. Estimates of SMR and SIR could therefore be overestimates, but the error is trivial.

The SMR for males continues to show that the death rate in this workforce is significantly lower than in the general population (adjusting for age differences and the general increase in life expectancy occurring in the Australian population in recent decades).

This low mortality rate is often noted in working groups and is known as the "healthy worker effect".[4,5] One cause of the "healthy worker effect" is the relative social and economic advantage of employed people, especially people with relatively secure employment. Unemployed people as a whole tend to have lower socioeconomic status, which commonly accompanies lower income, fewer years of education and lower health status, with higher age-adjusted mortality rates than employed people. Hence when the mortality of occupational cohorts is compared with that of the general population, the rate is higher in the latter because it includes many socially disadvantaged people whereas the workforce does not. Another factor is that people with life-threatening conditions, such as cancer, tend not to seek or obtain employment after diagnosis: this further lowers the mortality rate in the workforce compared with the general population, especially in the years immediately following recruitment of subjects into the cohort. In the Australian petroleum industry the "healthy worker effect" is very strong, with SMRs for men in the industry comparable to the lowest recorded in overseas occupational studies.

A common finding with the "healthy worker effect" is that it decreases as cohorts age, that is, the SMR tends to increase with time, approaching the general mortality experience of the population. This tendency is only slightly in evidence so far, as is evident from comparing these results with the previous analysis, given in the 11th *Health Watch* Report. In the 11th Report subjects lost to contact were included up to the cutoff date, so that such a comparison needs to be made with Table 6. The SMR in males is now 0.71 compared with 0.69 in the previous analysis when the cutoff date was 31/12/1998.

In females the SMR lower estimate is 0.70 and the upper estimate 0.72. The lower estimate of 0.70 is appropriate for comparison with the previous estimate of 0.60 in the 11th *Health Watch* report. There has thus been a very marked increase in the SMR for women over the last 4 years. The estimate of SMR compared with the general Australian females population is of marginal statistical significance (95% confidence interval 0.46-1.01).

3.3 Results in Females

The ability of *Health Watch* to carry out analysis of the data for women continues to be limited because of the small number of women in the study population.

3.3.1 Mortality by Major Cause for Females

Table 7 shows the mortality by separate major cause for females. Because of the small number of women in the industry, cancer and ischaemic heart disease are the only major disease categories where more than one death has been recorded. Mortality from cancer is almost identical to that of the general female population. For ischaemic heart disease the rate is slightly greater than in the general population, but the estimate is based on only 6 deaths. The extraordinarily low mortality for other causes of death is difficult to explain. A possible partial explanation is that some of the women who are lost to contact have died but their names not detected in the search of the National Death Index because of a change of name.

Table 7: Mortality by major cause, females

	Observed	Expected	SMR	95% C.I.
Cancer	18	17.54	1.03	0.61 - 1.62
Ischaemic heart disease	6	4.80	1.25	0.46 - 2.72
All Other Causes	3	15.28	0.20	0.04 - 0.57
All Causes	27	37.62	0.72	0.47 - 1.04

3.3.2 Cancer in Females

The overall and site-specific cancer incidence rates in females are shown in Table 8. Overall the standardised incidence ratio (SIR) is slightly lower than the population rate (SIR = 0.94, 95% confidence interval 0.69-1.24), based on 48 cases.

Table 8: Cancer incidence by major anatomical site, females

Anatomical Site	Observed	Expected	SIR	95% C.I.
Colon	6	5.62	1.07	0.39 - 2.32
Melanoma	9	6.16	1.46	0.67 - 2.77
Breast	14	17.63	0.79	0.43 - 1.33
Cervix	3	2.24	1.34	0.28 - 3.92
Bladder	2	0.64	3.13	0.38 -11.30
Pancreas	2	0.66	3.05	0.37 -11.00
Lung	2	2.83	0.71	0.09 - 2.56
Thyroid	3	1.21	2.47	0.51 - 7.22
Other	7	14.16	0.49	0.20 - 1.02
All cancers	48	51.15	0.94	0.69 - 1.24

There were no cases of leukaemia in females.

No cancer type has occurred in a statistically significant excess. However all comparisons are based on very low numbers. For the same reason the cancer data for females cannot be analysed reliably to show the distribution by workplace types or time variables. Nor can they be analysed by any exposure measures, as nearly all the observed person-years of hydrocarbon exposure for women in *Health Watch* are in the lowest exposure categories.

Results for females in Health Watch

The proportion of women in the Health Watch program remains very small and this prevents much detailed analysis. Women in the industry have death rates which are lower than that of women in Australia generally. No cancer type has occurred in a statistically significant excess, but the numbers of individual cancer types is too low for meaningful analysis.

3.4 Mortality in Males

3.4.1 All-cause Mortality and Time Relationships

Internal comparisons have been carried out for all causes of death combined to identify any association with the era of first employment in the industry, duration of employment in the industry, and time lapse between first employment in the industry and death. All analyses have been adjusted for age and calendar period of follow-up.

All-cause mortality by period of first employment

Table 9 shows the mortality rates of male cohort members according to the period of first employment in the industry. The comparisons are made with the category of most recent entrants to the industry – subjects who have started since 1975.

Table 9: All-cause mortality by period of first employment, adjusted for age and calendar period of follow-up

Period of First Employment	Person-Years	Deaths	RMR	95 % C.I.
Post 1975	119541	207	1.00	
1965-74	76505	345	1.16	0.96 - 1.40
1955-64	31408	363	1.34	1.08 - 1.67
Pre 1954	14913	232	1.26	0.98 - 1.61

Test for heterogeneity p = 0.06
Test for trend p = 0.06

The relative mortality rate for all causes combined is higher for men who entered the industry at all prior periods compared with those who entered after 1975, and there is a marginally significant trend to increasing all-cause mortality with earlier date of first employment in the industry. The relatively high mortality for those employed in the earlier periods is in fact likely to be due to a very low absolute mortality rate in the baseline group, who have entered the industry since 1975. If an external comparison is made between this baseline group and the general population, the resulting SMR is 0.61, whereas the SMRs of the other categories are all above 0.70. Generally SMRs of different subcategories cannot be compared with each other, but this analysis suggests that the trend to increasing RMR with earlier date of first employment is due to a low death rate, in absolute terms, in those subjects who entered the industry most recently. This is probably a manifestation of the "healthy worker effect"

discussed in Section 3.2, which is commonly found to decrease (ie the SMR increases), as cohorts are followed for increasing time.

Alteration in smoking patterns could also be a contributing factor. There is evidence that the fall in smoking prevalence in Australian males over recent decades has varied between occupational categories.[3,6] If successive entrants to the oil industry have reduced rates of smoking in comparison with other men of the same age, a reducing relative mortality over time could result.

All-cause mortality by duration of employment

Table 10 shows the mortality rates of male cohort members according to the duration of employment in the industry. The comparisons are made with the category of shortest duration in the industry – subjects who were employed between 5 and 9 years. (It should be noted that individual subjects can contribute to person-years in more than one category as their duration of employment increases).

Table 10: All-cause mortality by duration of employment, adjusted for age and calendar period of follow-up

Duration of Employment	Person-Years	Deaths	RMR	95 % C.I.
5-9 Years	55444	80	1.00	
10-15 Years	57967	156	1.17	0.88 - 1.55
16-19 Years	46787	174	1.06	0.80 - 1.41
20-24 Years	33161	160	0.96	0.72 - 1.29
>=25 Years	48987	577	1.21	0.93 - 1.59

Test for heterogeneity p = 0.08
Test for trend p = 0.22

Compared with the baseline group employed for 5-9 years, the mortality rate from all causes combined is also higher in all categories of duration of employment greater than 9 years, although the trend for increasing relative mortality according to duration of employment is not statistically significant. The findings are similar to those relating to period of entering the industry, and are largely due to a low absolute mortality rate in the baseline group employed for 5-9 years. The SMR for this group was 0.59 compared with a range of 0.63 to 0.79 for the other categories. (SMR data are not shown in the Tables). This is also likely to be due to the low mortality rate of those who entered the industry most recently, since those employed longest are likely to also be in the group who entered the cohort in earlier years.

All-cause mortality by time since first employment

Table 11 shows the mortality rates of male cohort members according to the time since first employment in the industry. The comparisons are made with the category of shortest duration in the industry – subjects who were employed between 5 and 9 years. (It should be noted that individual subjects can contribute to person-years in more than one category as their time since first employment increases).

Table 11: All-cause mortality by time since first employment, adjusted for age and calendar period of follow-up

Time Since First Employment	Person-Years	Deaths	RMR	95 % C.I.
5-9 Years	38956	42	1.00	
10-15 Years	50049	87	1.19	0.81 - 1.75
16-19 Years	46839	114	1.12	0.76 - 1.66
20-24 Years	38102	142	1.13	0.76 - 1.68
>=25 Years	68420	762	1.32	0.90 - 1.94

Test for heterogeneity p = 0.33
Test for trend p = 0.10

There is no significant trend in mortality with increasing time since first employment, although as with the two previous analyses the RMR is raised in all categories compared with the baseline category of subjects first employed in the previous 5-9 years. External comparison with the general population again shows that this is probably due to a very low standardised mortality ratio (SMR) in the baseline category of 0.54, compared with a range from 0.64 to 0.78 in the other categories (SMR data not shown in the Tables).

3.4.2 Mortality by Major Cause

The SMRs for major categories of cause of death are shown in Table 12. In all major categories the observed number of deaths is less than expected, and so all SMRs are below 1.0. The upper limits of confidence intervals are all below unity (1.0), ie mortality rates are significantly lower than in the general male population in all major categories of cause of death.

Table 12: Mortality by major cause – males

Cause	Observed	Expected	SMR	95 % C.I.
Cancer (Malignant)	459	553.09	0.83	0.76 - 0.91
Ischaemic heart disease	295	389.62	0.76	0.67 - 0.85
Stroke	50	79.77	0.63	0.47 - 0.83
Respiratory disease	79	99.79	0.79	0.63 - 0.99
All diseases of the digestive system	34	64.06	0.53	0.37 - 0.74
External Causes (eg accidents, violence, suicide)	100	153.92	0.65	0.53 - 0.79
All other causes	130	244.71	0.53	0.44 - 0.63
All causes	1147	1584.96	0.72	0.68 - 0.77

Ischaemic heart disease mortality

Ischaemic heart disease mortality, based on 295 male deaths, is low with an SMR of 0.76, with the upper limit of the confidence interval at 0.85. This low death rate would suggest that the incidence of ischaemic heart disease itself in this cohort is also low, and comparable with that in the more advantaged groups in Australian society. As discussed later in this report, the prevalence of smoking in this cohort is very similar to that of the Australian population. It is likely however that there are important differences between the smoking habits of the smokers in the *Health Watch* cohort and the smokers in the general population. The occurrence of heart disease depends not only on whether the person does or does not smoke, but on factors such as the number of cigarettes smoked, age at starting and tar content, as well as how recently former smokers quit. Variations in these factors could account for differences in heart disease rates even though the actual smoking prevalence is the same in the *Health Watch* cohort as in the general population.

Accidental death

Accidental death, which by definition includes homicide and suicide, has occurred at a significantly lower rate compared with the general male population - SMR 0.65, 95% confidence interval 0.53 - 0.79.

3.4.3 Cancer incidence and mortality – males and females

The cases (incidence) of cancer and the death rates (mortality) from cancer are dealt with together in this section. Cancers are now classified under the International Classification of Diseases, Revision 10 by morphological type (ie, where it arises in the body) and/or by histology (cell type). Cancers occurring in *Health Watch* members are analysed according to workplace type, smoking effects and exposure to hydrocarbons.

Tables 13 and 14 show the cancer incidence and cancer mortality in the *Health Watch* population.

The standardised incidence ratio (SIR) for cancer in males is slightly greater than that of the general population, but the increase is not statistically significant (SIR 1.02, 95% confidence interval 0.96-1.08). In females the incidence rate is slightly less than in the general population, but the decrease is not statistically significant (SIR 0.94, 95% confidence interval 0.69-1.24).

Table 13: All-site cancer incidence, males and females

Sex	Person-Years	Observed	Expected	SIR	95% C.I.
Males	227111	1232	1210.50	1.02	0.96 - 1.08
Females	13728	48	51.15	0.94	0.69 - 1.24

Table 14: All-Site cancer mortality, males and females

Sex	Person-Years	Observed	Expected	SMR	95% C.I.
Males	242367	459	553.09	0.83	0.76 - 0.91
Females	14906	18	17.54	1.03	0.61 - 1.62

The standardised mortality ratio (SMR) for cancer in males is significantly low in comparison with the general male population (SMR 0.83, 95% confidence interval 0.76-0.91).

The low SMR for cancer is probably a reflection of the so-called "healthy worker effect". As discussed in the section on all-cause mortality, this is believed to be largely a selection effect, that is, people in good health are more likely to obtain secure employment and to have a longer life expectancy as a group compared with the general population. Another possible factor may be the ready access to medical services for employed workers.

Indeed, it is of interest that the numerous epidemiological studies which demonstrated the "healthy worker effect" were not studies of disease incidence but of mortality. The simultaneous presentation of cancer incidence and cancer mortality studies by *Health Watch* indicates that a "healthy worker effect" is clearly demonstrable when mortality is used as the outcome measure but not when cancer incidence is used. This raises the intriguing possibility that the "healthy worker effect" is in fact not the consequence of a reduced disease incidence but of greater survival.[7]

It should be pointed out that the cancer incidence and cancer mortality data presented in Tables 13 and 14 are not fully comparable, as the cancer analysis has been updated only to the end of 2000, whereas the mortality analysis goes up to the end of 2001 (as is evident from the difference in person-years of observation). Nevertheless the differences in person-time could not account for the finding that cancer mortality is significantly reduced whereas cancer incidence is not.

3.4.4 Cancer by site – males

Site-specific cancer incidence and mortality ratios are shown in Tables 15 and 16 respectively. The tables list the number of cases or deaths of the particular cancer observed in the *Health Watch* population, the number expected, and the calculated standardised incidence and mortality ratios.

There are statistically significant excesses of mesothelioma, melanoma of the skin and prostatic cancer. There is a statistically significant lowering of incidence of lung cancer and a marginally significant lowering of incidence of cancer of the lip, tongue and pharynx.

Table 15: Cancer incidence by major anatomical site, males

Anatomical Site	Observed	Expected	SIR	95% C.I.
Lip, oral cavity and pharynx	55	73.03	0.75	0.57 - 0.98
Oesophagus	11	18.27	0.60	0.30 - 1.08
Stomach	35	35.95	0.97	0.68 - 1.35
Colorectal	186	179.84	1.03	0.89 - 1.19
Liver	8	12.15	0.66	0.28 - 1.30
Gallbladder	5	6.68	0.75	0.24 - 1.75
Pancreas	23	23.61	0.97	0.62 - 1.46
Larynx	18	20.86	0.86	0.51 – 1.36
Lung	113	163.80	0.69	0.57 - 0.83
Melanoma	191	139.02	1.37	1.19 - 1.58
Mesothelioma	18	10.20	1.77	1.05 - 2.79
Connective Tissue	5	8.83	0.57	0.18 - 1.32
Prostate	251	212.54	1.18	1.04 - 1.34
Testis	19	14.26	1.33	0.80 - 2.08
Bladder	60	51.43	1.17	0.89 - 1.50
Kidney	45	39.13	1.15	0.84 - 1.54
Eye	5	4.02	1.24	0.40 - 2.90
Brain & Nervous System	21	23.90	0.88	0.54 - 1.34
Non-Hodgkin lymphoma	48	53.96	0.89	0.66 - 1.18
Multiple myeloma	16	14.04	1.14	0.65 - 1.85
Leukaemia	34	31.90	1.07	0.74 - 1.49
Acute lymphatic leukaemia	3	1.76	1.70	0.35 - 4.97
Chronic lymphatic leukaemia	12	11.69	1.03	0.53 - 1.79
Acute myeloid leukaemia	8	8.27	0.97	0.42 - 1.91
Chronic myeloid leukaemia	5	4.57	1.09	0.36 - 2.55
Other Leukaemia	6	5.60	1.07	0.39 - 2.33
Acute nonlymphocytic leukaemia	*11*	*10.35*	*1.06*	*0.53 - 1.90*
Other & unspecified sites	66	73.01	0.90	0.70 - 1.15
Total	1232	1210.5	1.02	0.96 - 1.08

Table 16: Cancer mortality by major anatomical site, males

Anatomical Site	Observed	Expected	SMR	95% C.I.
Oesophagus	13	19.11	0.68	0.36 - 1.16
Stomach	19	22.94	0.83	0.50 - 1.29
Colon	40	52.68	0.76	0.54 - 1.03
Rectum	23	22.11	1.04	0.66 - 1.56
Liver	10	12.88	0.78	0.37 - 1.43
Gallbladder	3	3.49	0.86	0.18 - 2.51
Pancreas	22	24.59	0.89	0.56 - 1.35
Larynx	6	8.04	0.75	0.27 - 1.62
Lung	93	148.99	0.62	0.50 - 0.76
Pleura	8	4.84	1.65	0.71 - 3.26
Connective Tissue	3	3.46	0.87	0.18 - 2.53
Melanoma	19	20.81	0.91	0.55 - 1.43
Non-melanotic skin	3	5.75	0.52	0.11 - 1.52
Prostate	35	37.32	0.94	0.65 - 1.30
Bladder	9	11.15	0.81	0.37 - 1.53
Kidney	14	14.70	0.95	0.52 - 1.60
Brain	24	22.12	1.08	0.70 - 1.61
Unspecified	32	31.71	1.01	0.69 - 1.42
Multiple Myeloma	12	8.65	1.39	0.72 - 2.42
Non-Hodgkin lymphoma	22	22.21	0.99	0.62 - 1.50
Leukaemia	18	18.19	0.99	0.59 - 1.56
Acute lymphatic leukaemia	2	1.61	1.24	0.15 - 4.48
Chronic lymphatic leukaemia	1	3.33	0.30	0.01 - 1.67
Acute myeloid leukaemia	6	8.22	0.73	0.27 - 1.59
Chronic myeloid leukaemia	4	2.77	1.45	0.39 - 3.70
Other Leukaemia	5	2.26	2.21	0.72 - 5.15
Acute nonlymphocytic leukaemia	*6*	*9.03*	*0.66*	*0.24 - 1.45*
Other Sites	31	37.35	0.83	0.56 - 1.18
Total	459	553.09	0.83	0.76 - 0.91

No cause of death from site-specific cancer has occurred in significant excess. There is a statistically significant lowering of lung cancer mortality.

3.4.5 Cancer and Time Relationships - males

Cancer incidence and mortality according to period of first employment

Table 17 shows that there is no significant trend in cancer incidence with period of first employment. Cancer mortality rates are higher in earlier periods of initial employment in the industry, but the trend is not statistically significant.

Table 17: Cancer incidence and mortality by period of first employment, adjusted for age and calendar period of follow-up

Period of First Employment	Incidence			Mortality		
	Cancers	RIR	95 % C.I.	Deaths	RMR	95 % C.I.
Post 1975	272	1.00		80	1.00	
1965-74	369	1.01	0.84 - 1.20	143	1.17	0.87 - 1.58
1955-64	368	1.16	0.94 - 1.42	144	1.33	0.95 - 1.87
Pre 1954	223	1.07	0.85 - 1.35	92	1.30	0.89 - 1.92
Test for heterogeneity p = 0.33				Test for heterogeneity p = 0.41		
Test for trend p = 0.34				Test for trend p = 0.16		

Cancer incidence and mortality according to duration of employment

Table 18 shows relative cancer incidence and mortality by duration of employment. There is no significant trend in cancer incidence with increasing duration of employment.

The cancer mortality rate is relatively low in those employed for 5-9 years compared with those employed longer. This is likely to be due not to high mortality in those employed longer, but to a low absolute mortality rate in the 5-9 year category: external comparison of the different categories with the general population shows that the 5-9 year category has an SMR of only 0.63 than the other categories, in which the SMR ranges from 0.75 to 1.01. (SMR data are not shown in the Tables.) This lowering of the SMR in those employed for the least time, an effect not seen in the cancer incidence data, may be a manifestation of the "healthy worker effect." However there is no statistically significant trend with increasing time since first employment.

Table 18: Cancer incidence and mortality by duration of employment, adjusted for age and calendar period of follow-up

Duration of Employment	Incidence			Mortality		
	Cancers	RIR	95 % C.I.	Deaths	RMR	95 % C.I.
5-9 Years	115	1.00		22	1.00	
10-15 Years	182	0.95	0.75 - 1.21	68	1.73	1.06 - 2.83
16-19 Years	172	0.75	0.58 - 0.96	67	1.34	0.81 - 2.22
20-24 Years	186	0.82	0.64 - 1.06	69	1.35	0.81 - 2.25
>=25 Years	576	0.93	0.74 - 1.18	233	1.64	1.01 - 2.66
Test for heterogeneity p = 0.04				Test for heterogeneity p = 0.09		
Test for trend p = 0.98				Test for trend p = 0.23		

Cancer incidence and mortality by time since first employment

Table 19 shows relative cancer incidence and mortality by time elapsed from first employment to date of diagnosis or death. The findings are very similar to those relating to duration of employment.• There is no relationship between cancer incidence and time since first employment. Cancer mortality in categories employed more than 10 years prior to diagnosis is increased relative to those whose cancer arose within 10 years of joining the industry. This is attributable to a low absolute mortality rate in the baseline category of those subjects employed 5-9 years previously. On comparing mortality rates of each category with the general population, the SMR of the baseline category is 0.49, whereas the other categories vary from 0.72 to 1.05. Again, this appears to be a manifestation of the "healthy worker effect," which is greatest in the early years of follow-up of cohort studies. There is no statistically significant overall trend in either cancer incidence or mortality with increasing time since first employment.

Table 19: Cancer incidence and mortality by time since first employment, adjusted for age and calendar period of follow-up

Time Since First Employment	Incidence			Mortality		
	Cancers	RIR	95 % C.I.	Deaths	RMR	95 % C.I.
5-9 Years	52	1.00		8	1.00	
10-15 Years	124	1.31	0.93 - 1.83	38	2.49	1.14 - 5.46
16-19 Years	131	0.98	0.69 - 1.39	41	1.82	0.81 - 4.08
20-24 Years	178	1.10	0.77 - 1.56	65	2.25	1.01 - 5.00
>=25 Years	746	1.05	0.75 - 1.48	307	2.34	1.06 - 5.16
Test for heterogeneity p = 0.21				Test for heterogeneity p = 0.09		
Test for trend p = 0.57				Test for trend p = 0.19		

• The difference between duration of employment and time since first employment is that years of employment cease to accumulate when the person leaves the industry, whereas time since first employment continues regardless of when the person leaves the industry.

Cancer

The chance of getting cancer is the same for men in this industry as for other Australians. This is so for all cancers combined and for most individual cancer types. However some cancers – mesothelioma, melanoma of the skin and prostatic cancer - have been occurring at excess rates compared with the general population. There is a significant lowering of the lung cancer rate compared with the general population. The age-adjusted mortality rate from all cancers combined is significantly less than in the general population. Lung cancer mortality is also significantly lowered.

Some individual cancer types, including those occurring in excess, are considered in detail in Chapter 4.

Those who worked in the industry in earlier times have not been at greater risk of developing cancer than those who entered the industry more recently.

Cancer mortality rates are especially low in the early years following entry into the industry, possibly due to a selection effect; that is, people with cancer do not enter or remain in the workforce, so that in the earlier years of follow-up the death rate in the workforce is lower than in the general population.

3.4.6 Workplace Type and Health Outcomes

Analyses were undertaken for the five principal workplace types – refineries, terminals, airports, onshore production and offshore production. Table 20 shows the number of subjects from each workplace type included in this analysis. The numbers at each workplace are lower than those originally recruited (Table 1 in Chapter 1) since not all subjects recruited into *Health Watch* complete the five years of employment required to enter the analysis.

Table 20: Numbers of male subjects in each workplace type

Workplace Type	Number of subjects	%	Person-years	% of person-years
Refinery	6469	39.1	96491	39.8
Terminal	6466	39.1	97931	40.4
Airport	594	3.6	9267	3.8
Onshore Production	2326	14.1	28632	11.8
Off Shore Production	692	4.2	10048	4.1
Total	16547	100.0	242367	100.0

The all-cause mortality by workplace type is shown in Table 21. All-cause mortality is significantly lowered in all workplace types.

Table 21: All-Cause mortality by workplace type

Workplace Type	Person-Years	Observed	Expected	SMR	95% C.I.
Refinery	96491	459	667.66	0.69	0.63 - 0.75
Terminal	97931	548	693.45	0.79	0.73 - 0.86
Airport	9267	41	66.32	0.62	0.44 - 0.84
Onshore production	28632	80	121.33	0.66	0.52 - 0.82
Offshore Production	10048	19	36.21	0.52	0.32 - 0.82
	242367	1147	1584.96	0.72	0.68 - 0.77

Table 22 shows mortality from ischaemic heart disease (ie coronary artery disease) by workplace type. SMRs are lowered in each workplace type and the difference is statistically significant in refinery, airport and onshore production personnel.

Table 22: Ischaemic heart disease mortality by workplace type

Workplace Type	Person-Years	Observed	Expected	SMR	95% C.I.
Refinery	96491	122	165.93	0.74	0.61 - 0.88
Terminal	97931	152	173.17	0.88	0.74 - 1.03
Airport	9267	4	16.53	0.24	0.07 - 0.62
Onshore production	28632	14	26.44	0.53	0.29 - 0.89
Offshore Production	10048	3	7.56	0.40	0.08 - 1.16
All workplaces	242367	295	389.62	0.76	0.67 - 0.85

Table 23 shows the incidence of cancer in the different workplace types. All 5 categories of workplace type show total cancer risks which are no different from the general population.

Table 23: Cancer incidence by workplace type

Workplace Type	Person-Years	Observed	Expected	SIR	95% C.I.
Refinery	90424	489	502.38	0.97	0.89 - 1.06
Terminal	92225	568	531.57	1.07	0.98 - 1.16
Airport	8704	50	51.37	0.97	0.72 - 1.28
Onshore production	26379	98	95.74	1.02	0.83 - 1.25
Offshore Production	9379	27	29.39	0.92	0.61 - 1.34
	227111	1232	1210.45	1.02	0.96 - 1.08

As shown in Table 24, cancer mortality is lower than population rates in all workplace types, but the difference is statistically significant only in refinery and terminal workers.

Table 24: Cancer mortality by workplace type

Workplace Type	Person-Years	Observed	Expected	SMR	95% C.I.
Refinery	96491	184	232.20	0.79	0.68 - 0.92
Terminal	97931	211	244.88	0.86	0.75 - 0.99
Airport	9267	22	23.68	0.93	0.58 - 1.41
Onshore production	28632	34	40.47	0.84	0.58 - 1.17
Offshore Production	10048	8	11.86	0.67	0.29 - 1.33
	242367	459	553.09	0.83	0.76 - 0.91

Health and workplace type

The health of employees as measured from the Health Watch results differs very little between the various types of workplaces in the industry, such as upstream production sites and downstream refineries, terminals and distribution sites.

Generally the chances of dying at any age, or of getting cancer or heart disease are very similar no matter where Health Watch people work, and generally compare favourably with the rates in all Australian men.

3.4.7 Total Hydrocarbons Exposure and Health Outcomes

Tables 25 to 28 show the analyses of all-cause mortality and ischaemic heart disease mortality according to hydrocarbon exposure. Outcomes are analysed both according to the highest-hydrocarbon ranking job ever held, and the hydrocarbon ranking of the job held longest. All comparisons are adjusted for variations in age and the proportion of current smokers.

All-cause mortality, both when based on the highest hydrocarbon-ranked job ever held (Table 25) and the hydrocarbon ranking of the job held longest (Table 26) shows a significant increase with increasing hydrocarbon ranking.

Table 25: All-cause mortality by total hydrocarbon exposure (based on highest total hydrocarbon rank job ever held), adjusted for age, calendar year and smoking

Exposure Category	Person-Years	Deaths	RMR	95 % C.I.
1	44326	224	1.00	
2	21770	60	1.07	0.80 - 1.43
3	2635	12	1.04	0.58 - 1.86
4	111571	562	1.27	1.09 - 1.48
5	8974	31	1.03	0.71 - 1.50
6	38881	192	1.19	0.98 - 1.45
7	14177	66	1.26	0.96 - 1.66

Test for heterogeneity p = 0.09
Test for trend p = 0.02

Table 26: All-cause mortality by total hydrocarbon exposure (based on hydrocarbon ranking of job held longest) adjusted for age, calendar year and smoking

Exposure Category	Person-Years	Deaths	RMR	95 % C.I.
1	60954	270	1.00	
2	23317	58	0.97	0.73 - 1.29
3	3950	14	0.88	0.51 - 1.50
4	102481	554	1.29	1.12 - 1.50
5	6387	23	0.89	0.58 - 1.37
6	34812	178	1.17	0.97 - 1.42
7	6792	47	1.48	1.08 - 2.02

Test for heterogeneity p = 0.003
Test for trend p = 0.003

Tables 27 and 28 show the relative mortality from ischaemic heart disease according to hydrocarbon ranking. These also show a trend to increasing mortality with increasing hydrocarbon exposure ranking.

Table 27: Ischaemic heart disease mortality by total hydrocarbon exposure (based on highest total hydrocarbon rank job ever held), adjusted for age, calendar year and smoking

Exposure Category	Person-Years	Deaths	RMR	95 % C.I.
1	44326	54	1.00	
2	21770	10	0.76	0.38 - 1.49
3	2635	3	1.03	0.32 - 3.31
4	111571	152	1.42	1.04 - 1.94
5	8974	6	0.86	0.37 - 2.00
6	38881	49	1.23	0.83 - 1.81
7	14177	21	1.68	1.01 - 2.78

Test for heterogeneity p = 0.11
Test for trend p = 0.09

Table 28: Ischaemic heart disease mortality by total hydrocarbon exposure (based on hydrocarbon ranking of job held longest) adjusted for age, calendar year and smoking

Exposure Category	Person-Years	Deaths	RMR	95 % C.I.
1	60954	65	1.00	
2	23317	10	0.71	0.36 - 1.39
3	3950	4	1.01	0.37 - 2.77
4	102481	146	1.41	1.05 - 1.88
5	6387	4	0.66	0.24 - 1.80
6	34812	46	1.22	0.84 - 1.79
7	6792	18	2.34	1.39 - 3.94

Test for heterogeneity p = 0.01
Test for trend p = 0.01

Similar analyses for cancer incidence and cancer mortality (results not shown) show no association with increasing hydrocarbon exposure, whichever method of ranking is used.

Since there is no trend for increased cancer mortality with increased hydrocarbon exposure, it is therefore likely that heart disease is the most important contributing factor to the overall increase in mortality with increasing hydrocarbon exposure.

It is not apparent why heart disease mortality should increase with increasing hydrocarbon exposure. Difference in smoking prevalence is an unlikely cause since the analysis included controlling for smoking prevalence. Hydrocarbons are not generally recognized to have a causal role in coronary artery disease. Examination of the Relative Mortality Rates in successive categories in Tables 27 and 28 in fact show that no constant trend is present. The low p-value of the test is largely due to the preponderance of deaths in exposure category 4. This is the default category, ie for subjects in jobs where the exposure has not been assessed. Another factor is the high RMR of 2.34 in exposure category 7.

3.5 Smoking and alcohol

3.5.1 Smoking Status

The smoking status of each member of the cohort is based on smoking habit reported at initial and later interviews with information at the last interview being given prominence. After retirement or leaving the industry, additional information has been derived from postal surveys of all retired and resigned members carried out during 1994, 1996 and 1999 in combination with the health letter.

In the previous *Health Watch* report, the smoking prevalence was compared with national smoking data based on 1995 estimates,[3] using direct standardisation for age. The *Health Watch* male smoking rate was 24.1% compared with the Australian population rate of 28.2%. On this basis the age-standardised smoking prevalence was slightly less than in the Australian national population. Age-specific comparisons are shown in Figure 2. (It has not been possible to update the figure, as there are no updates of national data available.)

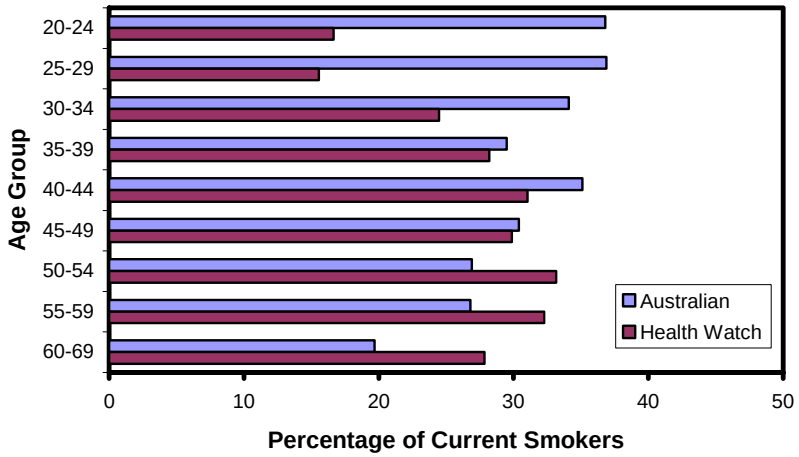

Figure 2*: Comparison of prevalence of smoking (expressed as a percentage) in the Health Watch cohort and in the general population in the 1990s, by age group. (Source of Australian estimates: reference 3)*

Figure 3 shows the smoking status of the *Health Watch* population based on data from the most recent contact, which are the bases for all smoking-related analyses in this Report. On the basis of the most recent information from subjects, 36% of subjects have never smoked, 24% are current smokers (or were still current smokers at time of death), 39% are ex-smokers, and 1% smoke a pipe or cigars only.

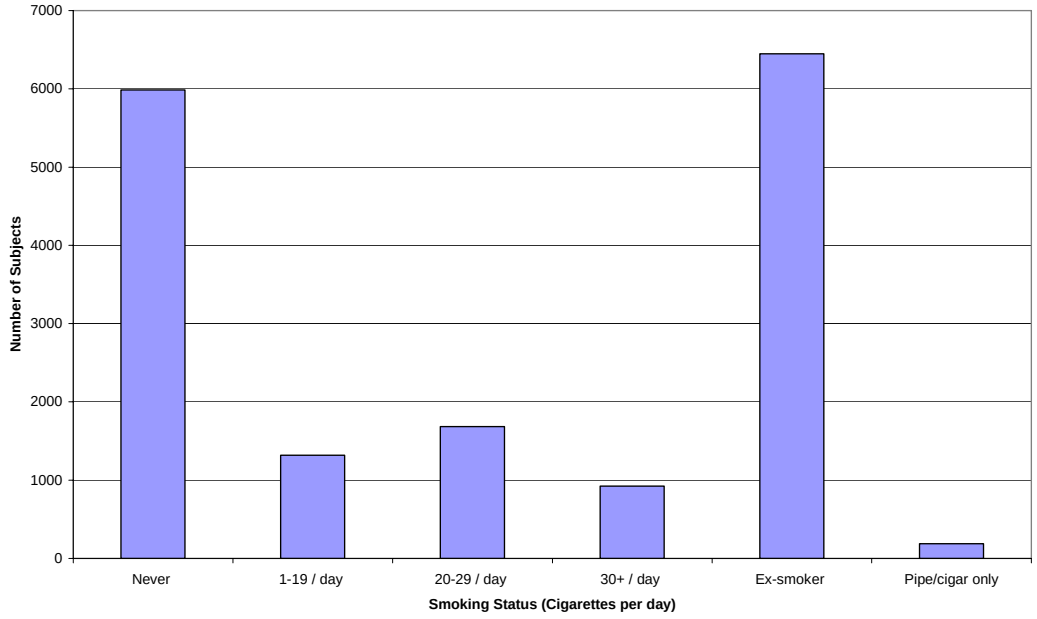

Figure 3: *Current smoking status of the Health Watch male study population*

3.5.2 Smoking and all-cause mortality

In Table 29 the relative mortality ratios for all-cause mortality are shown according to smoking habit. These tables compare various categories of smokers relative to a baseline of those who have never smoked. The comparison clearly shows a marked increase in age-adjusted mortality with increasing tobacco use. People smoking up to 19 cigarettes a day have double the age-adjusted death rate from all causes combined, compared with those who have never smoked. For those smoking 20-29 cigarettes per day there is a more than 2½-fold increase in risk, and there is a trebling of risk above 30 per day. There is no overall increase in risk for ex-smokers. The trend for increasing age-adjusted mortality with increasing smoking level is highly statistically significant.

Table 29: All cause mortality by smoking category, adjusted for age and calendar period

Smoking Category	Person-Years	Deaths	RMR	95 % C.I.
Never	83176	259	1.00	
1-19 / day	17892	108	2.14	1.71 - 2.68
20-29 / day	24310	200	2.74	2.28 - 3.30
30+ / day	13649	138	3.27	2.66 - 4.03
Ex-smoker	100645	416	0.91	0.78 - 1.07
Pipe/cigar only	2696	26	3.10	2.07 - 4.65

Test for trend among never and current smokers $p < 0.0001$

3.5.3 Smoking and Cancer

Tables 30 and 31 show the relationship between total cancer incidence and total cancer mortality and smoking. As with all-cause mortality, both of these outcomes show a significant increase with increasing tobacco use.

Table 30: Cancer incidence by smoking category, adjusted for age and calendar period

Smoking Category	Person-Years	Cancers	RIR	95% C.I.
Never	77507	334	1.00	
1-19 / day	16716	86	1.30	1.02 - 1.64
20-29 / day	22872	152	1.58	1.31 - 1.92
30+ / day	12868	88	1.59	1.26 - 2.01
Ex-smoker	94606	556	0.98	0.85 - 1.12
Pipe/cigar only	2542	16	1.48	0.90 - 2.44

Test for trend among never and current smokers $p < 0.0001$

Table 31: Cancer mortality by smoking category, adjusted for age and calendar period

Smoking Category	Person-Years	Deaths	RMR	95 % C.I.
Never	83176	107	1.00	
1-19 / day	17892	41	1.95	1.36 - 2.80
20-29 / day	24310	81	2.64	1.98 - 3.53
30+ / day	13649	56	3.16	2.29 - 4.37
Ex-smoker	100645	165	0.87	0.68 - 1.11
Pipe/cigar only	2696	9	2.55	1.29 - 5.03

Test for trend among never and current smokers $p < 0.0001$

Table 32 shows the relationship between smoking and lung cancer incidence. For this outcome, the relationship to smoking is very strong – a 17-fold increase in risk in those smoking up to 19 cigarettes per day compared with the risk in those who have never smoked; a 22-fold increase in risk for those who smoke 21-30 cigarettes per day, and a 43-fold increase in risk for those who smoke more than 30 cigarettes per day. Even those who report having quit smoking have a 5-fold increase in risk.

Table 32: Lung Cancer incidence by smoking category, adjusted for age and calendar period, never smokers as reference

Smoking Category	Person-Years	Cancers	RIR	95% C.I.
Never	77507	4	1.00	
1-19 / day	16716	13	16.85	5.49 - 51.69
20-29 / day	22872	25	22.31	7.76 - 64.18
30+ / day	12868	28	43.09	15.10 - 123.0
Ex-smoker	94606	40	5.46	1.95 - 15.28
Pipe/cigar only	2542	3	23.32	5.21 - 104.3

Test for trend among never and current smokers $p < 0.0001$

The gradient of increasing risk of lung cancer with increasing tobacco use is steeper than in most comparable studies. The likely reason is that in the present analysis only 4 lifelong non-smokers have developed lung cancer. Because of this low number the estimates of increasing risk with increasing tobacco use are approximate only. Nevertheless one of the great strengths of *Health Watch* is that the smoking histories have been collected prospectively. In most epidemiological studies smoking histories are collected retrospectively, giving lung cancer victims the opportunity to deny previous tobacco use.

This analysis reaffirms that lung cancer in people who have never been active smokers is a rare disease.

It should be emphasised that the comparisons in Table 30 showing excess risk are comparisons made *within* the cohort. The *Health Watch* cohort as a whole has a significantly low rate of lung cancer incidence and lung cancer mortality compared with the general male population (Tables 15 and 16).

Table 33 shows the association between smoking and lung cancer mortality. Here the trend is similar to that of lung cancer incidence, but the estimates of relative risk, which are greater than with lung cancer incidence are less reliable since the baseline comparison group of non-smokers contains only 2 deaths.

Table 33: Lung Cancer Mortality by smoking category, adjusted for age and calendar period

Smoking Category	Person-Years	Deaths	RMR	95 % C.I.
Never	83176	2	1.00	
1-19 / day	17892	10	25.83	5.66 - 117.9
20-29 / day	24310	26	46.00	10.91 - 194.0
30+ / day	13649	26	79.44	18.84 - 335.0
Ex-smoker	100645	26	7.06	1.67 - 29.76
Pipe/cigar only	2696	3	46.72	7.79 - 280.1

Test for trend among never and current smokers $p < 0.0001$

3.5.4 Smoking and Ischaemic Heart Disease

Many studies have shown that smoking is a major risk factor for ischaemic heart disease (often called coronary artery disease) and this is confirmed in the *Health Watch* cohort. Table 34 shows that smoking dramatically affects the chance of dying from heart attack in the *Health Watch* male cohort. It is reasonable to assume that smoking similarly increases the risk of suffering a heart attack, even if death is not the outcome.

Table 34: Ischaemic heart disease mortality by smoking category, adjusted for age and calendar period of follow-up

Smoking Category	Person-Years	Deaths	RMR	95 % C.I.
Never	83176	56	1.00	
1-19 / day	17892	25	2.30	1.43 - 3.68
20-29 / day	24310	46	2.88	1.95 - 4.26
30+ / day	13649	41	4.42	2.95 - 6.62
Ex-smoker	100645	116	1.13	0.82 - 1.55
Pipe/cigar only	2696	11	5.91	3.09 - 11.28

Test for trend among never and current smokers $p < 0.0001$

3.5.5 Smoking and Bladder cancer

An analysis was performed on the association between bladder cancer and smoking. The results are shown in Table 35. There is a strong and statistically significant trend to increased cancer incidence with increasing tobacco use. The estimated relative risk in the category smoking more than 30 or more cigarettes per day is in fact lower than the category smoking 20-29 per day, but the former estimate is based on only 4 cases.

Table 35: Bladder Cancer incidence by smoking category, adjusted for age and calendar period of follow-up, never smokers as reference

Smoking Category	Person-Years	Cancers	RIR	95% C.I.
Never	77507	7	1.00	
1-19 / day	16716	3	2.19	0.57 - 8.48
20-29 / day	22872	11	5.58	2.16 - 14.42
30+ / day	12868	4	3.53	1.03 - 12.07
Ex-smoker	94606	32	2.57	1.13 - 5.85
Pipe/cigar only	2542	3	13.45	3.47 - 52.12

Test for trend among never and current smokers p = 0.0004

3.5.6 Deaths Attributable to Smoking

Health Watch cannot identify which individual deaths are caused by smoking but can provide an indication of the numbers of premature deaths attributable to the smoking habit. The effect is so critical to the future health of those in the cohort, that even a crude figure is felt to be worth publishing (Figure 4). The effect of smoking in *Health Watch* is demonstrated in the results for cancer and ischaemic heart disease, being specific causes of death which can be analysed for smoking. In addition, there is no reason to suppose that other smoking-related diseases are not also happening in the cohort, just as they are in the Australian population as a whole.

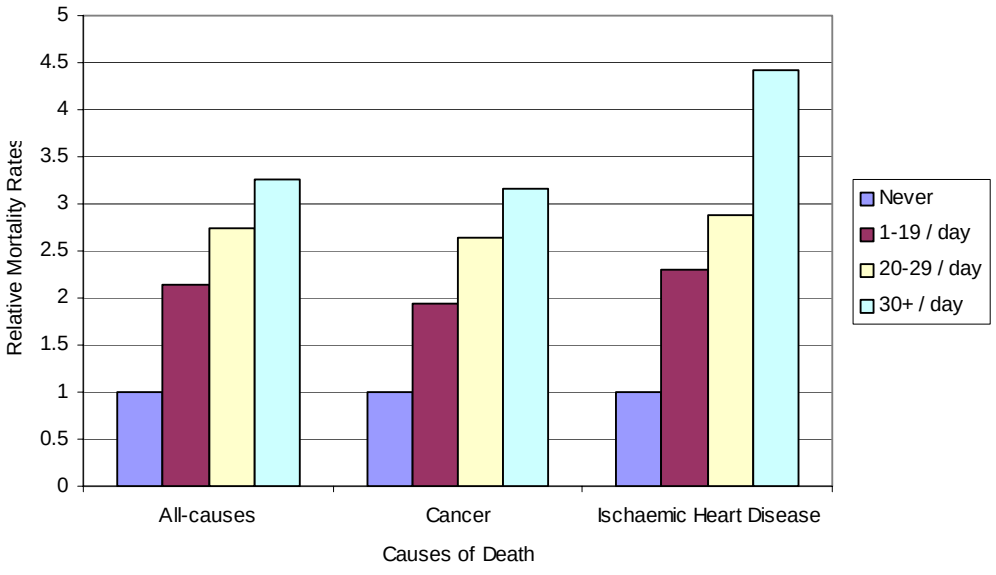

Figure 4: *Relative risk of dying from any cause, ischaemic heart disease or cancer for different smoking categories compared to a baseline of non-smoker. (The RMRs are adjusted for age and calendar year.)*

The results indicate that smoking probably causes about 45% of the ischaemic heart disease deaths and therefore about 132 men in the industry have died of heart attacks over the past 23 years due to smoking. Smoking accounts for nearly all lung cancers in the cohort, but many other cancers are smoking-related as well. Altogether it is estimated that smoking has been a

contributing factor to about 32% of all male cancer deaths in the cohort, ie about 147 men. Combining all causes of death, it is estimated that smoking has played a part in about 392, or 34% of the 1147 deaths that have occurred in the *Health Watch* cohort.•

3.5.7 Effects of Quitting

Men who give up smoking have better outcomes than those who continue to smoke. The effects of quitting are of interest to those in the cohort who have quit, and to those who might be encouraged to do so. The benefit of quitting on mortality and cancer incidence can be seen in the *Health Watch* cohort.

The relative mortality rate for deaths from all causes is not significantly different in ex-smokers compared with those who have never smoked (RMR=0.91, 95% CI 0.78-1.07). For lung cancer mortality the risk in ex-smokers is considerably higher than in those who have never smoked (RR 7.06, 95%CI 1.67-29.8) but less than one third of the risk in those who continue to smoke 1-19 cigarettes per day. These data are consistent with other studies which have shown that the risk of lung cancer declines as the time since quitting increases.[8-10] For all cancer deaths combined, the rate in ex-smokers is not significantly different from that of those who have never smoked (RMR=0.87, 95% CI 0.68-1.11). In the case of death from ischaemic heart disease the RMR in ex-smokers is slightly greater than of those who have never smoked, but the difference is not significantly different (RMR 1.13, 95% CI 0.82-1.55), and is less than one-half of the risk relative to those who continue to smoke 1-19 cigarettes per day.

3.5.8 Alcohol Consumption

All-cause mortality is influenced by alcohol intake. Table 36 shows the relationship between smoking and death from all causes. Because many important causes of death from alcohol are also affected by smoking, adjustment has been made in the analysis to allow for the influence of smoking. Up to consumption of 5 drinks per day (35 per week) alcohol is associated with a significant reduction in age-standardised mortality compared with total abstainers. Above this level, alcohol is associated with an increasing mortality rate.

Table 36: All-cause mortality by alcohol category, adjusted for age, calendar year and smoking

Number of Drinks/Week	Person-Years	Deaths	RMR	95 % C.I.
Nil	42387	252	1.00	
1-7	58810	246	0.83	0.70 - 0.99
8-21	72757	263	0.77	0.65 - 0.92
22-35	31556	144	0.89	0.72 - 1.09
36-49	18895	108	1.19	0.95 - 1.50
50+	17963	134	1.40	1.13 - 1.73

This protective effect of low to moderate drinking produces a "U-shaped" or “J-shaped” curve, as shown in Figure 5. This finding has been reported in other studies.[11,12]

• The estimates of excess deaths was computed by comparing the actual numbers of deaths with the number expected if the smokers had the same mortality rate as non-smokers. The expected numbers were derived by multiplying the rates for non-smokers by number of person-years of follow-up in all the smoking categories combined.

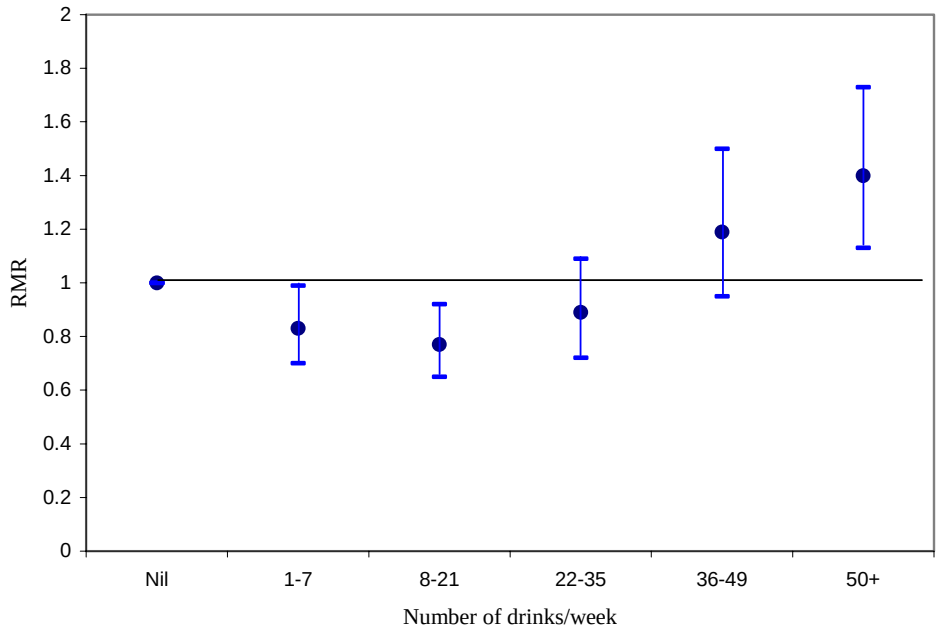

Figure 5: *Relative risk of dying (all-cause mortality) for different levels of alcohol consumption compared to the baseline of non-drinker. (The RMRs are adjusted for age, calendar year and smoking.)*

Table 37 shows the association between alcohol consumption and mortality from ischaemic heart disease. This analysis is also controlled for tobacco use, which is an important contributing factor to heart disease. This table shows a significant reduction in mortality from heart disease in those consuming up to 21 drinks per week compared with total abstainers. Above that level, the relative mortality rate converges towards the rate in total abstainers: at these higher levels of alcohol consumption the rate of heart disease mortality is still below that of total abstainers, but the difference is not statistically significant.

Table 37: Ischaemic heart disease mortality by alcohol category, adjusted for age, calendar year and smoking

Number of Drinks/Week	Person-Years	Deaths	RMR	95 % C.I.
Nil	42387	81	1.00	
1-7	58810	56	0.60	0.43 - 0.85
8-21	72757	70	0.65	0.47 - 0.90
22-35	31556	30	0.58	0.38 - 0.88
36-49	18895	28	0.97	0.63 - 1.50
50+	17963	30	0.97	0.63 - 1.48

3.6 Staging of cancer

As discussed in Section 3.4.3, there is a statistically significant lowering of mortality (SMR) compared with the general population for all major disease categories, including cancer mortality. However this effect has not occurred for cancer incidence: whereas the all-cause SMR for cancer mortality was significantly low (SMR 0.83, 95% CI 0.76-0.91) cancer incidence was not statistically different from that of the general male population (SIR 1.02, 95% CI 0.97- 1.08). The most important contributors to the difference between SMR and SIR are in fact cancers occurring in excess ie melanoma, prostatic cancer and bladder cancer. These findings suggested that low SMRs in occupational cohort studies are the result not of low cancer incidence but of greater survival. Since survival rate and survival time are strongly dependent on early diagnosis, it was hypothesized that *Health Watch* subjects were diagnosed at an earlier stage of cancer than is the case for the general population.

To test this hypothesis the staging of selected cancers registered in NSW in *Health Watch* subjects was compared with staging of all registered cancers of the same type in NSW. The study was carried out only for NSW because it is the only State where all cancers are staged at the time of registration. This study was carried out in early 2004 prior to the 2004 matching of *Health Watch* against national cancer registry data. Accordingly only cancers identified in the previous search (reported in the 11th *Health Watch* Report) were included.

The names of *Health Watch* subjects with the following cancers registered in NSW were submitted to the NSW Cancer Registry for the details of staging at registration: colon, rectum, larynx, lung, melanoma, prostate and bladder.

NSW cancers are staged as either localised, regional spread or distant spread. Staging of a number of matched cancers in the *Health Watch* was unknown. Deidentified data for the same cancers for all NSW males were obtained by age group and year of occurrence, and the expected number in each stage of each cancer type obtained after standardising for age and year. Observed cancers within each year and each age group were summed and compared with expected proportions in each stage for that group from NSW state data. The expected counts were then summed within each stage over year/age groups and compared with the observed cancers in that stage for each cancer type using a one-way chi-square statistic.

The distribution of cancers in the *Health Watch* cohort is shown in Table 38. One cancer was classified as *in situ.*

Table 38: Staging of selected cancers registered in New South Wales in Health Watch subjects

	Localised	Regional	Distant	Unknown
Colon	9	13	3	5
Rectosigmoid junction	2	5	2	0
Rectum	7	7	1	1
Larynx	3	0	0	3
Lung	9	8	7	4
Melanoma	51	3	2	2
Prostate	47	3	3	25
Bladder	7	1	0	5

The comparison of observed with expected numbers of cancers by stage is shown in Table 39. Cancers with stage given as unknown are excluded from the analysis.

Table 39: Comparison of numbers of selected cancers by stage in Health Watch subjects with expected number for all New South Wales

	Localised Obs/Exp	Regional Obs/Exp	Distant Obs/Exp	Chi-squared statistic	p-value
Colon	9/7.4	13/12.9	3/4.7	1.58	0.66
Rectum and rectosigmoid junction	9/8.9	12/11.6	3/3.5	0.08	0.96
Larynx	3/1.8	0/1.0	0/0.2	2.00	0.36
Lung	9/6.6	8/6.3	7/11.0	2.72	0.25
Melanoma	51/50.8	3/2.3	2/2.8	0.43	0.81
Prostate	47/43.2	3/5.4	3/4.4	1.90	0.39
Bladder	7/7.0	1/0.7	0/0.2	0.31	0.85

The distribution of staging of these cancers in *Health Watch* subjects is very similar to that of all cancers in males in NSW. In none of these cancers is there any significant tendency for the diagnoses to have occurred at a relatively early stage. (In fact the observed cancers in the localized cancer group exceeds the expected number for all cancer types examined.)

Accordingly it is concluded that the divergence between the cancer incidence rates (similar to population rates) and cancer mortality rates (low compared with population rates) is not due to cancers being diagnosed relatively early in the *Health Watch* cohort.

3.7 Cancer survival

As a further test of the hypothesis that the difference in cancer incidence and cancer mortality (SIR *vs* SMR) is due to better survival in the *Health Watch* cohort compared with the general

population, the relative survival of subjects with melanoma in the *Health Watch* cohort was compared with that of all subjects.

For the comparison, survival up to the end of 1997 was analysed, since national cancer survival figures extend only to that year. National melanoma survival rates were obtained from the AIHW website. Kaplan-Meier curves for survival were generated for *Health Watch* subjects and the male population.•

Actual numbers of melanoma deaths by year since diagnosis by age group and by year of occurrence were not available, so that adjustment by age and year of occurrence could not be performed. The AIHW data show that there has been improvement in relative survival nationally since the data collection began in 1983; for example relative survival after 7 years has risen from 80.7% in 1982-86 to 88.1% in 1992-97.

The superimposed survival curves are shown in Figure 6.

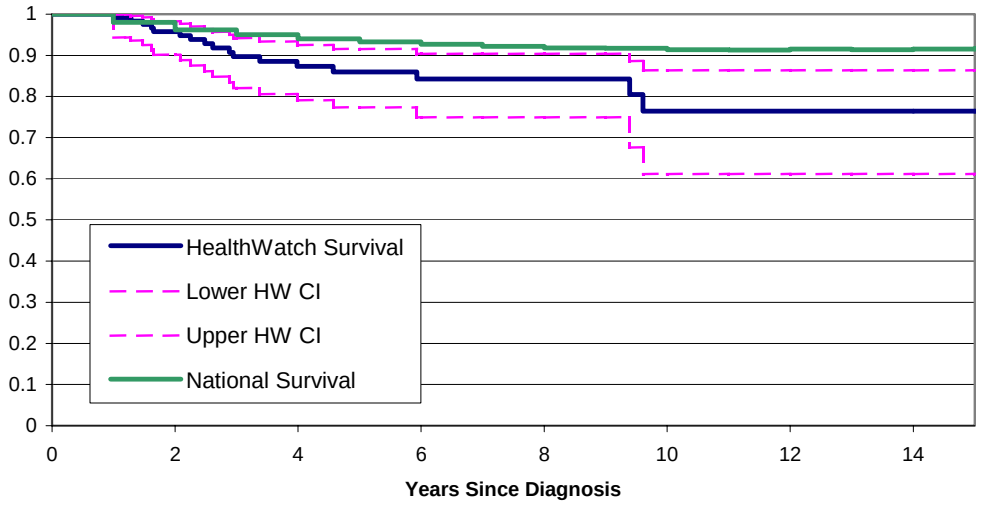

Figure 6*: Survival curves of melanoma of skin in Health Watch subjects and in the Australian population (males only)*

The survival curve for the *Health Watch* cohort is similar to that of the Australian population up to 3 years following diagnosis, but is slightly lower thereafter. This cannot be explained by confounding by year of birth. Melanoma incidence in fact climbed more steeply in the study population than in the general male population, ie the difference occurred despite negative confounding. Confounding by age group is possible if the melanoma cases in *Health Watch* were in general older than in the general population, but in fact the age distribution is slightly younger in the *Health Watch* cases.

Therefore the findings from available data do not support the hypothesis that the divergence between standardised incidence ratios and standardised mortality ratios for cancer in occupational cohorts is due to greater relative survival time.

• The survival curve plots the proportion of subjects who have not yet experienced an event, in our case death, versus time. The Kaplan-Meier method is one of the most commonly used. This method also takes into account subjects whose ultimate survival time is not known, a phenomenon called "censoring". The graph displays the probability of surviving by years since diagnosis. For example in the probability of any subject diagnosed with melanoma in the *Health Watch* cohort surviving for at least 5 years is 0.86 (or 86%).

3.8 Non-malignant disease from asbestos exposure

Apart from its association with certain types of cancer (mesothelioma and lung cancer), asbestos exposure can cause non-malignant conditions – pleural plaques and asbestosis. Pleural plaques are deposits of fibrous tissue (sometimes becoming calcified) on the pleural lining of the chest cavity. They are the commonest manifestation of asbestos exposure, but in general they are not disabling.

Asbestosis is a disease affecting the lung tissue itself, and can cause disability such as breathlessness, and can be fatal. Asbestosis is also associated with an increased risk of lung cancer. There is also evidence that asbestos exposure in itself, even in the absence of asbestosis, can increase the risk of lung cancer, although there is disagreement on this question.[13]

Only one member of the *Health Watch* cohort has died from asbestosis. This may not represent the full picture, as asbestosis is not necessarily a fatal condition and it is not possible to identify all living cases. Unlike cancer, for which there is mandatory notification and registration to state cancer registries, there is no universal register for asbestosis or pleural plaques. However some information is available from responses from *Health Watch* members to industry surveys and questionnaires sent to former employees.

37 subjects have reported an asbestos-related condition, described by subjects in a variety of ways which could indicate either pleural plaques or asbestosis. While in several cases it is clear that the subject has pleural plaques only, the possibility that some subjects have asbestosis cannot be ruled out on the available information (it is common for some people to regard the conditions as the same).

28 of the 37 cases were from refinery workers.

14 of the 37 subjects entered the industry in the 1950s, 13 in the 1960s, 7 in the 1970s and 3 in the 1980s. The minimum latency period for pleural plaques is believed to be 13 years,[14] and it is probable that most of these reported cases are referable to exposures, either in this industry or elsewhere, in earlier decades before current laws and control measures were implemented.

It is likely that these figures understate the prevalence of effects of asbestos exposure, especially of pleural plaques. Not all subjects reply to the periodic questionnaires. Moreover, since pleural plaques commonly produce no symptoms, they may remain undiagnosed unless the subject has a chest x-ray.

Full enumeration of these effects of asbestos exposure would require a study of different design to *Health Watch*.

4 SPECIFIC CANCERS

4.1 Mesothelioma (ICD-10 C45)

There were 18 pleural mesotheliomas, with a statistically significant excess (SIR 1.76, 95% confidence interval 1.05-2.79).

Mesothelioma is strongly related to asbestos exposure. Although the disease is most common in workers who have been heavily exposed, cases do occur in workers whose exposures have been too low to cause asbestosis. Moreover smoking does not appear to be a risk factor for mesothelioma.[15,16]

Because mesothelioma is nearly always associated with a history of occupational exposure to asbestos, every case should be regarded as significant in itself, irrespective of the statistical significance of the SIR or SMR.

The occupational histories of the 18 cases of mesothelioma are not always sufficiently detailed to assess the probability of asbestos exposure either while employed by a participating company or during prior employment.

15 of the 18 cases occurred in refinery workers. In most cases there is insufficient information to assess the probability or extent of exposure in these 15 subjects while working in a refinery, although in one case the history indicates significant asbestos exposure, and in two cases asbestos exposure appears to have been unlikely. The available work histories prior to entering the industry have been examined, and at least 2 had a definite history of asbestos exposure prior to entering this industry. Of the other 13 cases, the available histories suggest that prior asbestos exposure was probable in 5 cases, possible in 6, and unlikely in 2.

In the 3 non-refinery cases, asbestos exposure while in this industry appears unlikely. One of the cases had definite exposure prior to entering the industry.

The dates of hire of these subjects were examined. 6 of the 18 cases entered the industry in the 1950s, 8 in the 1960s, 3 in the 1970s and one in the 1980s. This may be a consequence of measures taken in recent years to eliminate asbestos exposures; on the other hand this may be a consequence of the long induction latency period between exposure and diagnosis of mesothelioma.

There were no cases of primary peritoneal mesothelioma.

4.2 Lung cancer

Although not the most frequently occurring cancer, lung cancer is the most frequent cause of mortality due to cancer. However both the incidence and mortality rates of lung cancer are significantly less in comparison with the general male population (SIR=0.69, 95% CI 0.57-0.83; SMR=0.62, 95% CI 0.50-0.76).

The low lung cancer rate may appear unexpected given the fact that the standardised prevalence of smoking in the cohort is similar to that of the Australian male population. The explanation may lie in the differences in smoking habits of the smokers. The comparison of smoking habits between *Health Watch* subjects and the Australian male population shown in Figure 2 in the previous chapter relates only to prevalence (ie whether the person smokes or not). However lung cancer risk is exquisitely sensitive to factors such as the number of cigarettes smoked, age at starting, age at quitting and tar content.[10] Thus although the prevalence of current smokers is similar in the *Health Watch* cohort and the general male population, it is quite possible that the average lifetime tobacco consumption in the *Health Watch* cohort is much less. This could be so if *Health Watch* smokers on average smoke less than other Australian men, and if those who have quit did so at an earlier age than in the general population. This could easily account for the low lung cancer incidence in the *Health Watch* cohort.

Evidence of the average lifetime tobacco use in the *Health Watch* cohort may also come from analyses relating to other diseases strongly related to smoking such as laryngeal cancer and chronic obstructive pulmonary diseases.

As shown in the previous chapter, the incidence of laryngeal cancer is below that of the general male population, although the lowering is not statistically significant (SIR 0.86, 95% CI 0.51-1.36).

Chronic obstructive pulmonary disease (COPD) is at least as strongly associated with smoking as is lung cancer. Indeed these diseases (mainly chronic bronchitis and emphysema) are uncommon in non-smokers. The mortality rate from COPD is very low (43 deaths vs 63.9 expected, SMR 0.67, 95% CI 0.49-0.90).

These figures suggest that the low lung cancer rate in the *Health Watch* population is likely to be due to low average lifetime tobacco use compared with the general population.

The occurrence of a number of cases of mesothelioma in the *Health Watch* cohort, and in other studies of oil refinery workers, raises the possibility of an asbestos-related lung cancer risk. However, given the low lung cancer incidence, the contribution of asbestos to this disease in the *Health Watch* cohort must be at most very small. In fact the concurrence of mesothelioma with low lung cancer rates, as reported here, has been a consistent finding in studies of oil refinery workers.[17] Nevertheless there have been reports suggesting that within these low lung cancer rates there may be some asbestos-related lung cancers in maintenance workers in refineries.[18.19] These claims have been made on the basis of an excess of lung cancer in refinery maintenance workers compared with non-maintenance workers, and in increasing lung cancer risk in the maintenance workers with increasing duration of employment. Although other studies have failed to confirm these findings,[20,21] a similar analysis was warranted in the *Health Watch* cohort, especially in view of the occurrence of asbestos-related pleural disease and possibly of pulmonary asbestosis as reported in the previous chapter. An advantage of such an analysis in this cohort is that smoking data, based on individual histories obtained prospectively from every subject in the cohort, are available.

All jobs for male *Health Watch* cohort members from first employment in the industry to 31/12/2001 were assigned a workplace type based on the company site code. Time on job was measured as the time between each job or until retirement/resignation. A subset of all refinery jobs was made and the job that was held the longest was selected and the tasks that the employee performed during that job were classified into maintenance or non-maintenance tasks. (The task that the employee spent the longest hours per week on was selected and if the task was both maintenance and other then it was classified as maintenance.) Office workers were then excluded.

There were 3925 are males who work or worked in a refinery other than in office work. There were 6 lung cancers in the 964 maintenance workers and 23 in the 2961 non-maintenance workers, and the incidence rate in the two groups was almost identical (RIR 0.98, 95% CI 0.40-2.42).

The analysis does not suggest any excess in maintenance workers compared with other non-office refinery workers. There were too few cases in maintenance workers to analyse any trend in lung cancer rate with duration of employment in refinery maintenance workers.

4.3 Melanoma of the skin

Melanoma is one of the commonest cancers in the *Health Watch* cohort, second only to prostatic cancer in men and to breast cancer in women.

There were 191 cases in men, and the incidence of melanoma is significantly raised (SIR=1.37, 95% CI 1.19-1.58). However there were only 19 deaths from melanoma, consistent with the generally favorable prognosis of this cancer in the general population.

The SMR does not differ statistically from the general population (SMR 0.91, 95% CI 0.55-1.43).

Table 39 shows that the melanoma incidence is elevated (ie SIR greater than 1) in all workplace types, and is significantly elevated in refinery and terminal workers. The lack of statistical significance in the other categories may be due to the relatively low numbers of subjects in these workplaces.

Table 39: Melanoma incidence by workplace type

Workplace Type	Person-Years	Observed	Expected	SIR	95% C.I.
Refinery	90424	77	56.03	1.37	1.08 - 1.72
Terminal	92225	84	58.79	1.43	1.14 - 1.77
Airport	8704	10	5.74	1.74	0.83 - 3.20
Onshore production	26379	14	13.69	1.02	0.56 - 1.72
Offshore Production	9379	6	4.76	1.26	0.46 - 2.75
	227111	191	139.02	1.37	1.19 - 1.58

Table 40 shows the relative cancer incidence in successive periods of employment, all categories being compared with those hired most recently, since 1975. There is no significant difference between categories and no significant trend.

Table 40: Melanoma incidence by period of first employment, adjusted for age and calendar period of follow-up

Period of First Employment	Person-Years	Cancers	RIR	95% C.I.
Post 1975	110337	60	1.00	
1965-74	72583	56	1.03	0.68 - 1.56
1955-64	29932	51	1.44	0.86 - 2.42
Pre 1954	14259	24	1.13	0.60 - 2.15

Test for heterogeneity p = 0.41
Test for trend p = 0.44

Table 41 shows the relative cancer incidence between categories of duration of employment, all categories being compared with those employed for the shortest period, from 5-9 years. There is statistically significant heterogeneity due to the relatively high incidence of melanoma in the 5-9 year category, although there is no significant overall trend.

Table 41: Melanoma incidence by duration of employment, adjusted for age and calendar period of follow-up

Duration of Employment	Person-Years	Cancers	RIR	95% C.I.
5-9 Years	53140	34	1.00	
10-15 Years	54590	32	0.65	0.39 - 1.06
16-19 Years	43651	22	0.42	0.24 - 0.74
20-24 Years	30487	27	0.60	0.34 - 1.05
>=25 Years	45226	76	0.76	0.45 - 1.28

Test for heterogeneity p = 0.02
Test for trend p = 0.75

Table 42 shows the relative cancer incidence according to time since hire, all categories being compared with least follow-up time since hire, 5-9 years. There is no significant difference between categories and no overall trend.

Table 42: Melanoma incidence by time since first employment, adjusted for age and calendar period of follow-up

Time Since First Employment	Person-Years	Cancers	RIR	95% C.I.
5-9 Years	38475	14	1.00	
10-15 Years	47931	30	1.23	0.64 - 2.35
16-19 Years	44371	28	0.92	0.46 - 1.83
20-24 Years	34950	23	0.74	0.35 - 1.56
>=25 Years	61384	96	0.96	0.47 - 1.99

Test for heterogeneity p = 0.55
Test for trend p = 0.56

Tables 43 and 44 show the relative incidence of melanoma in ascending ranks of hydrocarbon rank score. These fail to show any association between melanoma and hydrocarbon exposure.

Table 43: Melanoma Incidence by total hydrocarbon exposure (based on highest total hydrocarbon rank job ever held), adjusted for age and calendar period of follow-up

Exposure Category	Person-Years	Cancers	RIR	95% C.I.
1	41478	48	1.00	
2	20113	12	0.72	0.38 - 1.38
3	2485	4	1.51	0.54 - 4.18
4	104602	77	0.75	0.52 - 1.08
5	8405	4	0.52	0.19 - 1.45
6	36634	35	0.93	0.60 - 1.44
7	13365	11	0.86	0.44 - 1.65

Test for heterogeneity p = 0.52
Test for trend p = 0.52

Table 44: Melanoma Incidence by total hydrocarbon exposure (based on total hydrocarbon ranking of job held longest), adjusted for age and calendar period of follow-up

Exposure Category	Person-Years	Cancers	RIR	95% C.I.
1	57030	58	1.00	
2	21560	13	0.78	0.42 - 1.43
3	3721	4	1.12	0.41 - 3.10
4	96148	73	0.79	0.56 - 1.12
5	5997	3	0.52	0.16 - 1.66
6	32790	31	0.94	0.61 - 1.46
7	6414	6	0.88	0.38 - 2.05

Test for heterogeneity p = 0.77
Test for trend p = 0.48

The only finding of interest in this analysis is that the highest rate of melanoma incidence is in subjects employed for the shortest period of time, 5-9 years. The significance of this is not clear, but causal association with any exposure in the workplace is thus unlikely since increased melanoma incidence is not site-specific and shows no relationship to hydrocarbon exposure.

There were 9 cases of melanoma in females. The incidence is higher than in the general female population, but the increase is not statistically significant.

4.4 Bladder cancer

There were 60 bladder cancers in males. Whereas an excess of bladder cancer was reported in the previous *Health Watch* report, the most recent analysis has shown that there is now only a small excess, which is not statistically significant (SIR 1.17, 95%CI 0.89 – 1.50). There were only 9 deaths from bladder cancer, fewer than expected on the basis of population rates, but the difference is not statistically significant (SMR 0.81, 95% CI 0.37-1.53).

Bladder cancer did not occur in significant excess in any workplace type, and there was no trend in incidence with period of first employment, duration of employment or time since hire; nor was there any trend in incidence with hydrocarbon exposure ranking.

There were 2 bladder cancers in women.

4.5 Leukaemias

There were 34 leukaemia cases in males. The incidence is only slightly greater than in the general population, and the difference from the population rate is not statistically significant (SIR 1.07, 95% CI 0.74-1.49).

In individual leukaemia subtypes the rate was close to the population rate except for acute lymphatic leukaemia, where the SIR was 1.70 (95% CI 0.35-4.97) based on only 3 cases.

Mortality from leukaemia was similar to the population rate (SMR 0.99, 95%CI 0.59-1.56).

As shown in Table 45 there is no significant excess leukaemia incidence in any workplace type.

Table 45: Leukaemia incidence by workplace type

Workplace Type	Person-Years	Observed	Expected	SIR	95% C.I.
Refinery	90424	14	13.22	1.06	0.58 - 1.78
Terminal	92225	16	13.87	1.15	0.66 - 1.87
Airport	8704	2	1.34	1.49	0.18 - 5.39
Onshore production	26379	1	2.64	0.38	0.01 - 2.11
Offshore Production	9379	1	0.84	1.20	0.03 - 6.67
	227111	34	31.90	1.07	0.74 - 1.49

Tables 46 to 48 show the relative incidence of leukaemias, in successive periods of first employment, according to duration of employment, and according to time since first employment in the industry. Since there is uncertainty whether smoking increases the risk of leukaemia, separate analyses were performed both controlling and not controlling for possible confounding by smoking. Controlling for smoking did not affect the outcome, but only the results controlling for smoking are shown.

As seen in Table 46, there is no trend in incidence according to period of first employment in the industry.

Table 46: Leukaemia incidence by period of first employment, adjusted for age and calendar period of follow-up and smoking

Period of First Employment	Person-Years	Cancers	RIR	95% C.I.
Post 1975	110337	9	1.00	
1965-74	72583	11	0.95	0.36 - 2.51
1955-64	29932	8	0.97	0.28 - 3.34
Pre 1954	14259	6	1.14	0.28 - 4.68

Test for heterogeneity p = 0.99
Test for trend p = 0.85

Table 47 shows that incidence according to categories of duration of employment, the baseline category being those employed for 5-9 years. The rate in this baseline category was low relative to those employed longer, but the difference was not significant and there was no overall trend.

Table 47: Leukaemia incidence by duration of employment, adjusted for age and calendar period of follow-up and smoking

Duration of Employment	Person-Years	Cancers	RIR	95% C.I.
5-9 Years	53140	3	1.00	
10-15 Years	54590	6	1.55	0.37 - 6.45
16-19 Years	43651	8	2.19	0.52 - 9.15
20-24 Years	30487	6	1.96	0.42 - 9.13
>=25 Years	45226	11	1.50	0.33 - 6.96

Test for heterogeneity p = 0.81
Test for trend p = 0.76

As shown in Table 48 there is no significant trend in relation to lapse of time between first employment and diagnosis.

Table 48: Leukaemia incidence by time since first employment, adjusted for age and calendar period of follow-up and smoking

Time Since First Employment	Person-Years	Cancers	RIR	95% C.I.
5-9 Years	38475	3	1.00	
10-15 Years	47931	4	0.93	0.20 - 4.34
16-19 Years	44371	5	1.15	0.24 - 5.47
20-24 Years	34950	9	2.30	0.50 - 10.68
>=25 Years	61384	13	1.02	0.20 - 5.27

Test for heterogeneity p = 0.48
Test for trend p = 0.75

Tables 49 and 50 show the relative incidence of leukaemias in ascending order of hydrocarbon exposure rank score. In Table 49 the analysis is based on the highest hydrocarbon rank job ever held, and shows a marginally significant association between leukaemia incidence and increasing hydrocarbon exposure. Table 50 is based on the hydrocarbon rank of the job held longest, and shows no association between leukaemia incidence and increasing hydrocarbon exposure.

Table 49: Leukaemia incidence by total hydrocarbon exposure (based on highest total hydrocarbon rank job ever held), adjusted for age and smoking

Exposure Category	Person-Years	Cancers	RIR	95% C.I.
1	41478	3	1.00	
2	20113	1	0.96	0.10 - 9.34
3	2485	0	0.00	
4	104602	20	3.01	0.89 - 10.20
5	8405	1	2.02	0.21 - 19.55
6	36634	7	2.90	0.74 - 11.32
7	13365	2	2.43	0.41 - 14.62

Test for heterogeneity p = 0.39
Test for trend p = 0.09

Table 50: Leukaemia incidence by total hydrocarbon exposure (based on total hydrocarbon ranking of job held longest), adjusted for age and smoking

Exposure Category	Person-Years	Cancers	RIR	95% C.I.
1	57030	5	1.00	
2	21560	1	0.68	0.08 - 5.85
3	3721	0	0.00	
4	96148	20	2.44	0.91 - 6.52
5	5997	1	1.96	0.23 - 16.84
6	32790	7	2.42	0.76 - 7.67
7	6414	0	0.00	

Test for heterogeneity p = 0.18
Test for trend p = 0.13

There were no leukaemia cases in women.

4.5.1 Acute non-lymphocytic leukaemia (ANLL)

Although the leukaemias have been grouped for the analysis in the previous section, the different leukaemias are in fact different diseases. Since it is likely that benzene exposure is causally associated only with acute non-lymphatic leukaemia, this rubric is analysed separately.

There were 11 leukaemias in this category. The actual leukaemia types were

- Acute myeloid leukaemia – 8 cases
- Erythraemia/erythroleukaemia – 1 case
- Acute myelomonocytic leukaemia – 1 case
- Leukaemia of unspecified cell type – 1 case

The incidence of ANLL was only slightly above the general population rate and the difference was not statistically significant (SIR 1.06, 95% CI 0.53-1.90).

Table 51 shows the distribution of cases by workplace type. Nine of the 11 cases occurred in refinery or terminal employees. The SIR is raised in these categories but, as can be seen from the wide confidence intervals, the numbers are too low for meaningful analysis.

Table 51: ANLL incidence by workplace type

Workplace Type	Person-Years	Observed	Expected	SIR	95% C.I.
Refinery	90424	4	4.29	0.93	0.25 - 2.39
Terminal	92225	5	4.49	1.11	0.36 - 2.60
Airport	8704	1	0.43	2.31	0.06 -12.90
Onshore production	26379	1	0.87	1.15	0.03 - 6.42
Offshore Production	9379	0	0.27	0.00	
	227111	11	10.35	1.06	0.53 - 1.90

Tables 52 to 54 shows the distribution of the 11 cases by period of first employment, duration of employment, and time since first employment. Five of the 11 cases occurred in subjects who entered the industry before 1954, and 5 cases occurred in subjects employed for more than 25 years, and in the follow-up time of more than 25 years since hire, but relative incidence rates have not been generated because numbers are too low.

Table 52: ANLL incidence by period of first employment, adjusted for age and calendar period of follow-up

Period of First Employment	Person-Years	Cancers
Post 1975	110337	4
1965-74	72583	2
1955-64	29932	0
Pre 1954	14259	5

Table 53: ANLL incidence by duration of employment, adjusted for age and calendar period of follow-up

Duration of Employment	Person-Years	Cancers
5-9 Years	53140	1
10-15 Years	54590	3
16-19 Years	43651	0
20-24 Years	30487	2
>=25 Years	45226	5

Table 54: ANLL incidence by time since first employment, adjusted for age and calendar period of follow-up

Time Since First Employment	Person-Years	Cancers
5-9 Years	38475	1
10-15 Years	47931	3
16-19 Years	44371	0
20-24 Years	34950	2
>=25 Years	61384	5

Tables 55 and 56 show the distribution of the 11 cases according to category of hydrocarbon exposure. The cases were clustered in the middle to upper level exposure categories: there were no cases in the three lowest exposure categories in either table.

Table 55: ANLL incidence by total hydrocarbon exposure (based on highest total hydrocarbon rank job ever held), adjusted for age and smoking

Exposure Category	Person-Years	Cancers
1	41478	0
2	20113	0
3	2485	0
4	104602	7
5	8405	1
6	36634	2
7	13365	1

Table 56: ANLL incidence by total hydrocarbon exposure (based on total hydrocarbon ranking of job held longest), adjusted for age and smoking

Exposure Category	Person-Years	Cancers
1	57030	0
2	21560	0
3	3721	0
4	96148	7
5	5997	1
6	32790	3
7	6414	0

4.6 Prostatic cancer

Prostatic cancer was the commonest cancer in males. There were 251 cases, and the incidence was significantly elevated (SIR 1.18, 95% CI 1.04-1.34).

There were only 35 deaths from prostatic cancer, and the mortality rate was not significantly different from that of the general population (SMR 0.94, 95% CI 0.65-1.30).

The incidence of prostatic cancer is greater than in the general population rate in all categories of workplace type except for airport personnel, but the excess is not significant in any. There was no trend in prostatic cancer incidence with period of first employment, duration of employment, time since hire, or increasing rank of hydrocarbon exposure.

4.7 Other lymphohaematopoietic cancers

Other cancers of the blood and bone marrow have been of interest in the *Health Watch* study because of an apparent excess of these conditions in earlier years of follow-up. At that time these conditions were grouped together because the numbers in the specific diseases in this category were very low. In more recent years non-Hodgkin lymphoma, multiple myeloma and leukaemia have been analysed separately, and it became apparent that there was no increase in the incidence of non-Hodgkin lymphoma in this cohort. In the previous analysis there was an excess of multiple myeloma which was of marginal significance (SIR 1.68, 95% confidence interval 0.95-2.78). In the current analysis the SIR for multiple myeloma was a non-significant 1.14 (95% CI 0.65-1.85).

Comment on specific cancers

Mesotheliomas, melanoma of the skin and prostatic cancers all occurred in statistically significant excess in males. There was no excess mortality rate for any cancer type. There was a statistically significant lowering of lung cancer.

18 mesotheliomas have occurred in the cohort, 15 in refinery maintenance workers and operators. It is likely that several of these cancers are related to asbestos exposure in refineries, mostly before the 1970s, although some are likely to have resulted from asbestos exposure occurring prior to entering the oil industry.

There is no excess of lung cancer in refinery maintenance workers compared with refinery non-maintenance workers. This analysis was carried out in view of the reported excess in some other studies of lung cancer in refinery maintenance workers compared with non-maintenance workers (with the excess presumed to be related to asbestos exposure). However this analysis was based on a small number of cancers.

There is a statistically significant increase in the rate of melanoma. The rate does not increase with increasing duration of employment or with increasing exposure to hydrocarbons. Similarly, prostatic cancer shows no association with duration of employment or increasing hydrocarbon exposure. On this basis and from what is known of the causation of these two cancers, it is therefore unlikely that either is caused by a factor in the workplace in this industry.

There is no excess of leukaemias with all leukaemia types combined. Acute nonlymphocytic leukaemia, which is most likely to be causally associated with benzene exposure, is not present in significant excess. There are too few of these leukaemias for statistical analysis according to duration of employment or increasing hydrocarbon exposure, but all cases were clustered in the medium to higher exposure categories, ie none of the 11 cases occurred in subjects in the 3 lowest exposure categories. It is therefore uncertain whether benzene exposures in the petroleum industry have been high enough to cause any cases of acute non-lymphocytic leukaemia.

No cancer occurred in significant excess in females.

5 HEALTH OUTCOMES IN SPECIFIC JOBS

The ability to assess risk in particular jobs as defined by their AIP Jobcode, is recognised to be a most useful method of assessing risk in the industry, because workplace categories, eg all refinery workers, includes many jobs having very different exposures. However, analysing by AIP Jobcode is limited by the numbers of employees in any particular job. This number, with the multiplier arising from the length of time *Health Watch* has been in operation, produces person-years of observation for analysis. When person-years reach a sufficient size, analysis of risk for the employees holding that job can be done.

The AIP Jobcodes analysed in this report are "Drivers" (NB295x), "Refinery operators" (Bx, HX, Px, Rx), "Terminal operatives" (IB, NA, Bx, Px, RF, HX) and "Maintenance (refinery or terminal based)" (IX, Cx, Dx, Ex, Fx, GX, MX, LA, Rx), and shift workers. Each person's full job history since 1980 was checked and categorised according to whether the person has ever held the particular job classification. Those who have held more than one category appear in both categories in the analysis.

Analysis has been done for some major health outcomes including all cause mortality, ischaemic heart disease, cancer, and accidents and violence mortality in addition to cancer incidence. For many other health outcomes, numbers are very low and unreliable.

5.1 All-cause mortality

As shown in Table 57, all-cause mortality for each of these occupations is similar to the all cause-mortality for the whole cohort.

Table 57: All-cause mortality by AIP Jobcode

Job	Person-Years	Observed	Expected	SMR	95% C.I.
Driver	35090	161	223.35	0.72	0.61 - 0.84
Refinery	85884	333	473.81	0.70	0.63 - 0.78
Maintenance	46102	176	244.06	0.72	0.62 - 0.84
Shiftwork	119618	478	701.99	0.68	0.62 - 0.74

5.2 Cancer incidence

As shown in Table 58, there is a small but marginally significant increase in all-cancer incidence in drivers (SIR 1.15, 95% CI 1.00-1.32).

Table 58: Cancer incidence by AIP Jobcode

Job	Person-Years	Observed	Expected	SIR	95% C.I.
Driver	33043	203	175.81	1.15	1.00 - 1.32
Refinery	80371	389	370.44	1.05	0.95 - 1.16
Maintenance	43020	172	185.00	0.93	0.80 - 1.08
Shiftwork	112113	555	547.04	1.01	0.93 - 1.10

As with the cohort as a whole, there were more melanomas, prostate cancers and bladder cancers than expected from Australian population rates, although the excesses were not statistically significant.

5.2.1 Incidence of cancer of the kidney (ICD-10 C64-66, C68) in drivers

The only cancer in significant excess in drivers was cancer of the kidney, (12 cases vs 5.84 expected, SIR 2.05, 95% CI 1.06-3.59).

Because there were only 12 cases, it is not possible to conduct a meaningful analysis in terms of time-related factors. Nor is a meaningful analysis of trend with hydrocarbon exposure possible, since drivers are ranked in category 6 of hydrocarbon exposure. However as shown in Tables 59 and 60, analysis of kidney cancer in the entire cohort – that is, not just in drivers - shows increasing incidence with hydrocarbon exposure, although the incidence of kidney cancer in the whole cohort is not significantly raised (see Table 15 in Chapter 3).

Table 59: Kidney cancer incidence by total hydrocarbon exposure (based on highest total hydrocarbon rank job ever held) – total cohort

Exposure Category	Person-Years	Cancers	RIR	95% C.I.
1	41478	6	1.00	
2	20113	2	1.16	0.23 - 5.90
3	2485	1	2.88	0.34 - 24.04
4	104602	18	1.44	0.57 - 3.64
5	8405	0	0.00	
6	36634	13	2.64	0.99 - 7.04
7	13365	5	3.22	0.98 - 10.62

Test for heterogeneity p = 0.15
Test for trend p = 0.02

Table 60: Kidney cancer incidence by total hydrocarbon exposure (based on total hydrocarbon ranking of job held longest) – total cohort

Exposure Category	Person-Years	Cancers	RIR	95% C.I.
1	57030	6	1.00	
2	21560	2	1.32	0.26 - 6.65
3	3721	1	2.55	0.31 - 21.27
4	96148	19	1.91	0.76 - 4.79
5	5997	0	0.00	
6	32790	11	2.90	1.07 - 7.91
7	6414	4	5.28	1.49 - 18.74

Test for heterogeneity p = 0.11
Test for trend p = 0.01

Kidney cancer in the cohort shows no trend in incidence with increasing duration of employment, period of first employment or time since first employment.

5.2.2 Other cancers

Drivers also had a greater than expected number of testicular cancers, but the excess was not statistically significant (5 cases vs 1.86 expected, SIR 2.68, 95% CI 0.87-6.26).

5.3 Cancer mortality

As shown in Table 61, there were no significant excesses in all-cancer mortality in any of the occupational groups studied. The mortality rates were significantly lower than population rates in drivers and shiftworkers.

Table 61: Cancer mortality by AIP Jobcode

Job	Person-Years	Observed	Expected	SMR	95% C.I.
Driver	35090	57	79.38	0.72	0.54 - 0.93
Refinery	85884	142	164.26	0.86	0.73 - 1.02
Maintenance	46102	75	82.15	0.91	0.72 - 1.14
Shiftwork	119618	198	245.04	0.81	0.70 - 0.93

5.4 Ischaemic heart disease mortality

As shown in Table 62, ischaemic heart disease mortality is similar in each of these occupational groups to that of the cohort as a whole. The absence of excess mortality in shift workers from this disorder is notable, since some epidemiological studies have suggested that shift work is a risk factor for heart disease.[22]

Table 62: Ischaemic Heart Disease mortality by AIP Jobcode

Job	Person-Years	Observed	Expected	SMR	95% C.I.
Driver	35090	42	54.84	0.77	0.55 - 1.04
Refinery	85884	73	112.83	0.65	0.51 - 0.81
Maintenance	46102	44	57.18	0.77	0.56 - 1.03
Shiftwork	119618	119	169.34	0.70	0.58 - 0.84

5.5 Mortality from accidents and violence

As shown in Table 63 mortality rates in each of these occupational groups is similar to that of the cohort as a whole.

Table 63: Accident/violence mortality by AIP Jobcode

Job	Person-Years	Observed	Expected	SMR	95% C.I.
Driver	35090	16	21.54	0.74	0.42 - 1.21
Refinery	85884	41	53.64	0.76	0.55 - 1.04
Maintenance	46102	19	30.03	0.63	0.38 - 0.99
Shiftwork	119618	54	74.52	0.72	0.54 - 0.95

Mortality rates are significantly lower than population rates in each of the occupational groups studied.

Drivers have a small but statistically significant increase in cancer incidence, but the only specific cancer present in statistically significant excess in drivers was kidney cancer. The possible significance of this finding is discussed in the following chapter.

Mortality rates from heart disease are significantly lower in refinery workers and shift workers than in the general population.

6 DISCUSSION

Strengths and weaknesses of the study

A major strength of *Health Watch* is that there is at least one personal interview record for every subject in the cohort. First and most important is that written consent has been obtained from subjects to search for their names in periodic searches of cancer registry data. (A small number of participants withheld consent: their names are not included in files submitted to the cancer registries for matching unless they are deceased.) The interview-based data provides considerable detail about jobs and tasks performed in the industry; this forms the basis of hydrocarbon exposure estimates of each subject. It also means that details on smoking history and alcohol intake are available for each subject.

The availability of self-reports from surveys and questionnaires has also enabled some useful information to be produced on asbestos-related conditions. Although this information is probably incomplete, it is a useful adjunct to the other analyses on asbestos-related conditions.

Participation in *Health Watch* is voluntary. This could cause volunteer bias if those motivated to participate had a different health status from non-participants. This is not likely given that recruitment was an active process. Site rolls were provided to the survey interviewers, and each individual approached and invited to participate. Refusal to participate was uncommon, and the reason for the missing employees is in most cases difficulty in locating them through temporary absence such as shift work or annual leave. The high participation rates (93%) in the first two surveys make volunteer bias very unlikely. The participation rates were lower in the third and fourth surveys (estimated at 84% and 73% respectively). The latter resulted in a lack of recruits to the cohort in the Fourth Survey from offshore production, although this did not significantly alter the composition of the cohort: 4.0% of the cohort were in the offshore production sector, prior to the fourth survey and 3.7% after.

Another source of bias could be the ability of employees to volunteer to participate after becoming ill; that is subjects could have initially refused to participate in a *Health Watch* survey, but having then developed a disease, could then volunteer to participate in a later survey. This could cause an upward bias, ie an overestimate, of the mortality rate, but since all mortality rates of all major disease categories and of most individual cancers were less than expected, this is unlikely to have caused any misleading results. Joining the *Health Watch* cohort after developing cancer cannot affect the cancer analysis, since follow-up time does not commence until the person becomes a cohort member, and cancers occurring before subjects' follow-up time commences are excluded from the analysis.

A potential weakness of the study is that subjects' date of hire is obtained from subjects at the time of interview. This could affect analyses by time-related variables, ie period of hire, duration of employment and time since hire. Unfortunately the personnel records of most companies have been overhauled in recent years, making access to records from the era when most subjects were first hired very difficult. It has therefore been judged impractical to conduct an audit of the date of hire obtained at interview against dates from company records. Nevertheless error is likely to be random and hence unlikely to lead to bias. Moreover errors from imperfect recollection of the year of hire are likely to be small in relation to the size of time-related categories (eg period of employment categories are pre-1954, 1955-64, 1965-74, post-1975).

Date of termination is obtained from participating companies. Even here however information was not always complete. An audit of those classified as still employed by participating companies disclosed that many were not. Following a further check of company employment records and other follow-up measures, the errors from this source have now been minimised.

The follow-up rate has been satisfactory, with only 3.6% of males lost to contact on the cutoff date of 31/12/2001. Many of those lost to contact were in fact traced not long before the cutoff date, so that only 1.3% of person-time was lost. The loss of contact was relatively high in females, probably because of change of name. Because there were relatively few females in the cohort originally, it is unlikely that detailed analyses will ever be possible on females in this cohort.

Identification of cancer is a strength of the study as cancer registration is mandatory in all Australian States and Territories, and registration is virtually complete. However complete matching cannot be guaranteed, and some problems have occurred in reconciling information from the National Cancer Statistics Clearing House (NCHCS) held by the AIHW and the State cancer registries which supply the information to it. This has been discussed in Chapter 2.

Mesothelioma and other asbestos-related conditions

The occurrence of 18 cases of mesothelioma is a sure indication of past asbestos exposure and is consistent with the findings of other studies in oil refinery workers.[18,23] It is likely that some of these cases are attributable to asbestos exposure prior to entering the petroleum industry, but the number of self-reports of other asbestos-related conditions in *Health Watch* subjects – pleural plaques and possibly asbestosis – indicate that some asbestos exposure has occurred in refineries. Examination of the records of the individual mesothelioma cases indicates that the causal exposure occurred many decades ago. However this is simply a result of the long latency period between initial exposure and occurrence of the disease.[24] Of course stringent regulations to prevent asbestos exposure have been in place for several years and there is now a much greater awareness of the hazards of asbestos, so that it is unlikely that exposures such as in the 1950s and 1960s have occurred in recent years. Nevertheless mesotheliomas can follow quite low exposures, and it is important that any potential sources of exposure be identified and removed or controlled.

The occurrence of mesothelioma and other asbestos-related conditions raises concern over the possibility of asbestos-related lung cancer. As discussed in Chapter 4, the relatively low incidence of lung cancer suggests that there are few if any such cancers caused by asbestos. Nevertheless the possibility that some asbestos-related lung cancers have occurred in maintenance workers in refineries has been proposed, despite the consistent finding of low lung cancer rates in other studies of refinery workers. This question has been addressed in the *Health Watch* cohort by comparing lung cancer incidence in refinery maintenance personnel with other non-office refinery workers. The availability of individual smoking histories enabled controlling for the confounding effect of smoking. The analysis suggests that the lung cancer rate is not higher in the maintenance personnel, and therefore does not support the hypothesis that some asbestos-related lung cancers have occurred. However the analysis was based on small numbers of cancers.

Leukaemia

Leukaemia has been a disease of special concern in this industry because of its association with benzene exposure. The analyses early in the history of the Health Watch cohort indicated an excess of lymphohaematopoietic cancers, a broad category which includes the leukaemias, multiple myeloma and non-Hodgkin lymphoma, but not Hodgkin's disease. Subsequent analyses have found excesses confined to the leukaemias, and even with the leukaemias the excess has been lessening with successive analyses. Successive analyses of leukaemias have shown the following:

1987 (7th *Health Watch* Report): 9 observed, 2.7 expected, SIR 3.3, 95%CI 1.5-6.3
1988-9 (8th *Health Watch* Report): 12 observed, 3.6 expected, SIR 3.4, 95%CI 1.7-5.9
1992 (9th *Health Watch* Report): 18 observed, 6.4 expected, SIR 2.8, 95%CI 1.7-4.5
1998 (10th *Health Watch* Report): 28 observed, 14.1 expected, SIR 2.0, 95%CI 1.3-2.9
2000 (11th *Health Watch* Report): 30 observed, 19.9 expected, SIR 1.50, 95%CI 1.02-2.15
2004 (12th *Health Watch* Report): 34 observed, 31.9 expected, SIR 1.07, 95%CI 0.74-1.49

It can be seen that there is now no significant excess of leukaemias in the Health Watch cohort. Moreover, internal analysis within the cohort shows no significant trend in leukaemia incidence with duration of employment or with increasing hydrocarbon exposure. This finding is not unexpected, since "leukaemia" is not a single disease, but a composite of leukaemia types which are in fact different disease entities. Of these, only acute non-lymphocytic leukaemia is likely to be causally related to benzene exposure.

Acute non-lymphocytic leukaemia (ANLL)

ANLL is the leukaemia category of greatest interest because of its association with benzene. Overall there is no excess compared with the general population (11 cases observed and 10.35 expected). While this may suggest that benzene exposures in this industry may be too low to cause a detectable increase in the incidence of ANLL, it should be noted that the 11 cases are clustered in the medium to higher categories of hydrocarbon exposure; that is, there are no cases at all in the three lowest exposure categories.

It is possible that the absence of any cases in the low exposure categories could be due to errors in classification. As discussed in Section 2.2.5, this method of categorisation is a somewhat crude index of exposure. Furthermore several tasks in the industry have not been assigned an exposure category, and subjects who had been in such jobs were assigned to the default category 4, which is accordingly the largest category in terms of follow-up, and with the largest number of leukaemia cases. Nevertheless the analyses of ANLL by hydrocarbon exposure are similar to that of the Health Watch case-control study, in which careful estimates of benzene exposure were made.[25] This suggests that misclassification bias has not contributed significantly to the findings of the internal analyses.

This leaves two possible explanations for the clustering of the ANLL cases in the high exposure categories: either it is a chance finding due to random variation, or benzene exposure has actually caused some of the ANLL cases in this cohort.

Interpretation of whether or not this association is causal needs to include consideration of the SIR, that is the overall incidence to that of the general population. The SIR is 1.04; that is, the incidence is virtually the same as for the general population. However the upper 95% confidence limit is 1.86, so that a true elevation in leukaemia incidence is possible.

Interpretation may be assisted by referral to other studies. The largest study in the industry is a meta-analysis of the results of all cohort studies of the petroleum industry, covering 208000 workers in the US and the UK.[26] There was no increase in acute myelogenous leukaemia deaths, which comprises most deaths from ANLL. The authors attributed the findings to the low levels of benzene exposure in the industry. Since then the results of a Canadian cohort study have been published in two reports. The first of these studies found a marginally significant excess mortality from ANLL but most of the excess was in office workers.[27] The latter study showed no increase in ANLL incidence or mortality.[28]

A number of case-control studies in the industry have been published. In a study of petroleum marketing and distribution workers in the UK, the authors concluded that there was some suggestion of a relation between exposure to benzene and myeloid leukaemia, particularly acute myeloid leukaemia.[29] A case–control study nested within the Canadian cohort in 1996 has shown no association between increasing benzene exposure and risk of leukaemia.[30] On the other hand the case-control study from the *Health Watch* cohort has found a strong association with increasing benzene exposure.[31]

Because of the substantial differences between the findings of the *Health Watch* case-control study and those of the UK and Canada, a review of the three studies has been commissioned by CONCAWE, the health, safety and environment office of the European petroleum industry. The review is being undertaken by the Institute of Occupational Medicine (IOM), a Scottish-based consultancy. Because of the small number of cases (the total number of ANLL cases in the 3 studies is only 50), an examination is being made of the compatibility of the study methods with a view to a combined analysis.

At the time of writing this report it is not known how or whether the case-control study in the *Health Watch* study will be reconciled with the other contemporary case-control studies in the petroleum industry. However the findings of the cohort study indicate that, at most, only a very small number of workers in this industry have developed ANLL from benzene exposure.

Melanoma

The significance of the excess melanoma incidence is not clear, but no causal association with any exposure in the workplace is apparent since there is no tendency for increasing risk with increasing duration of employment, and risk shows no relationship to hydrocarbon exposure.

Despite the excess melanoma incidence the mortality rate is low, although not significantly different from that of the general population (SMR = 0.90, 95% CI 0.50-1.48). This finding is consistent with early recognition as the cause of the raised incidence rate. However if this were so it might be expected that melanomas are being diagnosed at a relatively early stage, whereas the analysis of staging of cancers registered in NSW showed that melanomas were not being diagnosed at an earlier stage than in the general NSW population.

Excess of melanoma mortality has been reported in UK refinery workers.[32] Excesses were reported for operators, administrative, clerical and managerial staff, and other craftsman. No occupational cause was apparent. A meta-analysis of 350000 workers in the petroleum industry reported a marginally significant excess of deaths from skin cancer, ie including non-melanoma skin cancers (SMR 1.10, 95% CI 0.99-1.22).[33] The only other cancer incidence study in the industry showed non-significant excesses of melanoma in both males (SIR 1.25, 95% CI 0.82-1.83), and females (SIR 1.46, 95% CI 0.83-1.27).[34]

Thus an excess of melanoma in this industry is not unusual, but no occupational cause is apparent. Apart from the well-established association with exposure to solar radiation, melanoma has a tendency to occur in higher socioeconomic groups.[35] There is no reason to suspect either factor being of special significance in this cohort, which has mostly excluded senior management.

Bladder cancer

Bladder cancer was found in significant excess in the previous analysis (SIR 1.37, 95% CI 1.00 to 1.83).[37] In this analysis the excess is smaller and not statistically significant (SIR 1.17, 95%CI 0.89-1.50). Bladder cancer mortality was not elevated.

An increased risk of bladder cancer mortality has not been noted in this industry, and in the only other cancer incidence study in the industry no excess was found.[28]

An analysis of the association between bladder cancer and smoking has been carried out. The relative risk of smoking (ever smoked vs never smoked) was 3.3, which is in accord with other published reports.[37]

Kidney cancer

Although the incidence of cancer of the kidney was not raised in the cohort as a whole, the incidence was statistically elevated in drivers. Since there were only 12 cases, meaningful analyses of incidence by time-related factors were not possible, and analyses by hydrocarbon exposure ranking is not possible because drivers are all given the same exposure ranking (category 6). However in the cohort *as a whole* there was a significant trend of increasing

relative incidence rate of kidney cancer with increasing hydrocarbon exposure ranking, even though the incidence of kidney cancer was not significantly elevated. As explained in the Methods chapter (Section 2.2.6) the hydrocarbon exposure ranking system is a crude index of exposure, so that some caution is required in interpreting this result. Moreover, in the whole cohort there was no trend to increasing incidence with increasing employment time, as might be expected with if the cancer were work-related.

There is limited prior evidence to suggest a possible link between kidney cancer and hydrocarbon exposure. A population-based case-control study published in 1989 found a weak positive association between renal-cell carcinoma and hydrocarbon exposure was found in males only.[38] Another population-based case-control study based on incident cases in the Danish Cancer Registry found a two-fold increase in risk of renal-cell carcinoma in workers occupationally exposed to gasoline (Odds Ratio 2.1, 95% CI 1.1-4.1).[39] In a 1993 report of Canadian petroleum distribution workers (which includes drivers) a non-significant excess mortality from kidney cancer (SMR 135) was found. Those exposed to hydrocarbons daily had a relative risk of mortality from kidney cancer of 3.80, although the excess was not statistically significant.[40] In another study of UK distribution workers, the SMR for kidney cancer in drivers was 141. 15 of the 25 deaths were in drivers with more than 20 years service, but the excess was not statistically significant.[41] However other mortality studies in the petroleum industry have not noted an increase in cancers of the kidney,[33] and the only other cohort study of cancer incidence in this industry found no excess of kidney cancer.[28]

The possibility of an association between cancer of the kidney and hydrocarbon exposure warrants further study, particularly in future studies of cancer incidence.

Healthy worker effect (HWE)

In the 11th *Health Watch* Report a difference was noted between mortality rates in the cohort, which are subject to a "healthy worker effect" and cancer incidence rates which are not. There was a marked elevation of SIR compared with SMR for a number of cancers, and it was hypothesised that the "healthy worker effect," at least in the case of cancer, is due not to low incidence but to longer survival. It was further proposed that prolonged survival for cancer in this cohort might be due to diagnosis of cancers, such as melanoma and bladder cancer, at earlier stages than in the general population.

To test the hypothesis that cancer in the cohort are diagnosed early in comparison to the general population, the staging of a number of selected cancers registered in NSW in *Health Watch* subjects was compared with the general NSW population. There was no overall difference in the staging. In particular cancers in the *Health Watch* cohort were not diagnosed earlier than in the NSW population, so the hypothesis was not supported.

To test that survival time is longer in the *Health Watch* cohort, relative survival from melanoma was compared with that of the Australian population. Prolonged survival was not found in the *Health Watch* cohort cancer cases: in fact relative survival was marginally lower than in the Australian male population. Again the hypothesis was not supported.

In their textbook Statistical Methods in Cancer Research, Breslow and Day state that the HWE appears to be smaller for cancer incidence than for cancer mortality. The only explanation they offer is that those with cancer are more likely to have left their job: however this would not explain disparity between cancer incidence and cancer mortality in a single cohort.[42]

The "healthy worker effect" was identified from cancer mortality studies, before cancer incidence data became available for epidemiological analysis. So far a satisfactory explanation for the absence of such an effect in cancer incidence studies is lacking.

5 REFERENCES

1 Tabershaw Occupational Medicine Associates. Job code classification system: Part1 – Petroleum refineries and selected petrochemical operations. Washington: API, 1979.

2 American Petroleum Institute OH Industrial Hygiene Sub-Committee. Job code classification system: Part II – Production operations and marketing/transportation operations. Washington: API, 1985.

3 Hill DJ, White VM, Scollo M. Smoking behaviours of Australian adults in 1995: trends and concerns. Med J Aust 1998; 168: 209-213.

4 McMichael AJ. Standardized mortality ratios and the "healthy worker effect": scratching beneath the surface. J Occ Med. 1976; 18: 165-8.

5 Monson RR. Observations on the Healthy Worker Effect. J Occ Med 1986; 28: 425.

6 McMichael AJ. Social class(as estimated by occupational prestige) and mortality of Australian males in the 1970s. Community Health Studies 1985; IX: 220-230.

7 Gun RT. Socioeconomic status and stage of presentation of colorectal cancer. Letter. Lancet 1999; 353: 409-410.

8 Halpern MT, Gillespie BW, Warner KESO. Patterns of absolute risk of lung cancer mortality in former smokers JNCI 1993; 85: 457-64.

9 Risch HA, Howe GR, Jain M et al. Are female smokers at higher risk for lung cancer than male smokers? A case-control analysis by histologic type. Am J Epidemiol 1993; 138: 281-93.

10 Peto R, Darby S, Deo H, Silcocks P, Whitley E, Doll R. Smoking, smoking cessation, and lung cancer in the UK since 1950: combination of national statistics with two case-control studies. BMJ. 2000;321:323-9.

11 Makela P, Valkonen T, Poikolainen K. Estimated numbers of deaths from coronary heart disease "caused" and "prevented" by alcohol: an example from Finland. J Stud Alcohol. 1997; 58: 455-63.

12 Keil U, Chambless LE, Doring A et al. The relation of alcohol intake to coronary heart disease and all-cause mortality in a beer-drinking population. Epidemiology 1997; 8: 150-6.

13 Australasian Faculty of Occupational Medicine. Asbestos-related cancers. In: Occupational cancer: a guide to prevention, assessment and investigation. Royal Australasian College of Physicians, Sydney, 2003.

14 Jarvholm B Pleural plaques and exposure to asbestos: a mathematical model. Int J Epidemiol. 1992;21:1180-4.

15 McDonald AD, Harper A, El Attar OA, McDonald JC. Epidemiology of primary malignant mesothelial tumors in Canada. Cancer 1970; 26: 914-919.

16 Gun RT, Costa A, Wishart R. Compensation for death from mesothelioma in South Australia. Proceedings of WorkCover Conference on dispute resolution, Adelaide, October, 1992.

17 Tsai SP, Waddell LC, Gilstrap EL, et al. Mortality among maintenance employees potentially exposed to asbestos in a refinery and petrochemical plant. Am J Ind Med 1996;29:89–98.

18 Gennaro V, Finkelstein M, Ceppi M et al. Mesothelioma and lung tumours attributable to asbestos among petroleum workers. Am J Ind Med 2000; 37:275-82.

19 Finkelstein M. Maintenance work and asbestos-related cancers in the refinery and petrochemical sector. Am J Ind Med 1999; 35: 201-205.

20 Satin KP, Bailey WJ, Newton KL et al. Updated epidemiological study of workers at two California petroleum refineries, 1950-95. Occup Env Med 2002; 59:248-252.

21 Rosamilia K, Wong O, Raabe GK. A case-control study of lung cancer among refinery workers. J Occup Environ Med 1999; 41:109-103.
22 Tenkanen L, Sjoblom T, Kalimo R et al. Shift work, occupation and coronary heart disease over 6 years of follow-up in the Helsinki Heart Study, Scand J Work Environ Health. 1997; 23: 257-65.
23 Gennaro V, Ceppi M, Boffetta P et al. Pleural mesothelioma and asbestos exposure among Italian oil refinery workers: Scand J Work Environ Health. 1994; 20: 213-5.
24 Peto J, Seidman H, Selikoff IJ. Mesothelioma mortality in asbestos workers: implications for models of carcinogenesis and risk assessment. Br J Cancer, 1982; 45: 124–135.
25 Monash University and Deakin University. Lympho-haematopoietic cancer and exposure to benzene in the Australian petroleum industry. Technical report and Appendices, June 2001. At www.aip.com.au
26 Wong O, Raabe GK. Cell-type-specific leukemia analyses in a combined cohort of more than 208,000 petroleum workers in the United States and the United Kingdom, 1937-1989. Regul Toxicol Pharmacol. 1995;21:307-21.
27 Lewis RJ, Schnatter AR, Katz AM et al. Updated mortality among diverse operating segments of a petroleum company. Occup Environ Med. 2000;57:595-604.
28 Lewis RJ, Schnatter AR, Drummond I et al. Mortality and cancer morbidity in a cohort of Canadian petroleum workers. Occup Environ Med. 2003;60:918-28.
29 Rushton L, Romaniuk H. A case-control study to investigate the risk of leukaemia associated with exposure to benzene in petroleum marketing and distribution workers in the United Kingdom. Occup Environ Med. 1997;54:152-66.
30 Schnatter AR, Armstrong TW, Thompson LS, Nicolich MJ, Katz AM, Huebner WW, Pearlman ED. The relationship between low-level benzene exposure and leukemia in Canadian petroleum distribution workers. Environ Health Perspect. 1996;104 Suppl 6:1375-9.
31 Glass DC, Gray CN, Jolley DJ et al. Leukaemia risk associated with low-level benzene exposure. Epidemiology 2003;14:569-77.
32 Rushton L. Further follow up of mortality in a United Kingdom oil refinery cohort. Br J Industrial Medicine 1993; 50:549-560.
33 Wong O, Raabe GK. A critical review of cancer epidemiology in the petroleum industry, with a meta-analysis of a combined database of more then 350000 workers. Reg Tox Pharmacol 2000;32:78-98.
34 Lewis RJ, A R Schnatter AR, Drummond I et al. Mortality and cancer morbidity in a cohort of Canadian petroleum workers. Occup Environ. Med 2003; 60: 918 – 928.
35 Lewis N, Nguyen H et al. Cancer maps for New South Wales; variation by Local Government Area 1991 to 1995. Cancer Epidemiology Research Unit and the NSW Central Cancer Registry. March 1999 www.nswcc.org.au
36 Gun RT, Pratt NL, Griffith EC, Adams GG, Bisby JA, Robinson KL. Update of a prospective study of mortality and cancer incidence in the Australian petroleum industry. Occup Environ Med. 2004 Feb;61(2):150-6.
37 English D, Holman CDJ. The quantification of drug caused morbidity and mortality in Australia. Edition: 1995 ed. Published: Canberra : Australian Govt. Publishing. Service.
38 Kadanami S, Asal NR, Nelson RY. Occupational hydrocarbon exposure and risk of renal cell carcinoma. Am J Ind Med 1989;15:131-41.
39 Mellemgaard A, Engholm G, McLaughlin JK, Olsen JH. Occupational risk factors for renal-cell carcinoma in Denmark. Scan J Work Environ Health 1994;20:160-65.

40 Schnatter AR, Katz AM, Nicolich MJ, Theriault G. A retrospective mortality study among Canadian petroleum marketing and distribution workers. Env Health Perspectives Supplements 1993; 101 (Suppl 6):85-99.

41 Rushton L. A 39-year follow-up of the UK oil refinery and distribution center studies: results for kidney cancer and leukaemia. Env Health Perspectives Supplements 1993; 101 (Suppl 6):77-84.

42 Breslow, N. and Day, N., *Statistical Methods in Cancer Research: The design and analysis of cohort studies*. 1987, International Agency for Research on Cancer, Lyon.