

Environmental Health Impact Assessment using R

The Health Impacts of Air Pollution

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OUTLINE

An Introduction to R

Health Impact Assessment associated with outdoor air pollution

An Introduction to R

STATISTICAL SOFTWARE

- ▶ Excel
 - ▶ simple descriptive statistics, plots, and regression can be done in the basic installation of Excel
 - ▶ the Analysis Toolpak allows many more methods to be used such as ANOVA and hypothesis tests.
- ▶ SPSS, SAS, Stata
 - ▶ general purpose statistical packages that can perform a very wide variety of analyses
 - ▶ cover everything from initial descriptive analyses to very complex methods.
 - ▶ GUI interfaces: functions found by menus.
- ▶ R
 - ▶ a language and environment for statistical computing and graphics
 - ▶ open source with many many user packages
 - ▶ it's free! (Open-Source)

RSTUDIO

RStudio

Project: (None)

Environment History

Global Environment -

Data

- dig 6800 obs. of 72 variables
- states.df 15527 obs. of 7 variables

Values

- my.model Large gam (48 elements, 830.9 Kb)
- stateMapEnv "R_MAP_DATA_DIR"

ID	TRTMT	AGE	RACE	SEX	EJF_PER	EJFMETH	CHESTX	BMI
1	1	0	66	1	1	40	2	0.50
2	2	0	77	1	1	32	1	0.56
3	3	0	72	1	2	36	1	0.68
4	4	1	57	1	1	31	1	0.48
5	5	0	74	1	1	35	1	0.53
6	6	0	69	2	2	45	1	0.70
7	7	1	64	1	2	30	1	0.52
8	8	1	60	2	1	39	1	0.40

Displayed 1000 rows of 6800 (5800 omitted)

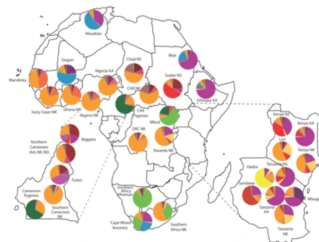
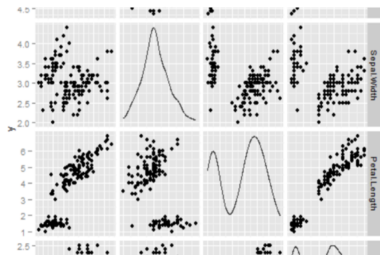
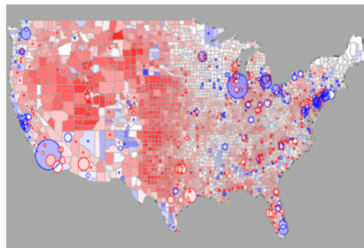
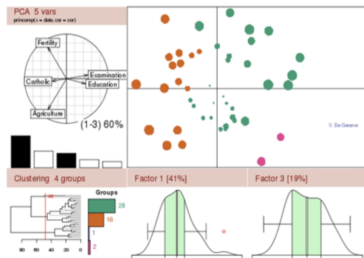
```

Console ~ /
4 13940 1 468 0 13940 0 13940 0 13940 0
3 746 0 1391 0 1391 0 1391 0 1391 0
4 1157 0 1157 0 1157 0 1157 0 1157 0
5 1550 0 1550 0 1550 0 1550 0 1550 0
6 1620 0 1620 0 1620 1 496 0 1620 0
OCVDDAYS RINF RINFSDAYS OTH OTHDAYS HOSP HOSPDAYS NHOSP DEATH DEATHDAY
1 1049 0 1438 1 533 1 533 6 0 1438
2 1360 0 1360 1 880 1 468 4 1 1360
3 1391 0 1391 0 1391 1 631 2 0 1391
4 1157 0 1157 0 1157 0 1157 0 0 1157
5 1550 0 1550 1 459 1 191 5 0 1550
6 1620 0 1620 1 966 1 496 5 0 1620
REASON DWHF DWHFDAYS
1 NA 1 1379
2 1 1 1329
3 NA 1 631
4 NA 0 1157
5 NA 1 191
6 NA 0 1620
> my.model<-gam(DEATH ~ TRTMT + s(DWHFDAYS), data=dig, family=binomial)
> summary(my.model)$coef
NULL
> plot(my.model)
> View(dig)
>
  
```

Files Plots Packages Help Viewer

Zoom Export Clear All

R GRAPHICS



DOES R HAVE EPIDEMIOLOGICAL PACKAGES?

- ▶ The default installation of R does not have packages that specifically implement epidemiological applications.
- ▶ However, many of the statistical tools that epidemiologists use are readily available, including statistical models such as unconditional logistic regression, conditional logistic regression, Poisson regression, Cox proportional hazards regression, and much more.

DOES R HAVE EPIDEMIOLOGICAL PACKAGES?

- ▶ To meet the specific needs of public health epidemiologists and health data analysts, there are many epidemiology packages.
- ▶ There are also packages to perform sample size calculations, survival analysis, clustering, mapping, almost everything you can think of.
- ▶ "During the last decade, the momentum coming from both academia and industry has lifted the R programming language to become the single most important tool for computational statistics, visualisation and data science."

BASE R COMES WITH MANY STATISTICAL TOOLS

Summary statistics

- ▶ `summary()`, `fivenum()`, `stem()` – examine the distribution of data
- ▶ `boxplots()`

Test statistics

- ▶ `t.test()` – returns a one-sample t-test. Can be used for a two-sample t-test by setting `paired=TRUE`
- ▶ `wilcox.test()` - returns a one-sample non-parametric Wilcoxon (Mann-Whitney) test. Similarly, can be used for a two-sample Wilcoxon test by setting `paired=TRUE`

SUMMARY STATISTICS IN R

- ▶ If we have a dataset `mydat` then we can summarise as follows

```
# Summary of data
```

```
summary(mydat$outcome1)
```

Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
4.186	16.680	20.110	19.990	23.480	36.620

```
summary(mydat$outcome2)
```

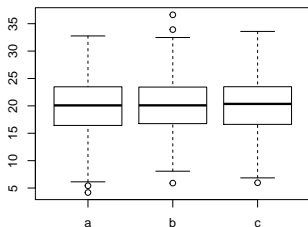
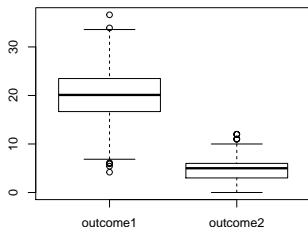
Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
0.000	3.000	5.000	4.975	6.000	12.000

SUMMARY STATISTICS IN R

- ▶ We can create boxplots as follows

```
boxplot(mydat)
```

```
boxplot(outcome1~grp, data=mydat)
```



TEST STATISTICS IN R

- ▶ We can perform test statistics such as t-test and Wilcoxon-Rank test as follows

```
t.test(mydat$outcome1,  
       mydat$outcome2)  
wilcox.test(mydat$outcome1,  
            mydat$outcome2)  
wilcox.test(mydat$outcome1,  
            mydat$outcome2,  
            paired=T)
```

OUTPUTS

- ▶ **Linear regression:** `lm(formula, data)`
- ▶ Returns object of class `lm`
 - ▶ `summary(x)` comprehensive summary of results
 - ▶ `print(x)` precise version of the object
 - ▶ `deviance(x)` residuals
 - ▶ `plot(x)` returns plot: residuals, fitted values and some diagnostics
 - ▶ `coef(x)` extract regression coefficients
 - ▶ `predict(x, newdata=...)` second argument takes a vector or matrix of new data values you want predictions for
 - ▶ `step()` add or drop terms, model with smallest AICs returned.

OUTPUTS

- ▶ Assign the function to an object to extract additional output:

```
my.reg <- lm(outcome1~outcome2, mydat)
summary(my.reg)
```

Call:

```
lm(formula = outcome1 ~ outcome2, data = mydat)
```

Residuals:

Min	1Q	Median	3Q	Max
-15.806	-3.423	0.260	3.491	16.834

Coefficients:

	Estimate	Std. Error	t value	Pr(> t)	
(Intercept)	19.48190	0.39883	48.847	<2e-16	***
outcome2	0.10208	0.07351	1.389	0.165	

PACKAGES ARE ADDITIONAL COLLECTIONS OF FUNCTIONS

- ▶ `rmeta`
- ▶ `ggplot2`
- ▶ `epicalc`
- ▶ `epi`
- ▶ `epitools`
- ▶ `epiR`
- ▶ `pwr`
- ▶ `MASS`
- ▶ `lattice`
- ▶ `lme4`
- ▶ `mgcv`
- ▶ `Survival`
- ▶ ...

Health Impact Assessment associated with outdoor air pollution

EXAMPLE: HIA OF AIR POLLUTION

- ▶ City XYZ, Population: 1,000,000
- ▶ Overall Mortality rate: 80/10000
- ▶ 6% increase in mortality per each $10\mu\text{gm}^{-3}$ $\text{PM}_{2.5}$ increase
- ▶ Counterfactual: $5\mu\text{gm}^{-3}$

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$\text{PM}_{2.5}$	RR	Rate	Deaths	Extra	Gain
5					

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5	1.00				

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$\text{PM}_{2.5}$	RR	Rate	Deaths	Extra	Gain
5	1.00	80.0			

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5	1.00	80.0	8,000		
15					

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$\text{PM}_{2.5}$	RR	Rate	Deaths	Extra	Gain
5	1.00	80.0	8,000		
15	1.06				

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$\text{PM}_{2.5}$	RR	Rate	Deaths	Extra	Gain
5	1.00	80.0	8,000		
15	1.06	84.8			

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$\text{PM}_{2.5}$	RR	Rate	Deaths	Extra	Gain
5	1.00	80.0	8,000		
15	1.06	84.8	8,480		

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5	1.00	80.0	8,000		
15	1.06	84.8	8,480	480.0	480.0
25					

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$\text{PM}_{2.5}$	RR	Rate	Deaths	Extra	Gain
5	1.00	80.0	8,000		
15	1.06	84.8	8,480	480.0	480.0
25	1.124				

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5	1.00	80.0	8,000		
15	1.06	84.8	8,480	480.0	480.0
25	1.124	89.9			

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25	1.124	89.9	8,989		

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35					

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25	1.124	89.9	8,989	988.8	508.8
35	1.19				

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15	1.06	84.8	8,480	480.0	480.0
25	1.124	89.9	8,989	988.8	508.8
35	1.19	95.3	9,528		

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25	1.124	89.9	8,989	988.8	508.8
35	1.19	95.3	9,528	1528.1	539.3
45					

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25	1.124	89.9	8,989	988.8	508.8
35	1.19	95.3	9,528	1528.1	539.3
45	1.26				

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45	1.26	101.0	10,100	2099.8	571.7
55					

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55	1.34				

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25	1.124	89.9	8,989	988.8	508.8
35	1.19	95.3	9,528	1528.1	539.3
45	1.26	101.0	10,100	2099.8	571.7
55	1.34	107.1	10,706	2705.8	606.0
65					

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35	1.19	95.3	9,528	1528.1	539.3
45	1.26	101.0	10,100	2099.8	571.7
55	1.34	107.1	10,706	2705.8	606.0
65	1.42				

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35	1.19	95.3	9,528	1528.1	539.3
45	1.26	101.0	10,100	2099.8	571.7
55	1.34	107.1	10,706	2705.8	606.0
65	1.42	113.5			

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45	1.26	101.0	10,100	2099.8	571.7
55	1.34	107.1	10,706	2705.8	606.0
65	1.42	113.5	11,348		

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- ▶ Counterfactual: $5\mu\text{gm}-3$

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45	1.26	101.0	10,100	2099.8	571.7
55	1.34	107.1	10,706	2705.8	606.0
65	1.42	113.5	11,348	3348.2	642.3
75					

EXAMPLE: HIA OF AIR POLLUTION

- ▶ City XYZ, Population: 1,000,000
- ▶ Overall Mortality rate: 80/10000
- ▶ 6% increase in mortality per each $10\mu\text{gm}-3$ $\text{PM}_{2.5}$ increase
- ▶ Counterfactual: $5\mu\text{gm}-3$

$\text{PM}_{2.5}$	RR	Rate	Deaths	Extra	Gain
5	1.00	80.0	8,000		
15	1.06	84.8	8,480	480.0	480.0
25	1.124	89.9	8,989	988.8	508.8
35	1.19	95.3	9,528	1528.1	539.3
45	1.26	101.0	10,100	2099.8	571.7
55	1.34	107.1	10,706	2705.8	606.0
65	1.42	113.5	11,348	3348.2	642.3
75	1.5				

EXAMPLE: HIA OF AIR POLLUTION

- ▶ City XYZ, Population: 1,000,000
- ▶ Overall Mortality rate: 80/10000
- ▶ 6% increase in mortality per each $10\mu\text{gm}-3$ $\text{PM}_{2.5}$ increase
- ▶ Counterfactual: $5\mu\text{gm}-3$

$\text{PM}_{2.5}$	RR	Rate	Deaths	Extra	Gain
5	1.00	80.0	8,000		
15	1.06	84.8	8,480	480.0	480.0
25	1.124	89.9	8,989	988.8	508.8
35	1.19	95.3	9,528	1528.1	539.3
45	1.26	101.0	10,100	2099.8	571.7
55	1.34	107.1	10,706	2705.8	606.0
65	1.42	113.5	11,348	3348.2	642.3
75	1.5	120.3			

EXAMPLE: HIA OF AIR POLLUTION

- ▶ City XYZ, Population: 1,000,000
- ▶ Overall Mortality rate: 80/10000
- ▶ 6% increase in mortality per each $10\mu\text{gm}-3$ $\text{PM}_{2.5}$ increase
- ▶ Counterfactual: $5\mu\text{gm}-3$

$\text{PM}_{2.5}$	RR	Rate	Deaths	Extra	Gain
5	1.00	80.0	8,000		
15	1.06	84.8	8,480	480.0	480.0
25	1.124	89.9	8,989	988.8	508.8
35	1.19	95.3	9,528	1528.1	539.3
45	1.26	101.0	10,100	2099.8	571.7
55	1.34	107.1	10,706	2705.8	606.0
65	1.42	113.5	11,348	3348.2	642.3
75	1.5	120.3	12,029		

EXAMPLE: HIA OF AIR POLLUTION

- ▶ City XYZ, Population: 1,000,000
- ▶ Overall Mortality rate: 80/10000
- ▶ 6% increase in mortality per each $10\mu\text{gm}-3$ $\text{PM}_{2.5}$ increase
- ▶ Counterfactual: $5\mu\text{gm}-3$

$\text{PM}_{2.5}$	RR	Rate	Deaths	Extra	Gain
5	1.00	80.0	8,000		
15	1.06	84.8	8,480	480.0	480.0
25	1.124	89.9	8,989	988.8	508.8
35	1.19	95.3	9,528	1528.1	539.3
45	1.26	101.0	10,100	2099.8	571.7
55	1.34	107.1	10,706	2705.8	606.0
65	1.42	113.5	11,348	3348.2	642.3
75	1.5	120.3	12,029	4029.0	680.9
85					

EXAMPLE: HIA OF AIR POLLUTION

- ▶ City XYZ, Population: 1,000,000
- ▶ Overall Mortality rate: 80/10000
- ▶ 6% increase in mortality per each $10\mu\text{gm}-3$ $\text{PM}_{2.5}$ increase
- ▶ Counterfactual: $5\mu\text{gm}-3$

$\text{PM}_{2.5}$	RR	Rate	Deaths	Extra	Gain
5	1.00	80.0	8,000		
15	1.06	84.8	8,480	480.0	480.0
25	1.124	89.9	8,989	988.8	508.8
35	1.19	95.3	9,528	1528.1	539.3
45	1.26	101.0	10,100	2099.8	571.7
55	1.34	107.1	10,706	2705.8	606.0
65	1.42	113.5	11,348	3348.2	642.3
75	1.5	120.3	12,029	4029.0	680.9
85	1.59				

EXAMPLE: HIA OF AIR POLLUTION

- ▶ City XYZ, Population: 1,000,000
- ▶ Overall Mortality rate: 80/10000
- ▶ 6% increase in mortality per each $10\mu\text{gm}-3$ $\text{PM}_{2.5}$ increase
- ▶ Counterfactual: $5\mu\text{gm}-3$

$\text{PM}_{2.5}$	RR	Rate	Deaths	Extra	Gain
5	1.00	80.0	8,000		
15	1.06	84.8	8,480	480.0	480.0
25	1.124	89.9	8,989	988.8	508.8
35	1.19	95.3	9,528	1528.1	539.3
45	1.26	101.0	10,100	2099.8	571.7
55	1.34	107.1	10,706	2705.8	606.0
65	1.42	113.5	11,348	3348.2	642.3
75	1.5	120.3	12,029	4029.0	680.9
85	1.59	127.5			

EXAMPLE: HIA OF AIR POLLUTION

- ▶ City XYZ, Population: 1,000,000
- ▶ Overall Mortality rate: 80/10000
- ▶ 6% increase in mortality per each $10\mu\text{gm}-3$ $\text{PM}_{2.5}$ increase
- ▶ Counterfactual: $5\mu\text{gm}-3$

$\text{PM}_{2.5}$	RR	Rate	Deaths	Extra	Gain
5	1.00	80.0	8,000		
15	1.06	84.8	8,480	480.0	480.0
25	1.124	89.9	8,989	988.8	508.8
35	1.19	95.3	9,528	1528.1	539.3
45	1.26	101.0	10,100	2099.8	571.7
55	1.34	107.1	10,706	2705.8	606.0
65	1.42	113.5	11,348	3348.2	642.3
75	1.5	120.3	12,029	4029.0	680.9
85	1.59	127.5	12,751		

EXAMPLE: HIA OF AIR POLLUTION

- ▶ City XYZ, Population: 1,000,000
- ▶ Overall Mortality rate: 80/10000
- ▶ 6% increase in mortality per each $10\mu\text{gm}-3$ $\text{PM}_{2.5}$ increase
- ▶ Counterfactual: $5\mu\text{gm}-3$

$\text{PM}_{2.5}$	RR	Rate	Deaths	Extra	Gain
5	1.00	80.0	8,000		
15	1.06	84.8	8,480	480.0	480.0
25	1.124	89.9	8,989	988.8	508.8
35	1.19	95.3	9,528	1528.1	539.3
45	1.26	101.0	10,100	2099.8	571.7
55	1.34	107.1	10,706	2705.8	606.0
65	1.42	113.5	11,348	3348.2	642.3
75	1.5	120.3	12,029	4029.0	680.9
85	1.59	127.5	12,751	4750.8	721.7
95					

EXAMPLE: HIA OF AIR POLLUTION

- ▶ City XYZ, Population: 1,000,000
- ▶ Overall Mortality rate: 80/10000
- ▶ 6% increase in mortality per each $10\mu\text{gm}-3$ $\text{PM}_{2.5}$ increase
- ▶ Counterfactual: $5\mu\text{gm}-3$

$\text{PM}_{2.5}$	RR	Rate	Deaths	Extra	Gain
5	1.00	80.0	8,000		
15	1.06	84.8	8,480	480.0	480.0
25	1.124	89.9	8,989	988.8	508.8
35	1.19	95.3	9,528	1528.1	539.3
45	1.26	101.0	10,100	2099.8	571.7
55	1.34	107.1	10,706	2705.8	606.0
65	1.42	113.5	11,348	3348.2	642.3
75	1.5	120.3	12,029	4029.0	680.9
85	1.59	127.5	12,751	4750.8	721.7
95	1.69				

EXAMPLE: HIA OF AIR POLLUTION

- ▶ City XYZ, Population: 1,000,000
- ▶ Overall Mortality rate: 80/10000
- ▶ 6% increase in mortality per each $10\mu\text{gm}-3$ $\text{PM}_{2.5}$ increase
- ▶ Counterfactual: $5\mu\text{gm}-3$

$\text{PM}_{2.5}$	RR	Rate	Deaths	Extra	Gain
5	1.00	80.0	8,000		
15	1.06	84.8	8,480	480.0	480.0
25	1.124	89.9	8,989	988.8	508.8
35	1.19	95.3	9,528	1528.1	539.3
45	1.26	101.0	10,100	2099.8	571.7
55	1.34	107.1	10,706	2705.8	606.0
65	1.42	113.5	11,348	3348.2	642.3
75	1.5	120.3	12,029	4029.0	680.9
85	1.59	127.5	12,751	4750.8	721.7
95	1.69	135.2			

EXAMPLE: HIA OF AIR POLLUTION

- ▶ City XYZ, Population: 1,000,000
- ▶ Overall Mortality rate: 80/10000
- ▶ 6% increase in mortality per each $10\mu\text{gm}-3$ $\text{PM}_{2.5}$ increase
- ▶ Counterfactual: $5\mu\text{gm}-3$

$\text{PM}_{2.5}$	RR	Rate	Deaths	Extra	Gain
5	1.00	80.0	8,000		
15	1.06	84.8	8,480	480.0	480.0
25	1.124	89.9	8,989	988.8	508.8
35	1.19	95.3	9,528	1528.1	539.3
45	1.26	101.0	10,100	2099.8	571.7
55	1.34	107.1	10,706	2705.8	606.0
65	1.42	113.5	11,348	3348.2	642.3
75	1.5	120.3	12,029	4029.0	680.9
85	1.59	127.5	12,751	4750.8	721.7
95	1.69	135.2	13,516		

EXAMPLE: HIA OF AIR POLLUTION

- ▶ City XYZ, Population: 1,000,000
- ▶ Overall Mortality rate: 80/10000
- ▶ 6% increase in mortality per each $10\mu\text{gm}-3$ $\text{PM}_{2.5}$ increase
- ▶ Counterfactual: $5\mu\text{gm}-3$

$\text{PM}_{2.5}$	RR	Rate	Deaths	Extra	Gain
5	1.00	80.0	8,000		
15	1.06	84.8	8,480	480.0	480.0
25	1.124	89.9	8,989	988.8	508.8
35	1.19	95.3	9,528	1528.1	539.3
45	1.26	101.0	10,100	2099.8	571.7
55	1.34	107.1	10,706	2705.8	606.0
65	1.42	113.5	11,348	3348.2	642.3
75	1.5	120.3	12,029	4029.0	680.9
85	1.59	127.5	12,751	4750.8	721.7
95	1.69	135.2	13,516	5515.8	765.0

105

EXAMPLE: HIA OF AIR POLLUTION

- ▶ City XYZ, Population: 1,000,000
- ▶ Overall Mortality rate: 80/10000
- ▶ 6% increase in mortality per each $10\mu\text{gm}-3$ $\text{PM}_{2.5}$ increase
- ▶ Counterfactual: $5\mu\text{gm}-3$

$\text{PM}_{2.5}$	RR	Rate	Deaths	Extra	Gain
5	1.00	80.0	8,000		
15	1.06	84.8	8,480	480.0	480.0
25	1.124	89.9	8,989	988.8	508.8
35	1.19	95.3	9,528	1528.1	539.3
45	1.26	101.0	10,100	2099.8	571.7
55	1.34	107.1	10,706	2705.8	606.0
65	1.42	113.5	11,348	3348.2	642.3
75	1.5	120.3	12,029	4029.0	680.9
85	1.59	127.5	12,751	4750.8	721.7
95	1.69	135.2	13,516	5515.8	765.0
105	1.79				

EXAMPLE: HIA OF AIR POLLUTION

- ▶ City XYZ, Population: 1,000,000
- ▶ Overall Mortality rate: 80/10000
- ▶ 6% increase in mortality per each $10\mu\text{gm}-3$ $\text{PM}_{2.5}$ increase
- ▶ Counterfactual: $5\mu\text{gm}-3$

$\text{PM}_{2.5}$	RR	Rate	Deaths	Extra	Gain
5	1.00	80.0	8,000		
15	1.06	84.8	8,480	480.0	480.0
25	1.124	89.9	8,989	988.8	508.8
35	1.19	95.3	9,528	1528.1	539.3
45	1.26	101.0	10,100	2099.8	571.7
55	1.34	107.1	10,706	2705.8	606.0
65	1.42	113.5	11,348	3348.2	642.3
75	1.5	120.3	12,029	4029.0	680.9
85	1.59	127.5	12,751	4750.8	721.7
95	1.69	135.2	13,516	5515.8	765.0
105	1.79	143.3			

EXAMPLE: HIA OF AIR POLLUTION

- ▶ City XYZ, Population: 1,000,000
- ▶ Overall Mortality rate: 80/10000
- ▶ 6% increase in mortality per each $10\mu\text{gm}-3$ $\text{PM}_{2.5}$ increase
- ▶ Counterfactual: $5\mu\text{gm}-3$

$\text{PM}_{2.5}$	RR	Rate	Deaths	Extra	Gain
5	1.00	80.0	8,000		
15	1.06	84.8	8,480	480.0	480.0
25	1.124	89.9	8,989	988.8	508.8
35	1.19	95.3	9,528	1528.1	539.3
45	1.26	101.0	10,100	2099.8	571.7
55	1.34	107.1	10,706	2705.8	606.0
65	1.42	113.5	11,348	3348.2	642.3
75	1.5	120.3	12,029	4029.0	680.9
85	1.59	127.5	12,751	4750.8	721.7
95	1.69	135.2	13,516	5515.8	765.0
105	1.79	143.3	14,327		

EXAMPLE: HIA OF AIR POLLUTION

- ▶ City XYZ, Population: 1,000,000
- ▶ Overall Mortality rate: 80/10000
- ▶ 6% increase in mortality per each $10\mu\text{gm}-3$ $\text{PM}_{2.5}$ increase
- ▶ Counterfactual: $5\mu\text{gm}-3$

$\text{PM}_{2.5}$	RR	Rate	Deaths	Extra	Gain
5	1.00	80.0	8,000		
15	1.06	84.8	8,480	480.0	480.0
25	1.124	89.9	8,989	988.8	508.8
35	1.19	95.3	9,528	1528.1	539.3
45	1.26	101.0	10,100	2099.8	571.7
55	1.34	107.1	10,706	2705.8	606.0
65	1.42	113.5	11,348	3348.2	642.3
75	1.5	120.3	12,029	4029.0	680.9
85	1.59	127.5	12,751	4750.8	721.7
95	1.69	135.2	13,516	5515.8	765.0
105	1.79	143.3	14,327	6326.8	810.9