

Incidence of Asthma Among Aluminum Smelter Workers “Potroom Asthma”

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- Background
- Aims
- Methods
- Statistical analysis
- Results
- Conclusions
- Limitations
- Acknowledgement



Aluminum

- Occurs naturally in soil in combination with other elements and compounds like oxygen, fluorine, silica, 8% of earth’s crust
- Bauxite, the principal source, minerals formed by weathering of aluminum-bearing rocks
- Commercial bauxite deposits exist in Australia, South America and the W. Indies



Aluminum Production

Bauxite extracted by open-cast mining



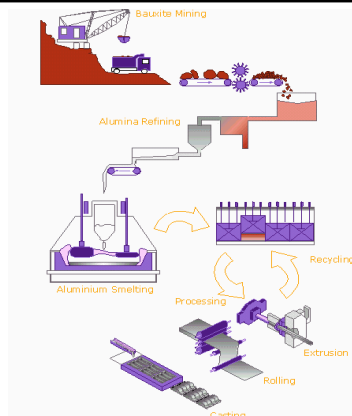
Refining of bauxite to yield alumina



Electrolytic reduction of alumina to yield aluminum (smelting)



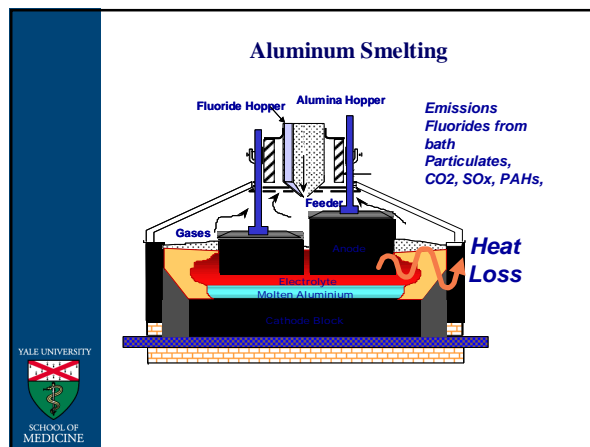
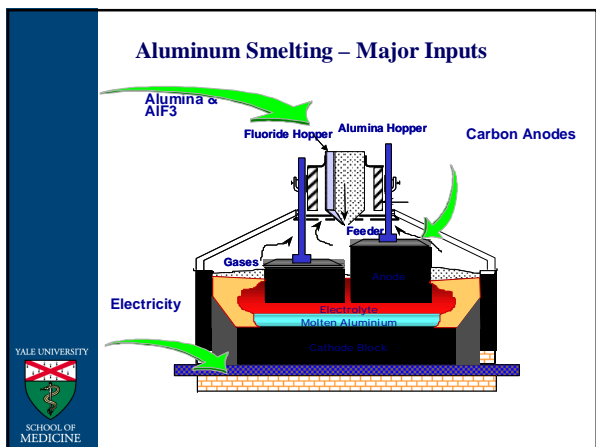
Aluminum casting into ingots for subsequent use



Aluminum Smelting

- Alumina reduced to aluminum by Hall-Héroult process (1886)
- Alumina dissolved in molten cryolite (sodium aluminum fluoride) in large carbon lined steel pot
- Electric current flows between carbon anode made of petroleum coke & pitch and cathode formed by pot lining
- Molten aluminum deposited at the bottom of the pot & siphoned off for casting ingots.





Potroom Asthma

- First reported by Frostad in 1936, Norway
- Since reported in other parts of Europe, Australia, New Zealand
- Studies of North American Potroom workers failed to show excess risk of asthma
- Annual incidence 2% (0.04-4%)
- Prevalence 10% in long-term workers

Potroom Asthma

- Etiology unknown
- Attributed to potroom emissions
 - Fluorides (particulate & gaseous as HF)
 - Alumina dust
 - Coal tar pitch volatiles (CTPV)
 - Sulfur dioxide (SO₂)
 - Short-term peak exposure (HF, SO₂)

Characteristics of Potroom Asthma

- Symptoms & airflow limitation associated with duration of potroom employment
- Immediate & late response described
- Irritant & allergic mechanisms possible
- Early removal results in reduced symptoms & bronchial hyperactivity
- Workers with prolonged exposure often remain symptomatic after removal



Aims

- Is there more asthma in U.S. potroom workers than in other aluminum production workers?
- What is the cause ?
- Dose-response relationship?



Study

- This study utilized seven years (1996-2002) of health and workplace exposure data from 13 U.S. Aluminum production locations including six smelters



Method: Exposure data

- Industrial hygiene exposure assessment software system (HYGenius)
- 5-8 samples per Similar Exposed Group (SEG)
- Air sample personal monitoring
- Personal sample collected
 - over 75% of shift (6-8 hours for 8 hr TWA)
 - 15 minutes for short-term exposure



Method: Exposure data

- Each sample results includes:
 - Location, dept, job title, task, employee ID,
 - date, strategy, exposure type
 - PPE, duration of sampling & shift length
- Total dusts - 1977
- CTPV, Fluorides - 1982
- SO₂ - 1984



Method: Health Data

- CHS : Insurance Claims database
- Employees with ICD-9 code 493 (asthma)
- At Risk Group
 - Asthma-free from 1/96-12/97 or
 - Hired after 1996 and asthma free for 2 years after hire
- Followed from 1/98-12/02 to determine annual incidence of asthma



Method: Health Data

- Abstraction from plant medical records (another project)
- Data obtained height, weight, education level, blood pressure, lipid profile, and smoking status
- No clinical end points from plant records were used for this analysis



Statistical Analysis

- No change in exposure for any of the agents over time except for CTPV which showed a decline
- Assigned exposure for each similar exposed group (SEG) was the mean value of all the TWA measurements taken for that SEG
- CTPV assigned exposure was the expected value based on the linear regression at the mid point of the study



Statistical Analysis

- Incidence rate of asthma within a SEG plotted vs. 8-hr TWA for average total fluoride exposure within SEG
- The line weighted by # employees in each SEG
- Using maximum likelihood estimates, a best fit line was determined
- Repeat for 8-hr average for other emissions
- Repeat for short-term HF and SO₂

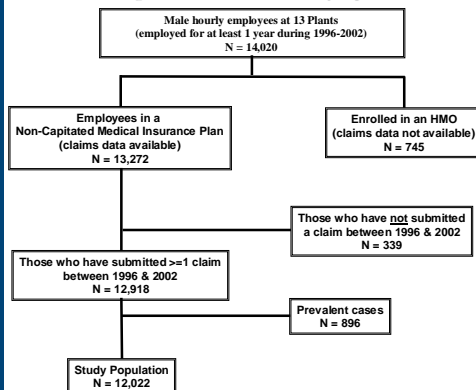


Statistical Analysis

- Generalized linear model with Poisson distribution
- Bivariate Analysis
 - Relationship between asthma incidence and each agent, smoking status & obesity
- Multivariate Analysis
 - All the exposure agents, smoking status and obesity included in the analysis



Figure 1: Derivation of the Study Population



Descriptive Statistics

- 12,022 male hourly employees at 13 locations with 46,672 person-years of follow-up
- 1,302 male hourly potroom workers with 4765 person-years of follow-up
- Average age 46.4 yrs
- Average tenure 18.7 yrs



Incidence of Asthma

- 455 new cases of asthma in study population
- Annual asthma incidence
 - Potroom workers = 1.17%
 - Non potroom workers = 0.95%
 - Incidence Ratio= 1.24 (0.93, 1.63)
 - After controlling for smoking
1.40 (1.03, 1.91)



Distribution of Potroom Emissions (mg/m³)

Emission	Number of Samples	Min	Max	Mean	Std Dev
Total Fluorides	1903	0.00	134.08	1.25	5.40
Particulate Fluorides	2003	0.00	134.00	1.02	5.26
HF	2014	0.00	7.81	0.22	0.43
SO ₂	1825	0.00	14.05	0.17	0.40
CTPV	3676	0.00	15.35	0.10	0.55
Total Dust	8577	0.00	204.00	7.03	85.10
Short-term HF	1425	0.00	37.00	1.89	3.39
Short-term SO ₂	1259	0.00	13.41	0.61	0.92

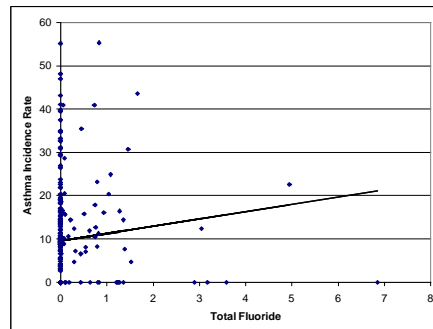


Association between Asthma & Emissions

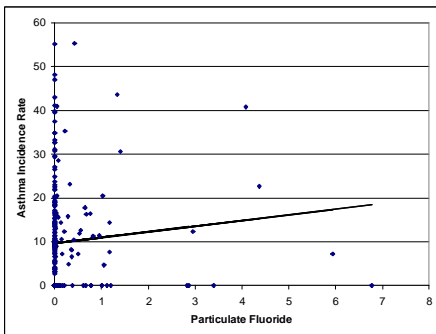
- Incidence rate of asthma within a SEG plotted against each agent
 - Total Fluoride
 - HF
 - Particulate Fluoride
 - SO₂
 - CTPV
 - Short-term HF
 - Short-term SO₂



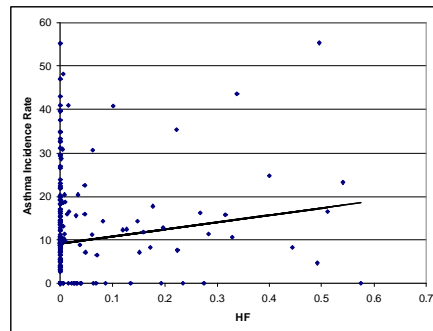
Total Fluoride vs. Asthma Incidence

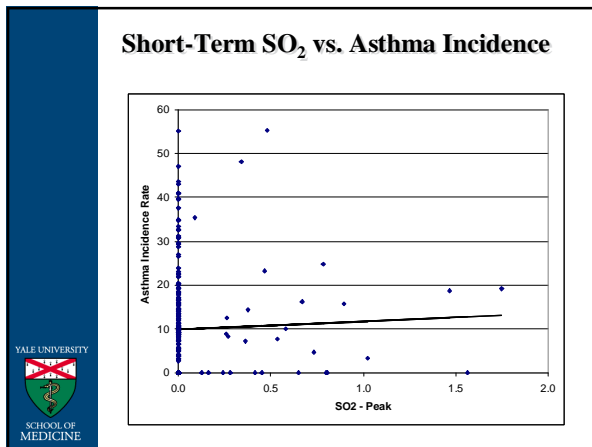
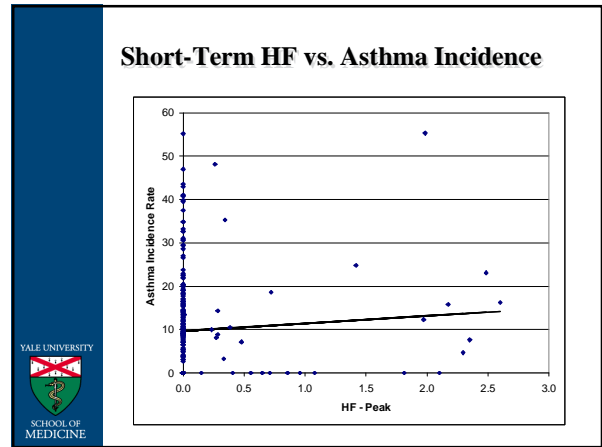
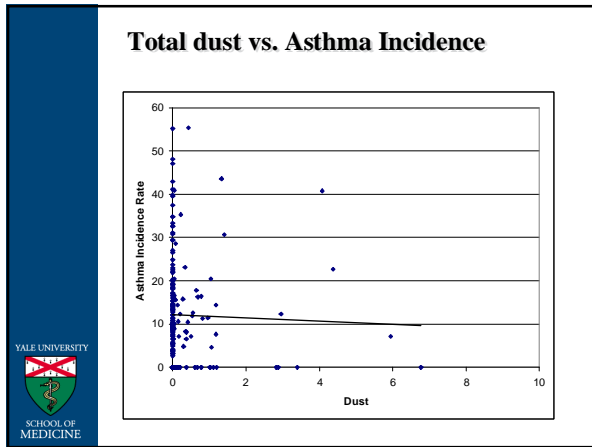
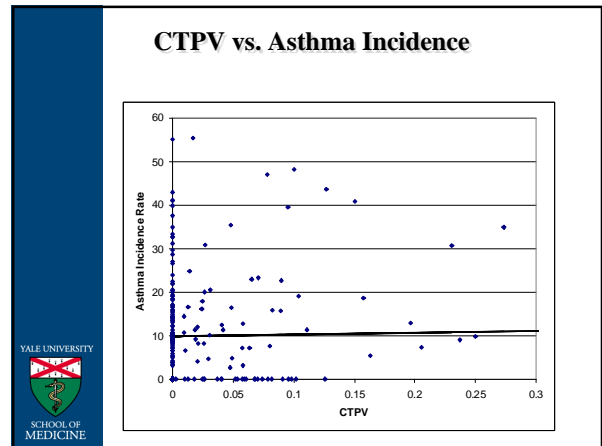
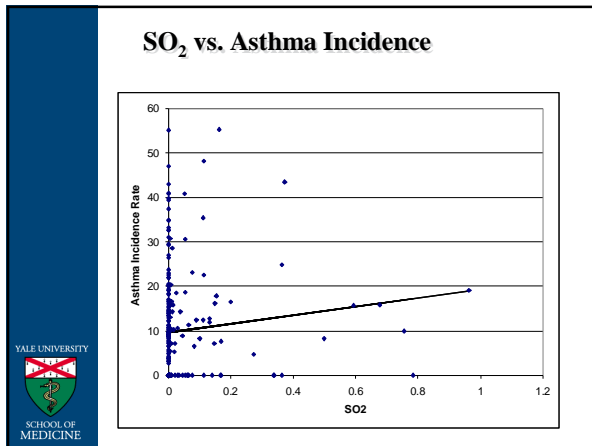


Particulate Fluoride vs. Asthma Incidence



HF vs. Asthma Incidence





Asthma Incidence vs. Variables Poisson Regression Model

Agent	Bivariate Analysis				Multivariate Analysis			
	Parameter Estimate	Standard Error	Chi_Square	p-value	Parameter Estimate	Standard Error	Chi_Square	p-value
Total Fluoride	0.1435	0.0921	5.34	0.0209	-	-	-	-
Particulate Fluoride	0.1086	0.0507	4.6	0.032	-	-	-	-
HF	1.435	0.3558	15.91	<.0001	1.6525	0.3728	19.65	<.0001
SO ₂	0.812	0.3915	4.3	0.0381	-	-	-	-
CTPV	0.2738	0.1976	2.13	0.1444	-	-	-	-
Dust	0.0005	0.0062	0.01	0.9323	-	-	-	-
HF Shortterm	0.1544	0.0284	3.38	0.066	-	-	-	-
SO ₂ Shortterm	0.1186	0.2178	0.3	0.5861	-	-	-	-
Obese	0.5995	0.488	1.51	0.2193	-	-	-	-
Smoke	1.7487	0.4827	13.13	0.0003	1.7065	0.4847	12.4	0.0004
Age	-0.0118	0.0109	1.17	0.2794	-	-	-	-

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Association between Asthma & Variables

- **Bivariate Analysis**
 - Significant relationship with total fluoride, HF, particulate fluoride, SO₂ & smoking
 - Weaker relationship with short HF & SO₂
 - No relationship with CTPV, total dust or obesity



Association between Asthma & variables

- **Multivariate Analysis**
 - Only HF & smoking were significant
 - HF: RR 4.2 (2.4, 10.8)
 - Smoking RR 5.5 (2.1, 14.2)
 - No interaction between HF * smoking
 - Both independent factors



Summary

- 40% increase risk of asthma in potroom workers vs. non-potroom aluminum production workers after controlling for smoking
 - OR = 1.40 (1.03, 1.91)
- In a multivariate model, strong relationship between asthma incidence and mean HF
- Smoking a significant and independent factor



Conclusion

- Control measures to reduce fluoride exposure focusing on gaseous fluoride (HF)
- Smoking cessation programs
- Effects of frequent short-term exposures to HF and SO₂ require further investigation



Limitations

- **Case definition of Asthma**
 - Physician diagnosis of asthma
 - Tried 2 diagnoses of asthma (no difference)
 - Probably underestimates true asthma incidence
- **Current exposure rather than cumulative exposure**
 - May induce misclassification
 - Drives the association towards null
- **Unable to assess the effects of other host factors**
 - Atopy, childhood asthma



Acknowledgement

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