

Hanford Washington Problem

Radioactive Contamination part v1

Problem:

In an article taken from the Journal of Environmental Health, May-June 1965, Volume 27, Number 6, pages 883-897, author Robert Fadely explains that the Atomic Energy Plant in Hanford, Washington has been a plutonium production facility since the Second World War. Some of the waste have been stored underground in the same area. Radioactive waste has been seeping into the Columbia River, and eight Oregon counties and the city of Portland have been exposed to radioactive contamination. The table below lists the number of cancer deaths per 100,000 residents for Portland and these counties. The table also includes an index of exposure that measures the proximity of the residents to the contamination. The index is based on the assumption that city or county exposure is directly proportional to river frontage and inversely proportional both to the distance from Hanford, WA site and to the square of the county's or city's average distance from the river.

Table

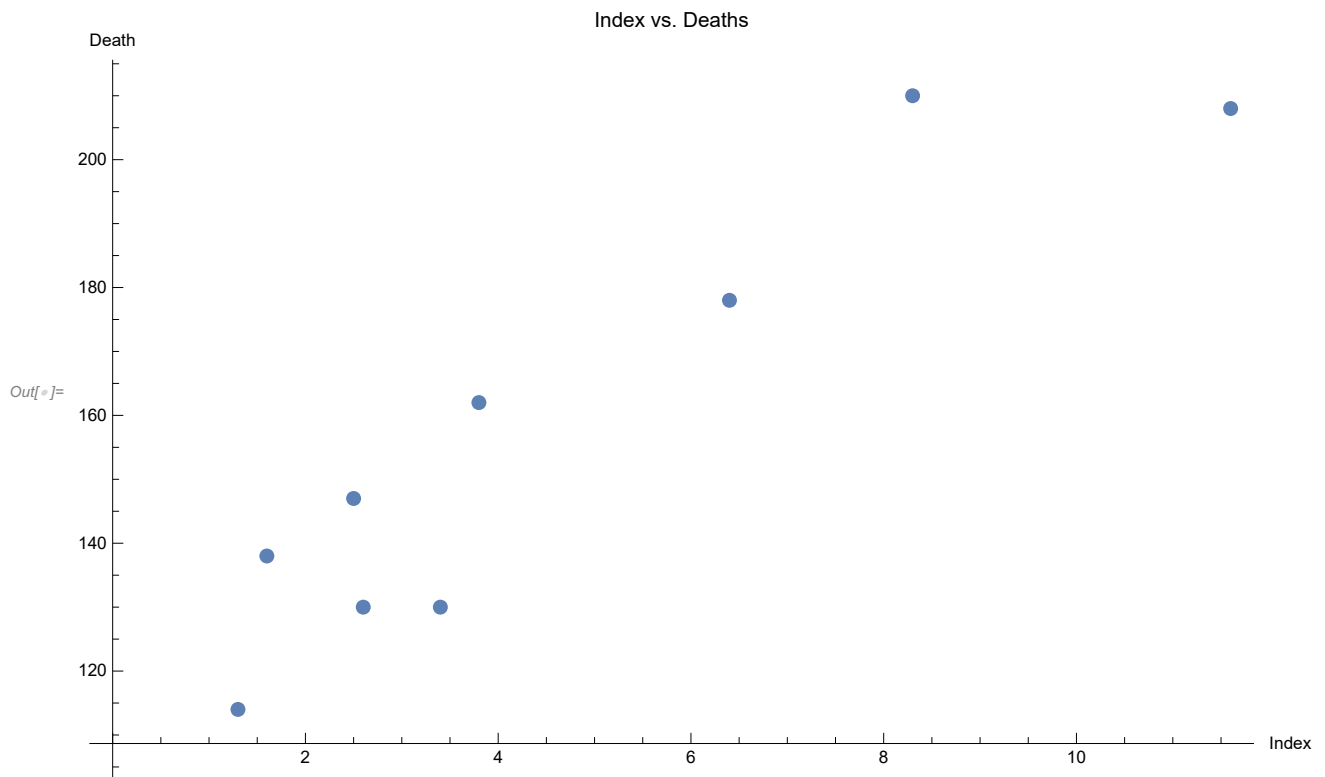
```
In[ ]:= Location = {"Location", "Umatilla", "Morrow", "Gilliam",
  "Sherman", "Wasco", "Hood River", "Portland", "Columbia", "Clatsop"};
Index = {"Index", 2.5, 2.6, 3.4, 1.3, 1.6, 3.8, 11.6, 6.4, 8.3};
Death = {"Death", 147, 130, 130, 114, 138, 162, 208, 178, 210};
Grid[{"Location", Index, Death}, Frame -> All]
```

Location	Umatilla	Morrow	Gilliam	Sherman	Wasco	Hood River	Portland	Columbia	Clatsop
Index	2.5	2.6	3.4	1.3	1.6	3.8	11.6	6.4	8.3
Death	147	130	130	114	138	162	208	178	210

Graph

```
In[ ]:= Index = {2.5, 2.6, 3.4, 1.3, 1.6, 3.8, 11.6, 6.4, 8.3};  
Death = {147, 130, 130, 114, 138, 162, 208, 178, 210};  
data = Transpose[{Index, Death}];
```

```
In[ ]:= ListPlot[data, AxesLabel → {"Index", "Death"},  
ImageSize → Full, PlotLabel → "Index vs. Deaths"]
```



Two-Point Line

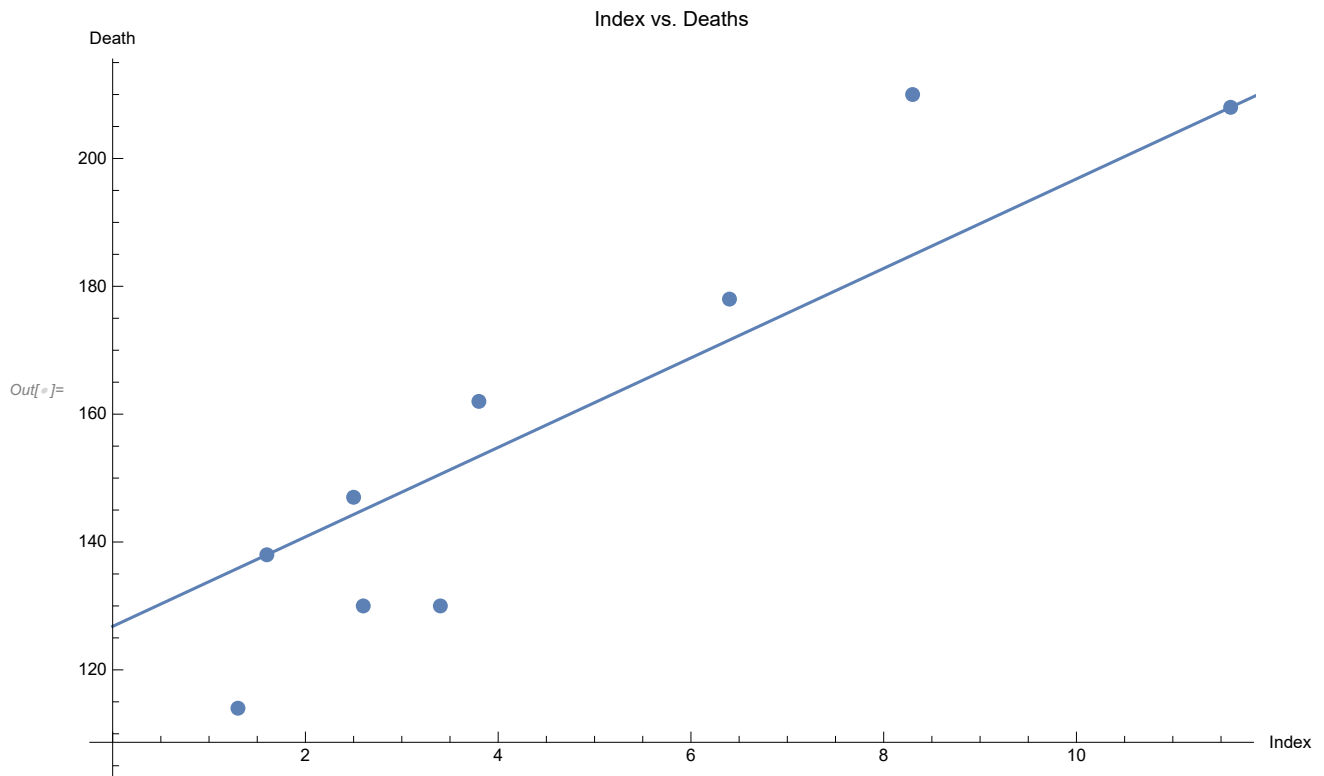
```
In[ ]:= data = Sort[data]
```

```
Out[ ]:= {{1.3, 114}, {1.6, 138}, {2.5, 147}, {2.6, 130},
          {3.4, 130}, {3.8, 162}, {6.4, 178}, {8.3, 210}, {11.6, 208}}
```

```
In[ ]:= twoline[x_] = Fit[{Part[data, 2], Part[data, 9]}, {1, x}, x]
```

```
Out[ ]:= 126.8 + 7. x
```

```
In[ ]:= Show[ListPlot[data, AxesLabel -> {"Index", "Death"}, ImageSize -> Full,
             PlotLabel -> "Index vs. Deaths"], Plot[twoline[x], {x, 0, 15}]]
```

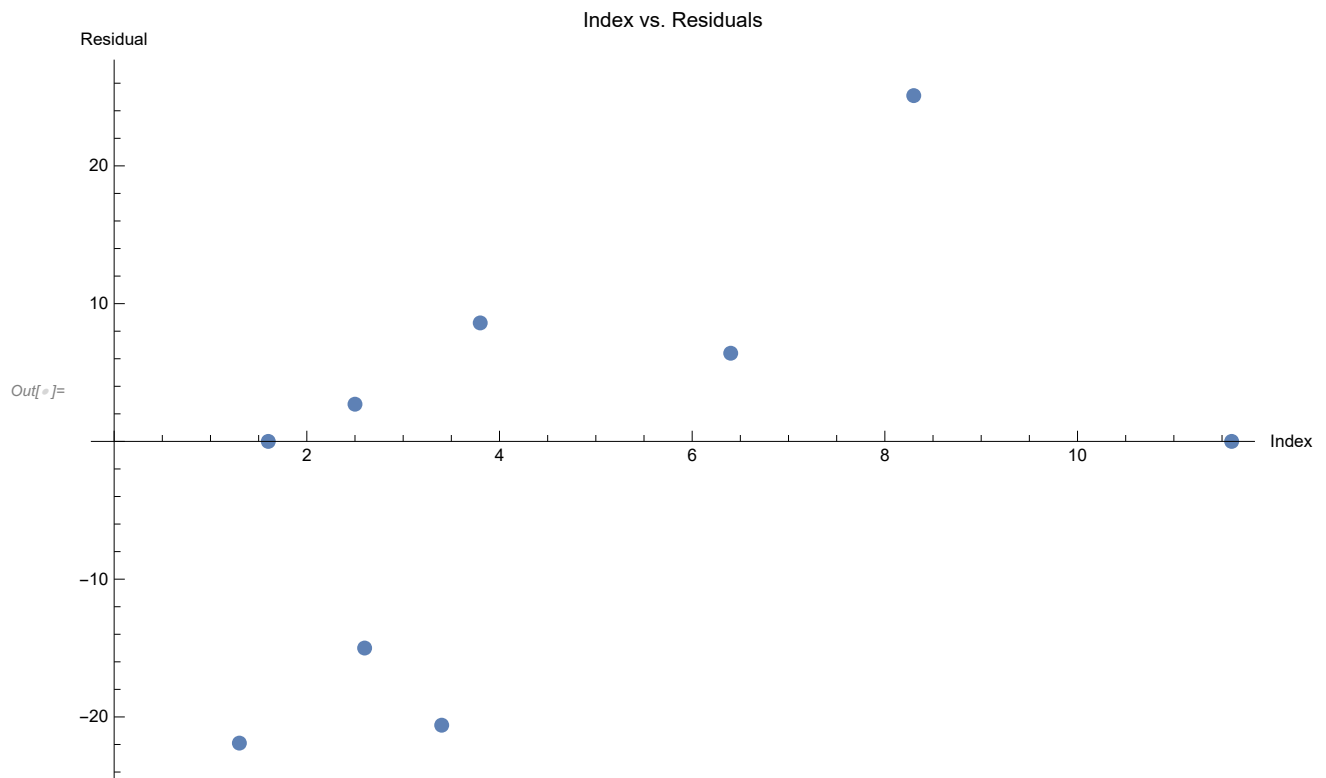


```
In[ ]:=
```

```
twolineresiduals = Transpose[{Index, Death - twoline[Index]}]
```

```
Out[ ]:= {{2.5, 2.7}, {2.6, -15.}, {3.4, -20.6}, {1.3, -21.9},
          {1.6, 8.52651 × 10-14}, {3.8, 8.6}, {11.6, 8.52651 × 10-14}, {6.4, 6.4}, {8.3, 25.1}}
```

```
In[ ]:= Show[ListPlot[twolineresiduals, AxesLabel → {"Index", "Residual"},  
ImageSize → Full, PlotLabel → "Index vs. Residuals"]]
```



```
In[ ]:=
```

```
twolineresidualsum = Total[Abs[Death - twoline[Index]]]
```

```
Out[ ]:= 100.3
```

Median-Median Line

```
In[*]:= mIndex = Sort[Index]  
        mDeath = Sort[Death]
```

```
Out[*]:= {1.3, 1.6, 2.5, 2.6, 3.4, 3.8, 6.4, 8.3, 11.6}
```

```
Out[*]:= {114, 130, 130, 138, 147, 162, 178, 208, 210}
```

```
In[*]:= mIndex = {Part[mIndex, 2], Part[mIndex, 5], Part[mIndex, 7]}  
        mDeath = {Part[mDeath, 2], Part[mDeath, 5], Part[mDeath, 7]}
```

```
Out[*]:= {1.6, 3.4, 6.4}
```

```
Out[*]:= {130, 147, 178}
```

```
In[*]:= median = Transpose[{mIndex, mDeath}]
```

```
Out[*]:= {{1.6, 130}, {3.4, 147}, {6.4, 178}}
```

```
In[*]:= line = Fit[{{1.6, 130}, {6.4, 178}}, {1, x}, x]
```

```
Out[*]:= 114. + 10. x
```

```
In[*]:= medianL[x_] := 10 x + 114
```

```
In[*]:= medianpoint = (medianL[3.4] - Part[mDeath, 2]) / 3 + medianL[3.4]
```

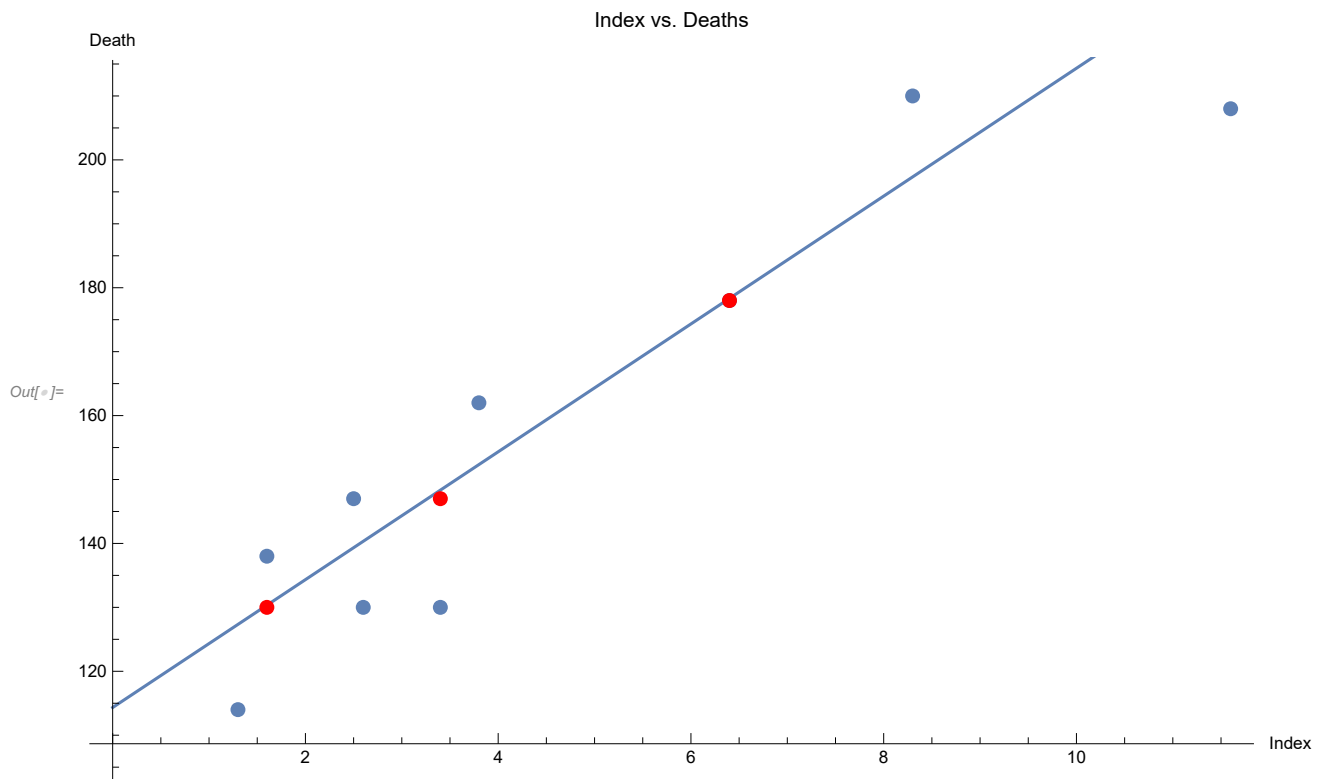
```
Out[*]:= 148.333
```

```
In[*]:= b = medianpoint - 10 * 3.4
```

```
Out[*]:= 114.333
```

```
In[*]:= medmedLine[x_] := b + 10 x
```

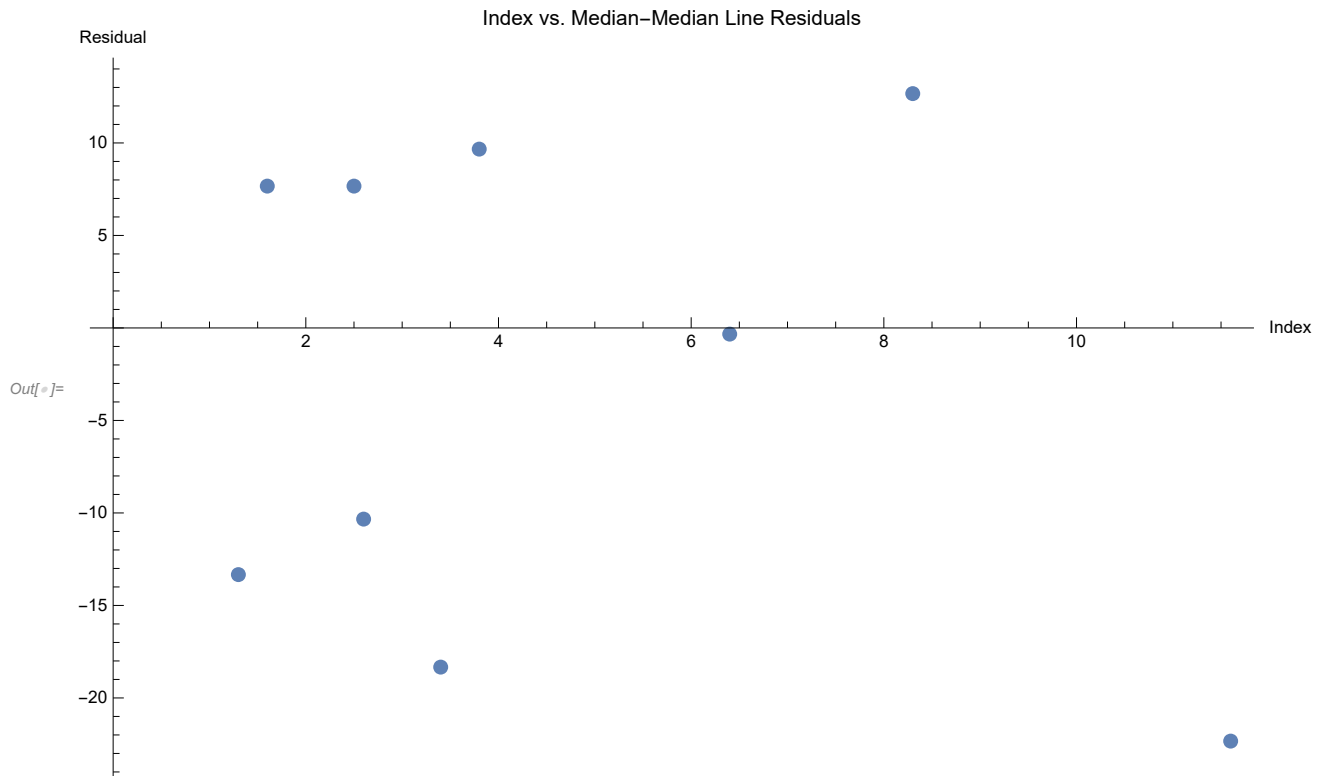
```
In[ ]:= Show[ListPlot[data, AxesLabel -> {"Index", "Death"},
  ImageSize -> Full, PlotLabel -> "Index vs. Deaths"],
  Plot[medmedLine[x], {x, 0, 15}], ListPlot[median, PlotStyle -> {RGBColor[1, 0, 0]}]]
```



```
In[ ]:= medmedresiduals = Transpose[{Index, Death - medmedLine[Index]}]
```

```
Out[ ]:= {{2.5, 7.66667}, {2.6, -10.3333}, {3.4, -18.3333}, {1.3, -13.3333},
  {1.6, 7.66667}, {3.8, 9.66667}, {11.6, -22.3333}, {6.4, -0.333333}, {8.3, 12.6667}}
```

```
In[ ]:= Show[ListPlot[medmedresiduals, AxesLabel -> {"Index", "Residual"},  
ImageSize -> Full, PlotLabel -> "Index vs. Median-Median Line Residuals"]]
```



```
In[ ]:= medmedresiudalsum = Total[Abs[Death - medmedLine[Index]]]
```

Out[]:= 102.333

Least Squares Line

```
In[ ]:= a = Total[Death^2];
        b = Total[Index^2];
        c = Total[Index];
        d = Total[Index * Death];
        e = Total[Death];
```

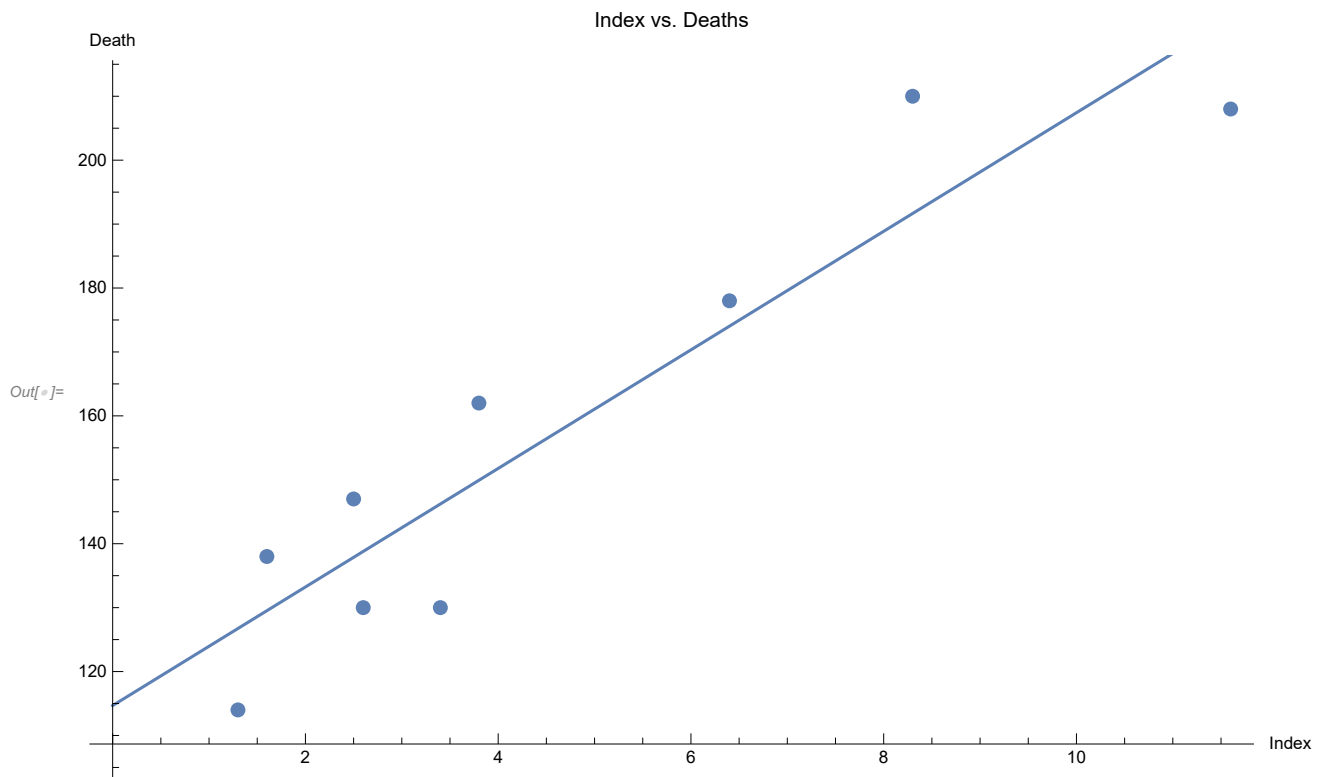
```
In[ ]:= m = (9 * d - e * c) / (9 * b - c^2)
        B = (e * b - d * c) / (9 * b - c^2)
```

```
Out[ ]:= 9.27386
```

```
Out[ ]:= 114.682
```

```
In[ ]:= leastsquareline[x_] := m * x + B
```

```
In[ ]:= Show[ListPlot[data, AxesLabel -> {"Index", "Death"}, ImageSize -> Full,
             PlotLabel -> "Index vs. Deaths"], Plot[leastsquareline[x], {x, 0, 15}]]
```

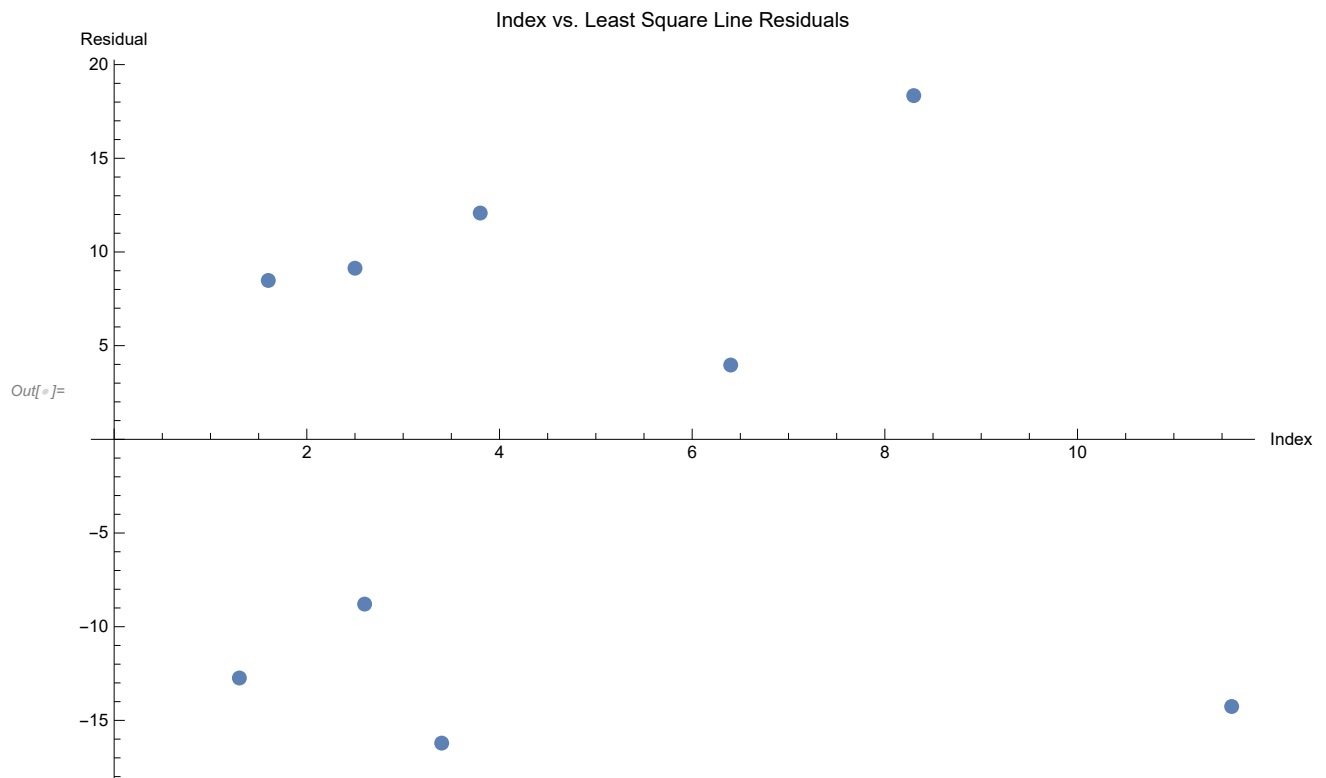


```
In[ ]:= leastsquareresiduals = Transpose[{Index, Death - leastsquareline[Index]}]
```

```
Out[ ]:= {{2.5, 9.13371}, {2.6, -8.79367}, {3.4, -16.2128}, {1.3, -12.7376},
          {1.6, 8.48019}, {3.8, 12.0777}, {11.6, -14.2585}, {6.4, 3.96564}, {8.3, 18.3453}}
```



```
In[ ]:= Show[ListPlot[leastsquareresiduals, AxesLabel -> {"Index", "Residual"},  
ImageSize -> Full, PlotLabel -> "Index vs. Least Square Line Residuals"]]
```



```
In[ ]:=  
leastsquareresidual = Total[Abs[Death - leastsquareline[Index]]]
```

```
Out[ ]:= 104.005
```

Line Comparison

```

In[ ]:= Show[ListPlot[data, AxesLabel → {"Index", "Death"},
  ImageSize → Full, PlotLabel → "Index vs. Deaths"],
  Plot[{twoline[x], medmedLine[x], leastsquareline[x]}, {x, 0, 15},
  PlotStyle → {RGBColor[1, 0, 0], RGBColor[0, 1, 0], RGBColor[0, 0, 1]}, PlotLegends →
  Placed[{"Two Point Line", "Median-Median Line", "Least Squares Line"}, Below]]]

```

