9/11 AND ITS HAZARDOUS EFFECTS

Young Women in Computing

(Team 59)

New Mexico

Supercomputing Challenge

Final Report

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Executive Summary

When the World Trade Centers were attacked on September 11, 2001, many people risked their lives to save victims in the burning and collapsing buildings. The toxins from that attack took a tragic toll on the health of the survivors. These toxins (asbestos, benzene, particulate glass and others) have been shown to cause lung disease, cancer, and numerous other health problems. In the first few years, the effects of these toxins were harder to understand, because of their slow processes of toxicity. However, after ten years, most of the health effects have become more traceable.

We studied this problem because the 9/11 attacks changed our nation and imparted lasting health effects on the survivors. Computer modeling (in NetLogo) was used to demonstrate how toxins in the dust have caused diseases to occur at a higher rate among first responders than in the average United States population with similar characteristics.

We calculated the distributions of cancer and sickness against age. The results are on the graph and were exported to a Microsoft Excel document for further analysis.

We predicted the population with cancer, the percentage of sick, and the bell-curve of the number of sick. Our model will allow health professionals to acknowledge and better prepare for the health risks from tragedies such as the twin tower collapse in the future and in treating in their patients in a timely fashion. Also, these results will enable health professionals to further understand the time needed for a toxin to become deadly in a population. The study will help to prepare the community for future health-related events.

Problem

We needed to find the rate of cancer and lung disease in the first responders exposed to the dust from the Twin Towers when they were attacked and compare it to the normal population. (Normal population represents the population of the United States of America that was not exposed to the 9-11 toxins). First, we evaluated the civilian population of the same era. Then, we evaluated and statistically compared it to the population of surviving first responders. We took means and calculated the variability for sample mean. We wanted to see if there was a statistically significant higher cancer rate among first responders sample and the normal population. We assumed that each group's cancer rates were distributed evenly around different percentages for different age groups.

Methods: A Program Definition

We used NetLogo to model different population getting sick with varying rates of diseases to compare the amount of sickness in each population, especially the populations exposed to 9-11 versus the normal population (the people not exposed). We chose Netlogo over other agent-based modeling programs because one can adjust variables of the simulation and see immediately how it affects the population to better understand the simulation and the simulated effects. Also, the method by which Netlogo can use ticks to count the situations "time" allowed us to study our scenarios using each tick as a month, thus allowing us to do calculations corresponding to real life.

Some of the variables we first wanted to have were whether or not the people came in contact with the 9-11 disaster area, how much time they spent in the area and to what extent they were involved in situations exposing them to hazardous chemicals, and whether or not they wore masks. However, research on this topic presented many contingencies and limits; we were limited in the amounts of data found in databases, print, or on the web due to the short period of time since the tragedy of 9-11. At first we wanted to model lung disease and cancer in four different scenarios: first responders exposed to 9-11 toxins, normal first responder population, average citizens exposed to 9-11 toxins, and normal population not exposed to 9-11 toxins. Now, we are only looking at the first responders exposed to toxins on 9-11 and the normal population affected by cancer.

We set up different "breeds of turtles" to both show the differences between the first responders and normal population, and to simplify the code for diagnosing cancer. To visually portray people getting sick in each run, we programmed Netlogo to change the color of sick people from yellow to red. (Yellow represents a person not affected by cancer. Red represents the person affected by cancer). In each scenario of the 9-11 study and the normal population study, we programmed a plot to automatically run for both the number of people who had different health issues (i.e. lung cancer) and the percentage of the population who different health (i.e. lung cancer). At first the cancer percentages were estimated and put in as placeholder values to test the other aspects of the program. However, when we went back to look for more data to fill in the gaps, we found that there was not enough data to accurately "diagnose" lung disease in our different scenarios and that there was not enough data to warrant the normal first responder or civilians exposed to 9-11 scenarios. Cancer was the most studied health risk, so we based our model on the cancer rates of 9-11 first responders sample and the general population of the country.

For cancer rates, we tried to find a model for the way that it varied with time. Our research indicated that cancer rates widely differed depending on age, and as we wanted to model long term effects, this would have to enter into our calculations. Therefore, we randomly set ages, making them from 25 to 65 as an estimate of the starting ages of the first responders, and determined cancer rates according to the age groups for which our data gave percentages. But gender was another issue we ran into trying to make our cancer rates more realistic. Cancer rates vary widely between men and women. In order to compensate for this, we used a weighted average of the cancer percentages of the men and women in the different age groups using the average ratio of men to women in the United States. This did not take into account the differences between the normal population and the first responder population, which used the same percentages times a constant. We hypothesized that as time went on the differences between the rates of cancer of the first responder population and of a comparable normal population would increase as the toxins had more time to run through the first responders system. We already knew that the first responders currently have a rate of cancer 10 percent higher than the comparable normal population, but to try to model our hypothesis, we made the first few age groups differ in cancer percentages by 10%. Later age groups differ by higher percentages. This idea was flawed, due to the variety of ages at the time of exposure to the 9-11 disaster scene, so some people who had just been exposed were being assumed to have a 20% higher chance of cancer than the normal population, and others when exposed 10 years are only assumed to have a 15% higher chance of cancer than the normal population.

In another area, we made a death sequence, using another variable, vitality, to avoid people from only dying at a certain age. Some of the 9-11 victims may have died before being diagnosed with cancer. Due to limited data was found data on death rates, how the person died, and the ages of the people that died of normal and 9-11 populations, we were unable to model this aspect of the study.

To correct these many statistical errors that were pointed out in the design of our program, we were forced to make many changes to the program, and in some cases put limitation on it to improve its accuracy, and look for more information about our topic. When searching for this information, we were able to find a complete version of the study from *The Lanclet*, which was a main source of information in our model, and found much information that greatly simplified our problems. In one parameter, we discovered was that the study included only firefighters, and not other first responders, so we could only safely extend the results of our research to firefighters instead of all first responders as we had hoped to do. The mean age and standard deviation of the subjects in *The Lanclet* allowed us to base the ages of our populations on evidence. We assumed a Normal distribution and programmed the ages to have the empirically determined mean and standard distribution. We made a histogram (see Appendix B) for Histogram 1 and Histogram 2) of age to make sure the standard deviation and mean were correct, then kept the histogram because it helped to show the passage of time and helped to give more information. This histogram provided us with a source of visual (and easily interpreted) information that helped us to draw our conclusions. We found that the source we were using didn’t use females (to avoid statistical errors) because of the differences in cancer rates between the genders. Therefore, we were able to use only the male percentages and cut out another source of error. We stopped the death sequence and instead stopped simulations after 30 years to avoid having large statistical errors resulting from subjects who should have been dead with old age or sickness. We also made our program more visually appealing by making the different environments match the subject matter of our study.

Finally, we improved the mechanism for diagnosing cancer as time passes. We made a new variable, Percentage-Cancer-Rate-Changes-Every-Year, to provide flexibility in this new way of diagnosing. The percentage, which is present only for diagnosing firefighters, not the normal population, works by increasing the percentage of people who get sick each year by multiplying the normal percentage by 1 added to the Percentage-Cancer-Rate-Changes-Every-Year (to make it the normal percentage in addition the normal percentage multiplied by the variable) with the latter part of the equation raised to the power of the number of years since 9-11 occurred (or ticks / 12 in the program world). This in effect makes each year's percentage Percentage-Cancer-Rate-Changes-Every-Year higher than the previous year. This allows different modeling based on different input information, and allows different outcomes of sicknesses to be predicted based on the assumed rate of change per year.

Research

We found several important studies, including one that had been printed in *The Lancet*. It gave us a standardized incidence ratio. We also used data from a few of the tables (see Appendix C for Table 1, Table 2, and Table 3) from the article in *The Lancet*. In the tables, we found a point to compare our data and their data for validity. According to the tables, at 87 months, 16 people had cancer. If our values of the number of people that have cancer were close to 16 people in the 9-11 scenario, then our model is valid. In the study, Table 2 and Table 3 were primarily used for their information on cancers. Table 2 was used to determine the mean and the standard deviation of age. Table 3 was used for the information it had on cancers.

We used various sites (see References) to find the cancer rates of the general population. On these sites, we used the male cancer rates because if the statistics for women were combined with those of the men, it would lead to inconsistencies that would cloud our data. We used the data in the top column of men to determine the probability of cancer by age. We did not limit our cancer rate to one specific kind of cancer; we used the rates for all cancers related to the 9-11 toxins.

Analysis

According to the data from *The Lancet*, at the end of the study, on December 31 of 2008 (87 months after 9-11), including the cancers that were diagnosed early instead of "correcting" by excluding those with a long lag time, exposed firefighters are 10% more likely to have cancer than the average population. However, we could not use exact numbers to compare our model to *The Lancet* data because we were forced to use less precise data for how often certain age groups get cancer due to a lack of ethnicity data and precise age data. The difference between the data in our model and *The Lancet* report, however, is the same across both models. Dividing the first responder scenario into the most accurate variable of the average normal population at 87 months after 9-11 in our model should cancel out any inaccuracies and be equal to 1.1—because the division will cancel any differences between the model and *The Lancet* data. Therefore, the average cancer incidence in the 9-11 firefighter scenario with the most accurate Percentage-Cancer-Rate-Changes-Every-Year value divided by the average value of the cancer incidences in the normal population at 87 months (which we found to equal 27.05 out of 1000 by averaging 75 trial runs) should equal 1.1. This means we looked for the variable which if used has 29.76 firefighters with cancer at 87 months, because the 27.05 normal multiplying the 1.1 firefighter to normal ratio should be the average number of firefighters with cancer at this time. At between .97 and 1 Percentage-Cancer-Rate-Changes-Every-Year, our values were the most accurate to this test. For further tests we used the value .98 because when using it in the trials a mean of 29.26 close to the desired value of 29.76 was found at 87 ticks.

We compared both scenarios at 20 years (240 ticks) and at 30 years (360 ticks). (One tick represented one month). Each scenario was run 50 times for validity.

At 20 years (240 ticks):

	Mean (people out of 1000)	Standard Deviation (people)
Normal Population Scenario	99.34	8.23
9-11 Scenario	109.2	13.2

At 30 years (360 ticks):

	Mean (people out of 1000)	Standard Deviation (people)
Normal Population Scenario	182.3	10.80
9-11 Scenario	203.6	36.6

At 20 years, the people affected at the site of the 9-11 event produced a greater mean and standard deviation than the normal population. At 30 years, the people affected by the 9-11 event also possessed a greater mean and standard deviation than the normal population. This shows that the collapse of the 9-11 twin towers did have an effect on the health of the people at the event.

Most Significant Achievement

Over the course of the past few months, our team has faced and overcome a few challenges regarding our project. The most significant achievement would have to be overcoming the obstacle of lack of information. Due to the fact that this tragic event only occurred ten years ago, there are few studies on this subject. We had a difficult time finding the information we needed, and that compromised our project.

We found all sorts of information on this topic, but none of it pertained to our project. Some of them would contradict each other, and others did not have the information that we needed. Some included both genders, while others only included men. We had originally intended to include both men and women in our project, but the statistics made it difficult to represent the data using computer programming.

Then, we had an idea to include both first responders and firefighters in our representation. We wanted to show the average cancer rate among first responders who were at the World Trade Center when the towers came down, compared to first responders in other cities. We wanted to do the same with the firefighters. However, the information was just not there; we couldn't locate specific information for this aspect of the model.

We caught a break when we found the study on cancer by *The Lancet*. Most of the information we needed was in that study. We used some other websites, but it took us a few months to gather up all the information needed. We found the cancer rates in an American Cancer Society Surveillance Research study.

When we found all the information that we needed, we felt a weight lifted off our shoulders. We had accomplished one of our greatest goals. We had what we needed to complete the project. Even though it took a while longer than we had hoped, it was a relief to finally have the research done. The research had always been our biggest obstacle, and when we finally overcame it, it was the greatest feeling in the world.

Conclusion

After modeling the 9-11 affect people who were exposed to the toxins in the air, on that day, were more likely to have cancer, as opposed to the normal population. More first responders at the site of the event will be diagnosed with cancer in the next ten and twenty years.

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Appendix A: The Code

```
breed [ responder responders]
breed [normal normals]
turtles-own [age ]

to setup
     clear-all
     if Scenario = "Normal Population"
     [setup-normal
     setup-patches]

     if Scenario = "9-11 Firefighters"
     [setup-responders
     setup-epicenter]
     assign-age
     do-plots
end

to assign-age
  ask turtles [set age ( random-normal 44.0 6.7 ) ]
  end

to setup-patches
     ask patches [ set pcolor scale-color sky ( random 2500 +
45000) 0 100000 ]
     ask patches [if ( pycor < 9 ) [ set pcolor scale-color
green  (random 5000 + 40000) 0 100000]]
end

to setup-epicenter
  ask patches [ set pcolor scale-color gray ( random 2500 +
50000) 0 100000 ]
     ask patches [if ( pycor < 9 ) [ set pcolor scale-color
black  (random 5000 + 10000) 0 100000]]
  ask patches with [ ( pxcor < -2 and pxcor > -11 and pycor <=
14 ) or ( pxcor < 11 and pxcor > 2 and pycor <= 14 ) ] [set
pcolor scale-color black  (random 5000 + 30000) 0 100000]
end

to setup-normal
  create-normal 1000
  ask normal [ setxy random-xcor random-ycor ]
  ask normal with [ ycor > 9.1] [set ycor ycor - 7.7 - random 9]
  ask normal with [ycor < -15] [set ycor ycor + 1]
  ask normal [set color yellow ]
  ask normal [set shape "person" ]
```

```
  ask normal [set size size * 1.7 ]
end

to setup-responders
  create-responder 1000
  ask responder [ set shape "firefighter" ]
  ask responder [ set color yellow ]
  ask responder [ setxy random-xcor random-ycor ]
     ask responder with [ ycor > 9.1] [set ycor ycor - 7.7 -
random 9]
  ask responder with [ycor < -15] [set ycor ycor + 1.3]
  ask responder [set size size * 2.5 ]
end

to go
  if ticks >= 360 [stop]

  move-turtles
  add-age

  if Scenario = "9-11 Firefighters"
     [diagnose-affected-responder]

  if Scenario = "Normal Population"
  [diagnose-normal]

  tick

  do-plots
end

to move-turtles

  ask turtles with  [ycor >= -15 and ycor <= 9] [
     right random 180
     forward 0.2
  ]
  ask turtles with [ycor < -15]
  [
     set heading 45
     forward 0.3
  ]
  ask turtles with [ycor > 9]
  [
   set heading 135
   forward 0.3
  ]
```

```
end

to add-age
  ask turtles [
     set age age + ( 1 / 12 )
     ]
end

 to diagnose-normal
   ask normal with [age <= 39.9999 and color = yellow] [
     if random-float 100 < ( 1.45 / ( 39.9999 * 12 ) ) [ set
color red]
   ]
   ask normal with [age >= 40 and age <= 59.9999 and color =
yellow ] [if random-float 100 < ( 8.68 / ( 20 * 12) ) [set color
red]
   ]
   ask normal with [ age >= 60 and age <= 69.9999 and color =
yellow] [ if random-float 100 < ( 16.00 / ( 20 * 12) ) [set
color red]
   ]
   ask normal with [ age >= 70 and color = yellow] [
     if random-float 100 < ( 38.27 / (30 * 12) ) [set color red]
   ]
 end

to diagnose-affected-responder

   ask responder with [age <= 39.9999 and color = yellow] [
     ;;as time grows larger, percentage higher chances grow
higher
     if random-float 100 < ( ( 1.45 * ( (1 + ( Percentage-
Cancer-Rate-Changes-Every-Year / 100 ) ) ^ ( ticks / 12 ) ) ) /
( 39.99999 * 12 ) ) [ set color red]
   ]
   ask responder with [age >= 40 and age <= 59.9999 and color =
yellow ] [
     if random-float 100 < ((( 8.68 * ( (1 + ( Percentage-
Cancer-Rate-Changes-Every-Year / 100 ) ) ^ ( ticks / 12 ) ) ) )
/ ( 20 * 12) ) [set color red]
   ]
   ask responder with [ age >= 60 and age <= 69.9999 and color =
yellow] [
     if random-float 100 < ( (( 16.00 * ( (1 + ( Percentage-
Cancer-Rate-Changes-Every-Year / 100 ) ) ^ ( ticks / 12 ) ) ) )
/ ( 20 * 12) ) [set color red]
```

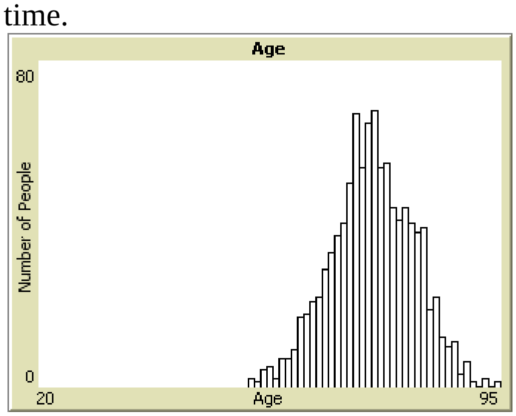
```
   ]
   ask responder with [ age >= 70 and color = yellow] [

     if random-float 100 < ((( 38.27 * ( (1 + ( Percentage-
Cancer-Rate-Changes-Every-Year / 100 ) ) ^ ( ticks / 12 ) ) ) )
/ (30 * 12) ) [set color red]
   ]
 end

to do-plots
  set-current-plot "Population with Cancer"
  set-current-plot-pen "Cancer"
  plot count turtles with [color = red]
  set-current-plot "Percentage sick"
  set-current-plot-pen "Cancer"
  plot (count turtles with [color = red] * 100 ) / ( count
turtles )
  set-current-plot "Age"
  set-current-plot-pen "age"
  histogram [age] of turtles
end
```

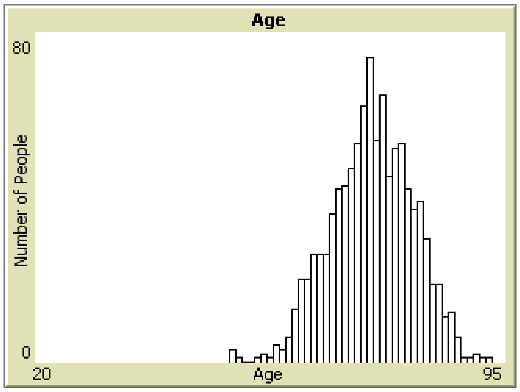
Appendix B: Histograms

Below (Histogram 1) is one of the generated histograms from the Netlogo model of the normal population. The ages of the people aren't going to be the same every single run, due to the random factor in each run. However, it consists of the same mean and standard deviation each time.



(Histogram 1)

Below (Histogram 2) is another generated histogram from the model of the 9-11 health effects. Each run presents a whole new set of data of the ages of the people, consisting of the same mean and standard deviation.



(Histogram 2)

Appendix C: Reference Tables from *The Lancet*

Table 1

This is the "distribution of exposure categories in World-Trade-Center-exposed firefighters" (*The Lancet)*.

	Number of WTC-exposed firefighters (N=8927*)
FDNY exposure categories†—time of first arrival at WTC site	
Morning of 9/11	1600 (18%)
Afternoon of 9/11	4409 (49%)
Day of Sept 12, 2001	1616 (18%)
Any day between Sept 13, 2001, and Sept 24, 2001	1211 (14%)
Any day between Sept 25, 2001 and July 25, 2002	91 (1%)
Common exposure categories‡—type of exposure on day of 9/11	
Heavily exposed to the dust cloud	1702 (19%)
Working on the pile but not heavily exposed to dust cloud	4218 (47%)
Present but not working on the pile and not heavily exposed to the dust cloud	123 (1%)
Not present in lower Manhattan on 9/11	2700 (30%)
Missing type of exposure information	184 (2%)

Table 2

These are the "selected characteristics of the total Fire Department of the City of New York analytic cohort" (*The Lancet).*

	Cohort (n=9853)
Race and ethnic origin	
Non-Hispanic white	9289 (94%)
Non-Hispanic black	294 (3%)
Hispanic	270 (3%)
Self-reported never smokers by end of study (n=8467)	5313 (63%)
Retired as of 9/11	1482 (15%)
Mean age as of 9/11 (years)	44·0 (6·7)
Mean age at start of follow-up (years)	38·4 (6·7)
Mean years of service as FDNY firefighters	20·8 (5·9)
Mean length of follow-up (years)	12·7 (1·2)

Table 3

Here are the "observed and expected number of cancers and standardized incidence ratios (SIRs and corrected SIRs) for male firefighters from the Fire Department of the City of New York with USA (Surveillance Epidemiology and End Results) cancer rates for comparison" (*The Lancet).*

	Observed	Expected	SIR (95% CI)
All sites			
Exposed (61 884 person-years)	263	238	1·10 (0·98–1·25)
Non-exposed (60 761 person-years)	135	161	0·84 (0·71–0·99)
SIR ratio*	..	..	1·32 (1·07–1·62)
All sites (corrected)†			
Exposed	242	238	1·02 (0·90–1·15)
Non-exposed	135	161	0·84 (0·71–0·99)
SIR ratio*	..	..	1·21 (0·98–1·49)
Oesophagus			
Exposed	≤5	3	0·58 (0·15–2·32)
Non-exposed	≤5	2	0·44 (0·06–3·13)
SIR ratio*	..	..	1·32 (0·12–14·53)
Stomach (including gastro-oesophogeal junction)			
Exposed	8	4	2·24 (0·98–5·25)
Non-exposed	≤5	2	1·23 (0·40–3·83)
SIR ratio*	..	..	1·82 (0·44–7·49)
Colon (excluding rectum)			
Exposed	21	14	1·52 (0·99–2·33)
Non-exposed	9	9	1·01 (0·53–1·94)
SIR ratio*	..	..	1·50 (0·69–3·27)
Pancreas			
Exposed	≤5	5	0·78 (0·29–2·09)
Non-exposed	≤5	3	0·31 (0·04–2·20)
SIR ratio*	..	..	2·52 (0·28–22·59)
Lung			
Exposed	9	21	0·42 (0·20–0·86)
Non-exposed	8	15	0·52 (0·26–1·05)
SIR ratio*	..	..	0·80 (0·29–2·18)
Lung (corrected)†			
Exposed	6	21	0·28 (0·13–0·62)
Non-exposed	8	15	0·52 (0·26–1·05)
SIR ratio*	..	..	0·53 (0·18–1·54)
Melanoma			
Exposed	33	21	1·54 (1·08–2·18)
Non-exposed	15	16	0·95 (0·57–1·58)
SIR ratio*	..	..	1·61 (0·87–2·99)
Prostate			
Exposed	90	60	1·49 (1·20–1·85)
Non-exposed	45	33	1·35 (1·01–1·81)
SIR ratio*	..	..	1·11 (0·77–1·59)

(Table 3.1)

Prostate (corrected)†			
Exposed	73	60	1·21 (0·96–1·52)
Non-exposed	45	33	1·35 (1·01–1·81)
SIR ratio*	..	..	0·90 (0·62–1·30)
Testicular			
Exposed	≤5	6	0·86 (0·36–2·06)
Non-exposed	11	7	1·54 (0·85–2·78)
SIR ratio*	..	..	0·56 (0·19–1·60)
Bladder			
Exposed	11	11	1·01 (0·56–1·83)
Non-exposed	6	8	0·79 (0·36–1·76)
SIR ratio*	..	..	1·28 (0·47–3·46)
Kidney			
Exposed	10	12	0·86 (0·46–1·60)
Non-exposed	≤5	7	0·30 (0·07–1·18)
SIR ratio*	..	..	2·91 (0·64–13·30)
Thyroid			
Exposed	17	6	3·07 (1·86–5·08)
Non-exposed	≤5	3	0·59 (0·15–2·36)
SIR ratio*	..	..	5·21 (1·19–22·74)
Thyroid (corrected)†			
Exposed	12	6	2·17 (1·23–3·82)
Non-exposed	≤5	3	0·59 (0·15–2·36)
SIR ratio*	..	..	3·67 (0·82–16·42)
Hodgkin's lymphoma			
Exposed	0	2	..
Non-exposed	≤5	2	0·82 (0·20–3·27)
SIR ratio*	..	..	..
Non-Hodgkin lymphoma			
Exposed	21	13	1·58 (1·03–2·42)
Non-exposed	9	11	0·83 (0·43–1·60)
SIR ratio*	..	..	1·90 (0·87–4·15)
Non-Hodgkin lymphoma (corrected)†			
Exposed	20	13	1·50 (0·97–2·33)
Non-exposed	9	11	0·83 (0·43–1·60)
SIR ratio*	..	..	1·81 (0·82–3·97)
Multiple myeloma			
Exposed	≤5	3	1·49 (0·56–3·97)
Non-exposed	0	2	..
SIR ratio*	..	..	..
Leukaemia			
Exposed	9	6	1·40 (0·73–2·70)
Non-exposed	7	5	1·47 (0·63–3·40)
SIR ratio*	..	..	0·98 (0·33–2·77)

(Table 3.2)