

It's the Vog! (Or is It?): Respiratory Effects of Volcanic Air Pollution

Liz Tam, MD

American Lung Association of Hawai'i
and Leahi Fund Endowed Chair of Respiratory
Health

John A. Burns School of Medicine, Department
of Medicine

3 types of air pollution, which has the lowest concentration of volatile organic compounds (VOC), metals, and Class A carcinogens?

Environmental Tobacco Smoke...

Traffic-Related Air Pollution (TRAP)

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10-year old Hawai'i Island schoolchildren born
after the eruption of Kilauea volcano, asthma prevalence
has significantly increased in the area with volcanic air pollution that



Low
Intermittent
Frequent
Acid

There was no significant difference.

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10-year old Hawai'i Island schoolchildren born



in the first eruption of Kilauea volcano, the prevalence

of FVC < 0.80 was slightly increased in the area with vol

air pollution that was:

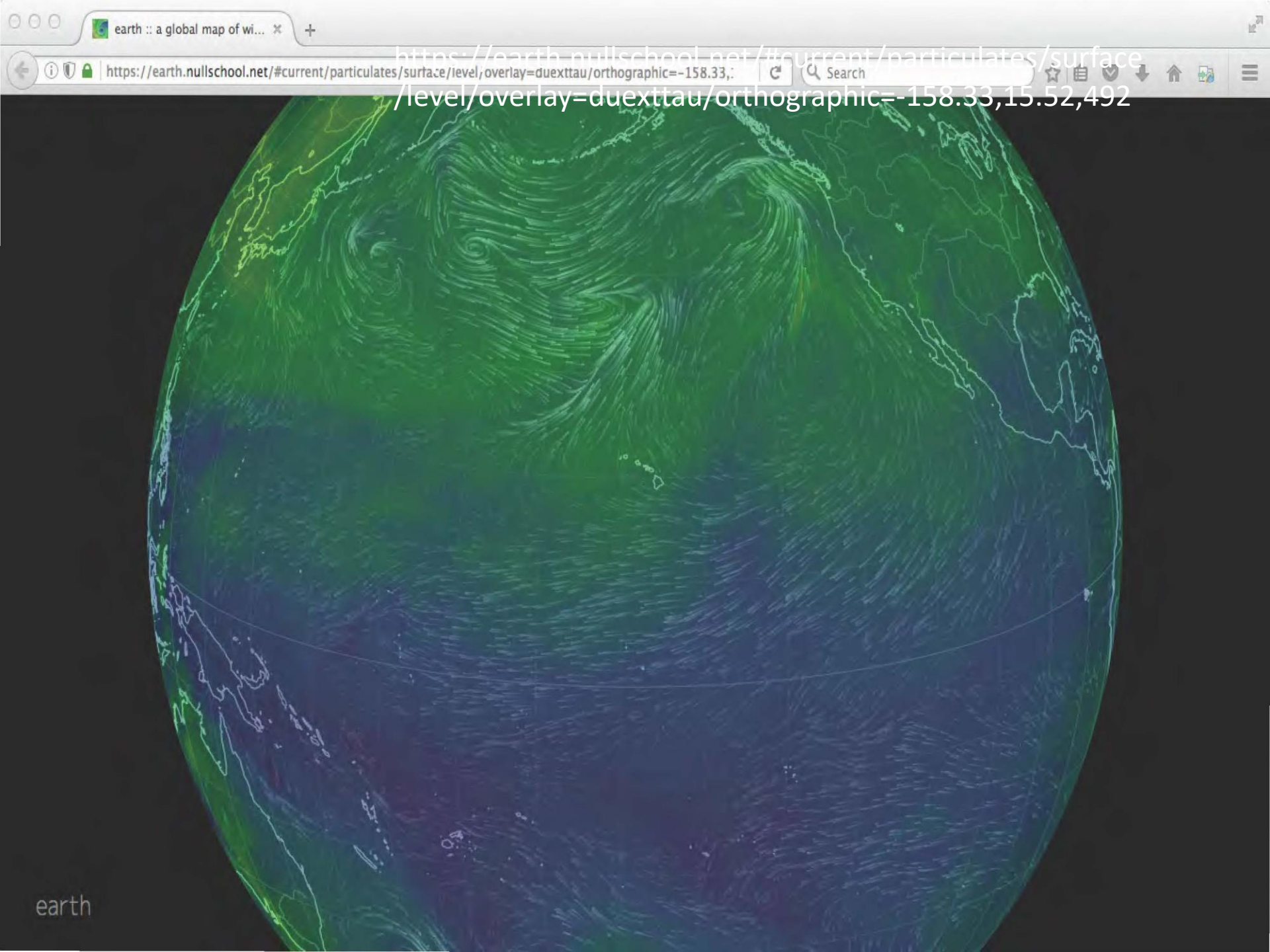
Low
Intermittent
Frequent
Acid

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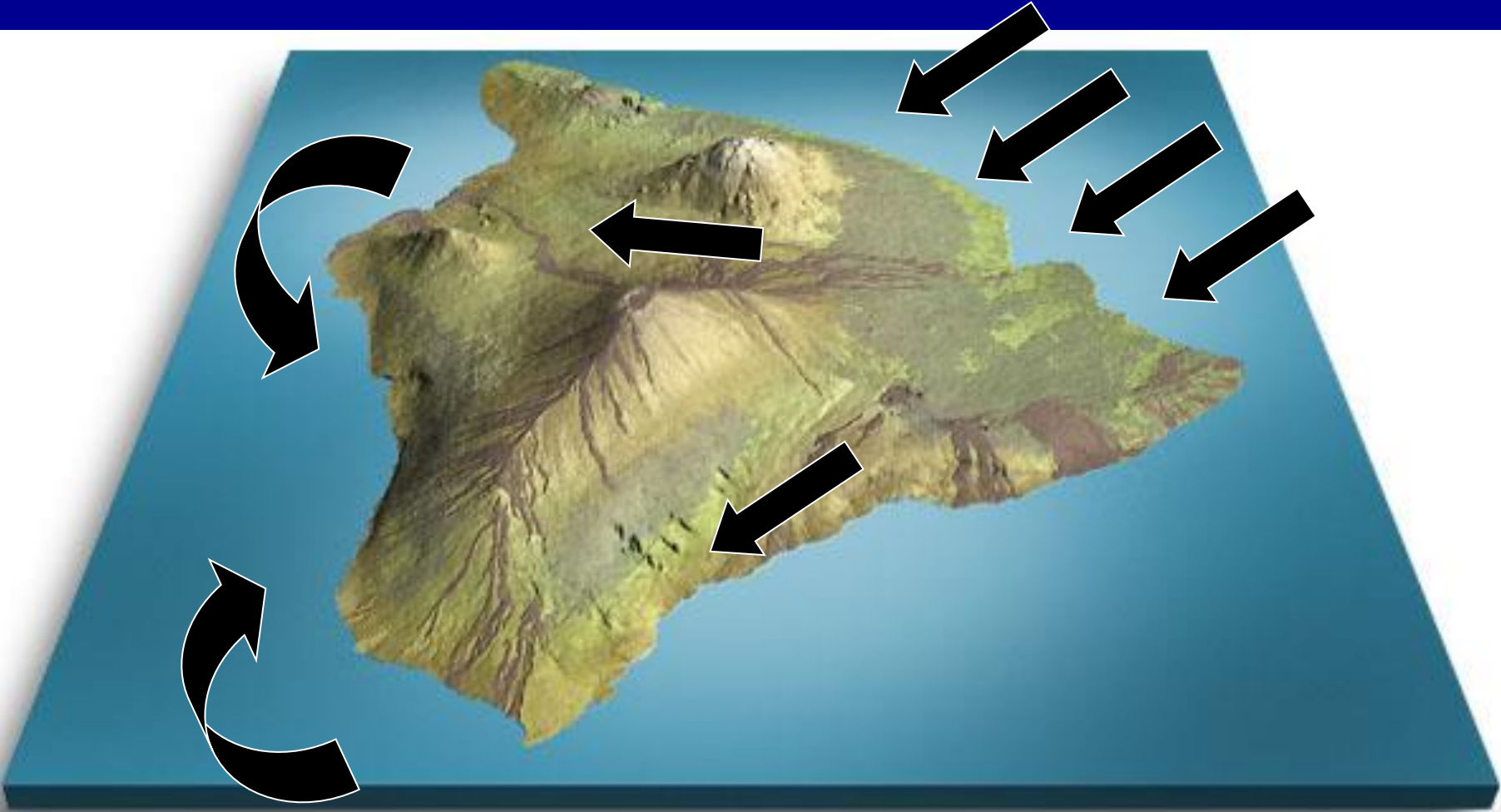


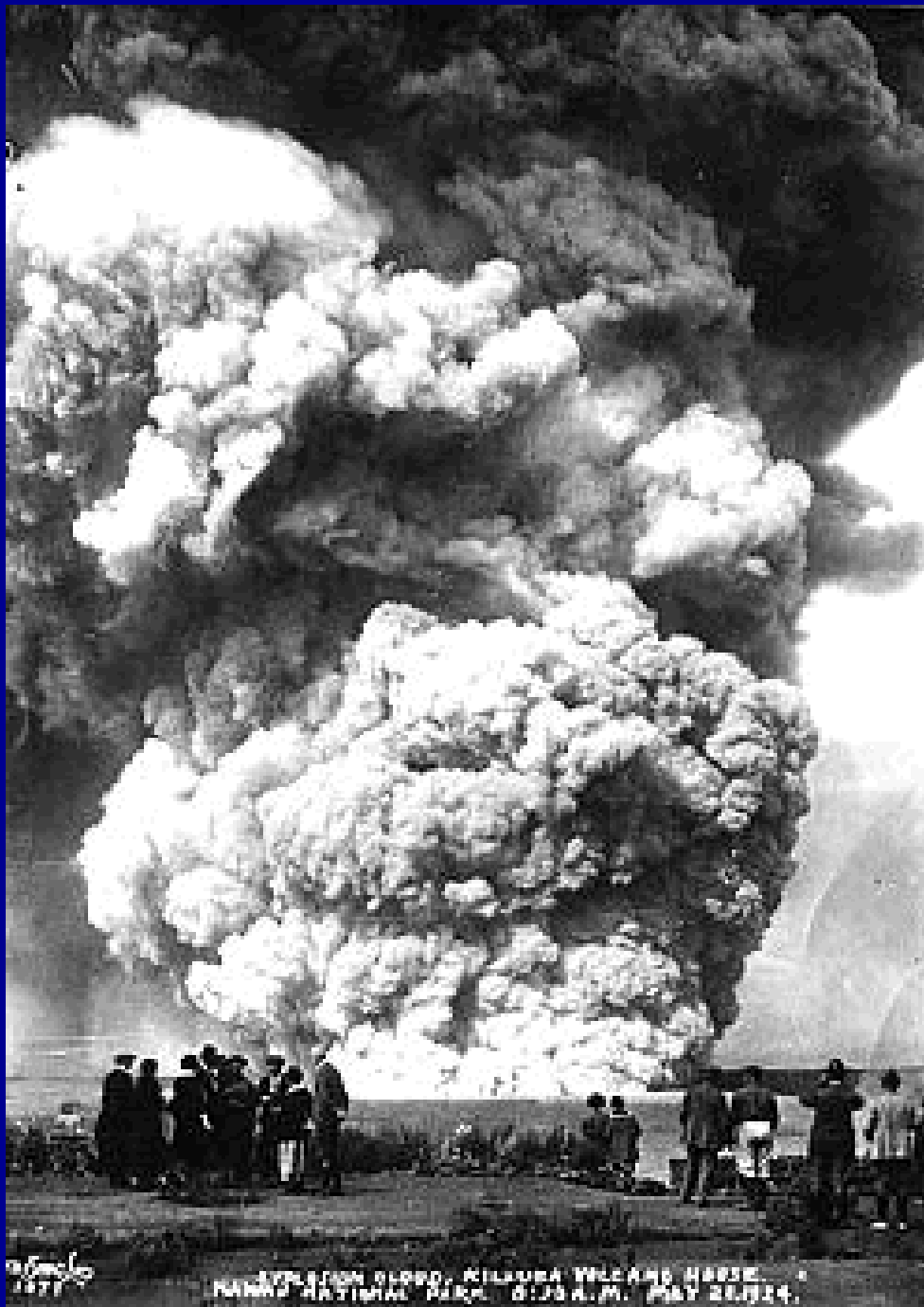
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earth

Prevailing Trade Winds

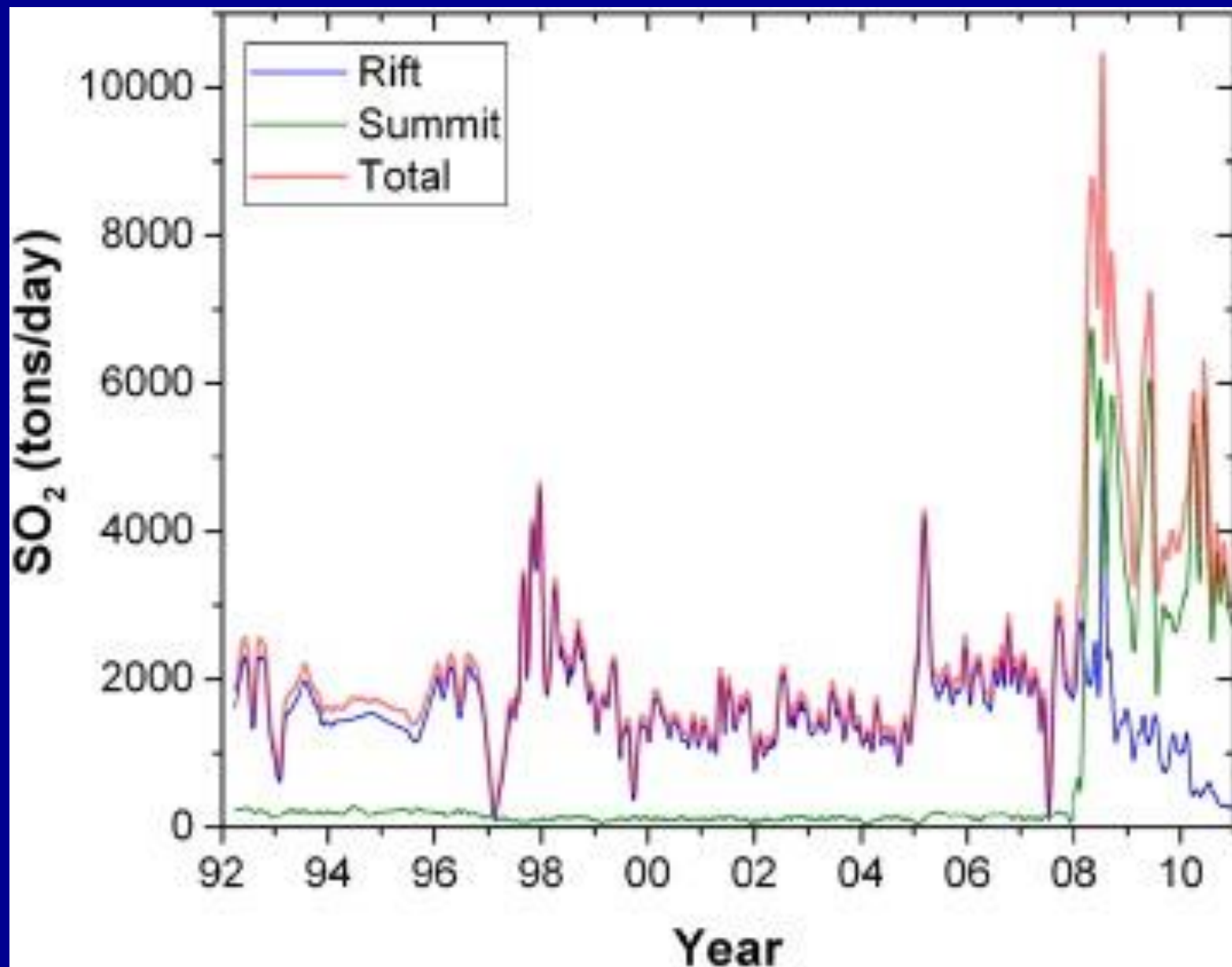




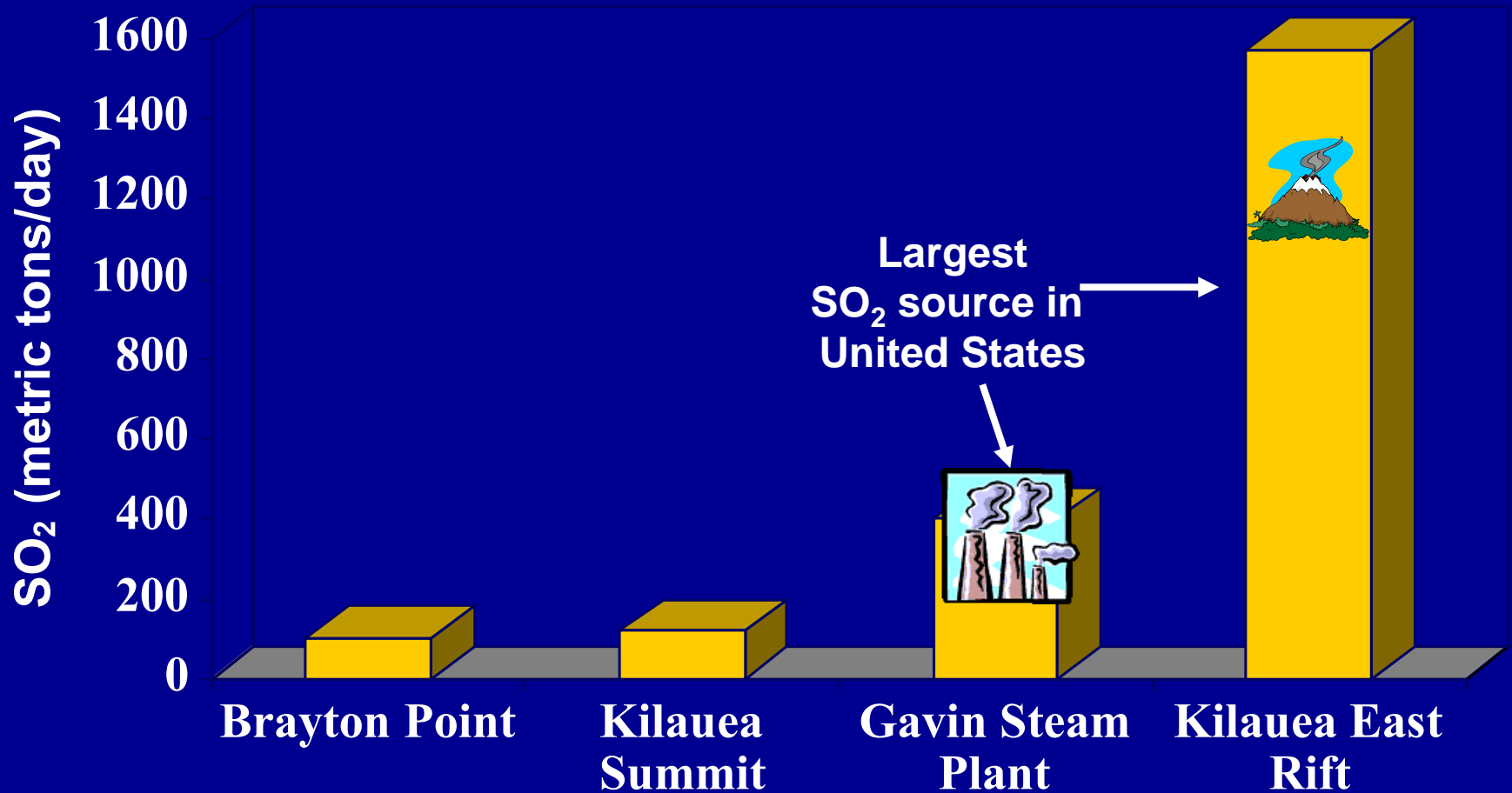
Sulfur Dioxide

- Kilauea has erupted continuously since 1983
- 300 tons per day emitted *during pauses.*
- Can exceed 30,000 tons per day in eruptions
- More than twice as much as highest EPA-ranked stationary source in US

Emissions



Sulfur Dioxide Emissions



Vog dispersal

Wind, Mountain, Ocean



- Inversion layer at 6000 ft.
- Spread is influenced by low level wind direction
- Prevailing trades
- Occasional pauses or reversals in wind
- Effects of terrain
- Effects of ocean cooling and warming

Primary National Ambient Air Quality Standard for Sulfur Dioxide

AGENCY: Environmental Protection Agency (EPA).

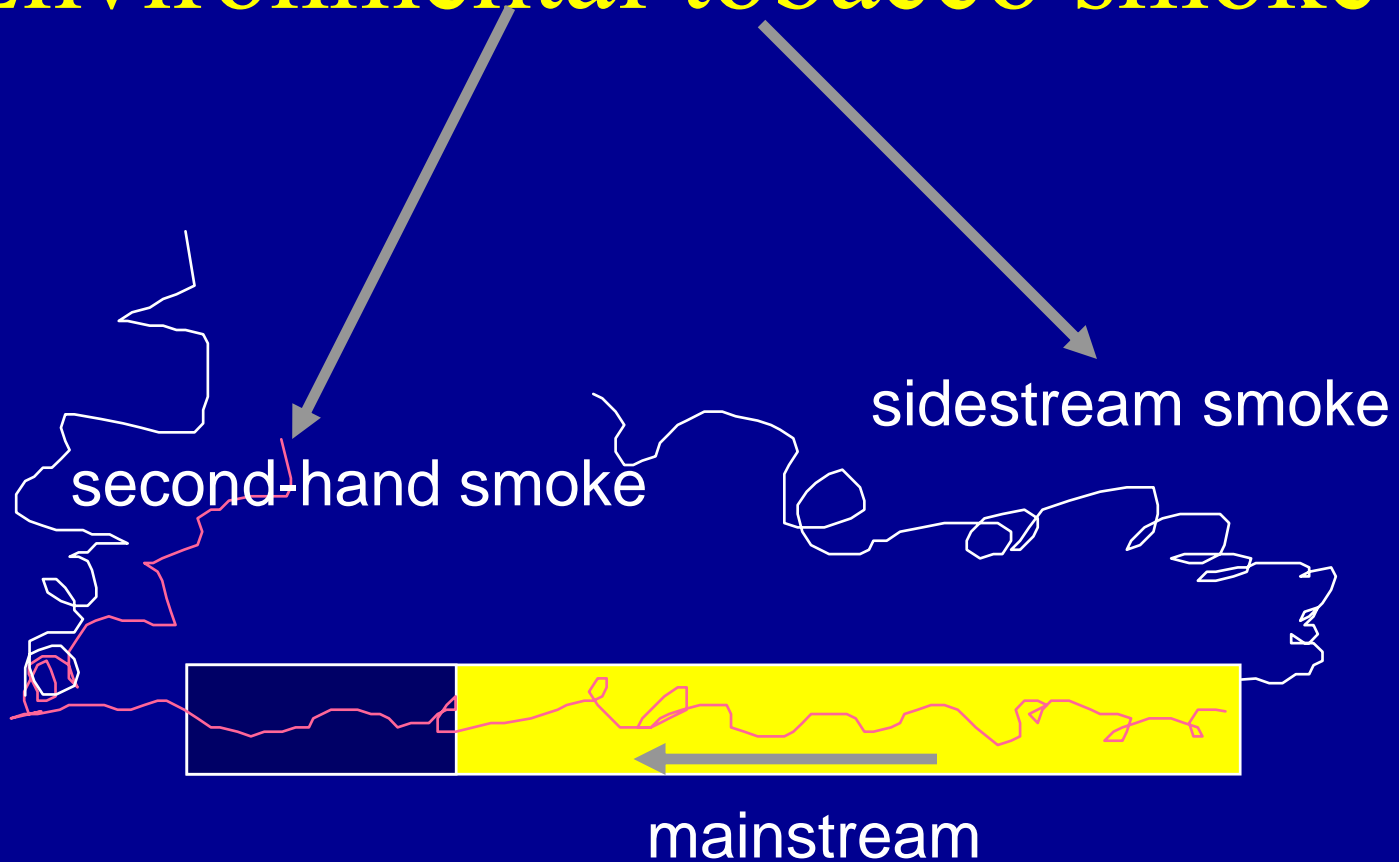
ACTION: Final rule.

SUMMARY: EPA established a new 1-hour SO₂ standard at a level of 75 parts per billion (ppb), based on the 3-year average of the annual 99th percentile of 1-hour daily maximum concentrations. The EPA also revoked both the existing 24-hour and annual primary SO₂ standards.

DATE: 2010

Tobacco smoke

Environmental tobacco smoke



Gases

Sidestream/Mainstream Concentration

Acrolein	8 - 15
Ammonia	3.7 - 5.1
Benzene	5 - 10
1,3-Butadiene	3 - 6
Carbon dioxide	8 - 11
Carbon monoxide	2.5 - 4.7
Formaldehyde	0.1 - ~50
Formic Acid	1.4 - 1.6
Hydrazine	3
Hydrogen cyanide	0.1 - 0.25
Methylamine	4.2 - 6.4
3-Methylpyridine	3 - 13
Nitrogen oxide	4 - 10
N-Nitrosodiethylamine	1-40
N-Nitrosodimethylamine	20 - 100
N-Nitrosopyrrolidine	6 - 30
Pyridine	6.5 - 20
Toluene	5.6 - 8.3
3-Vinylpyridine	20 - 40

US EPA Report 1993

Particles

Sidestream/Mainstream concentration

4-Aminobiphenyl

31

Aniline

30

Benz[a]anthracene

2 - 4

Benzo[a]pyrene

2.5 - 3.5

γ

Cadmium

7.2

Cholesterol

0.9

Glycolic Acid

0.6 - .095

Harman

0.7 - 1.7

Hydroquinone

0.7 - 0.9

2-Naphthylamine

30

Nickel

13 - 30

Nicotine

2.6 - 3.3

N-Nitrosodiethanolamine

1.2

N-Nitrosonornicotine

0.5 - 3

NNK

1 - 4

Particulate matter

1.3 - 1.9

PCDDs and PCDFs

2

Phenol

1.6 - 3.0

Polonium-210

1.0 - 4.0

Quinoline

3 - 11

Succinic acid

0.43 - 0.62

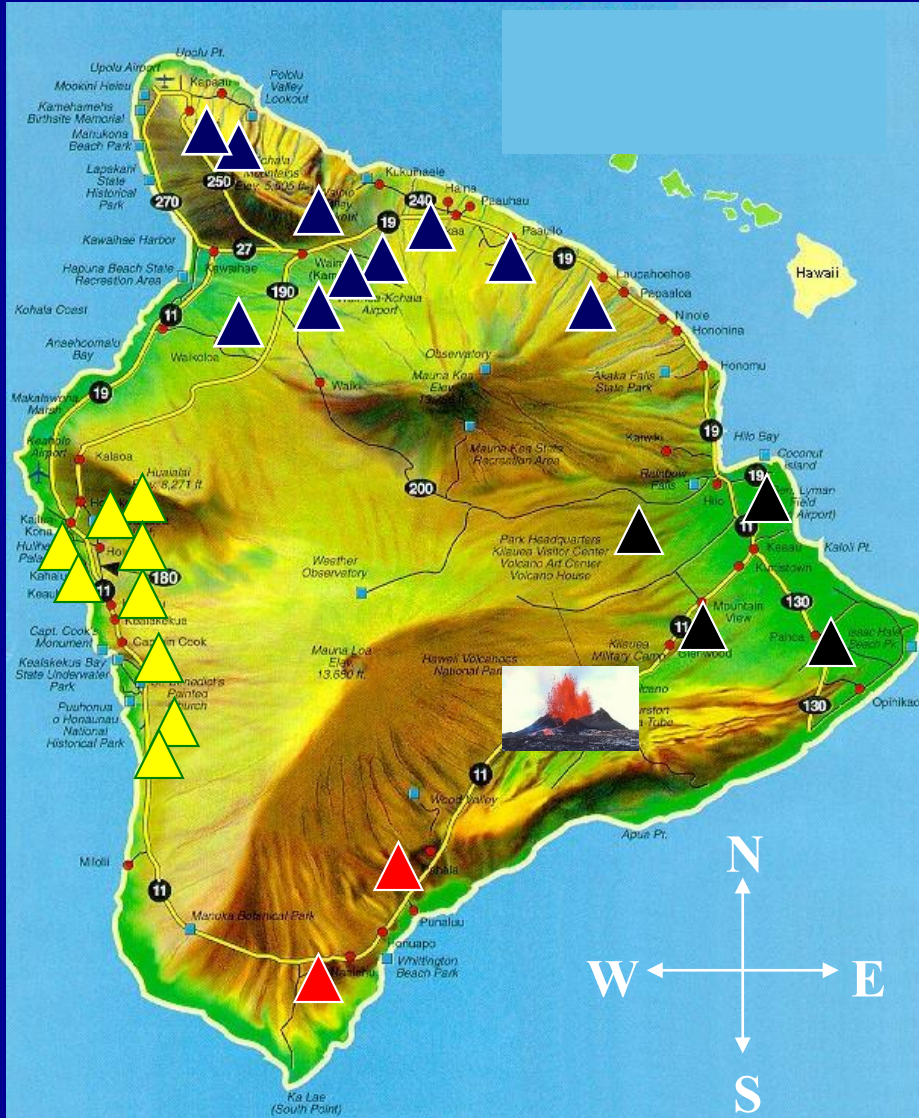
2-Toluidine





19

Zinc

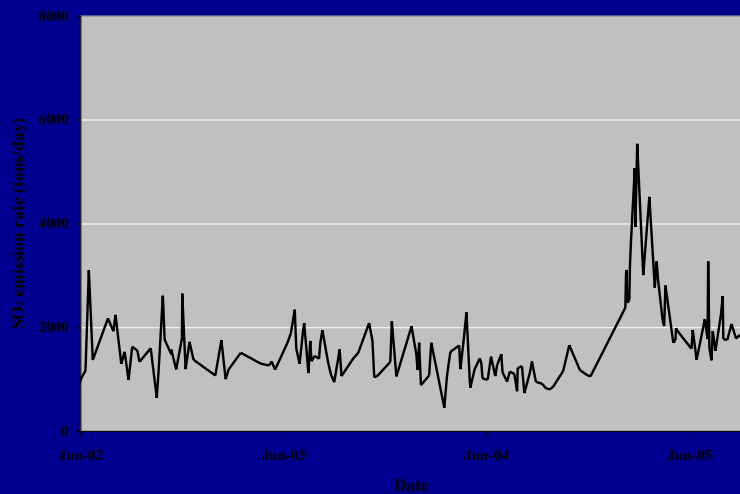
6.7

US EPA Report
1993

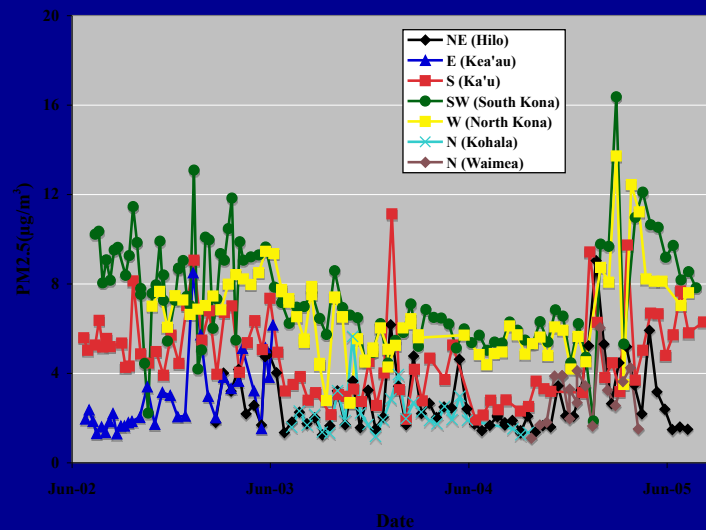


-  = Low
-  = Intermittent
-  = Frequent
-  = Acid

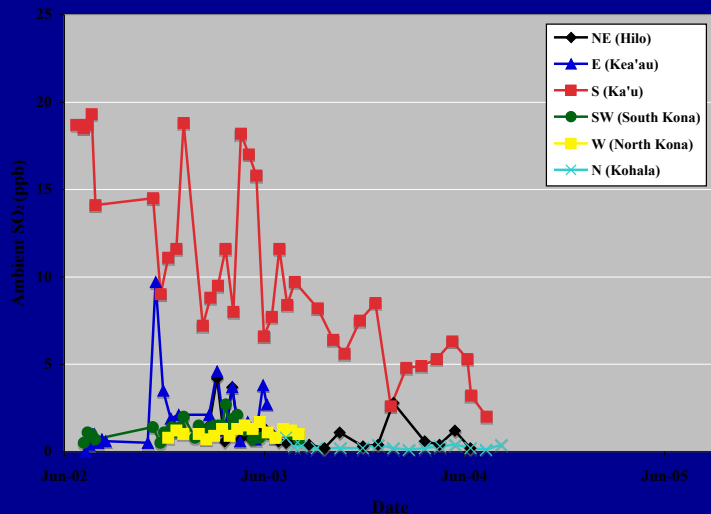
Kilauea East Rift Zone SO₂ Emission Rates (2002 to 2005)



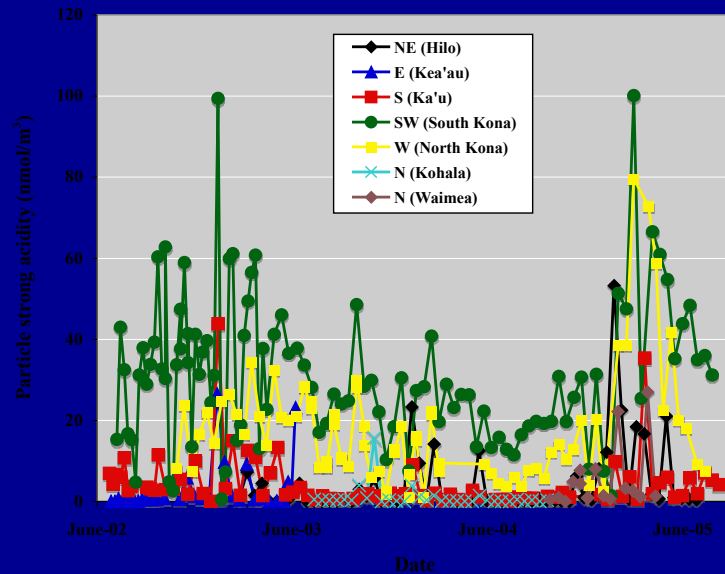
Fine Particulate Matter- PM2.5 (2002-2005)



Ambient Sulfur Dioxide (2002-2004)



Particle Strong Acidity (2002-2005)



SO₂, PM_{2.5}, and particulate acidity in 4 exposure zones, 2002–2005, 1- to 2-week integrated exposures, mean ± s.d. (n, range)

	Low	Intermittent	Frequent	Acid
SO ₂ , ppb	0.3 ± 0.2 (n = 15, 0.1–0.8)	1.6 ± 1.8 (n = 42, 0–9.7)	10.1 ± 5.2 [?] (n = 36, 2–18.7)	1.2 ± 0.4 (n = 52, 0.5–2.7)
PM _{2.5} , μg/m ³	2.5 ± 1.2 (n = 45, 1.3–5.6)	2.8 ± 1.5 (n = 100, 2.0–6.2)	4.8 ± 1.9 [?] (n = 77, 1.9–11.1)	7.2 ± 2.3 [?] (n = 163, 0.1–16.4)
Particulate acidity, nmol H ⁺ /m ³	0.6 ± 1.1 (n = 12, 0.3–15.6)	4.0 ± 6.8 (n = 35, 0.5–23.3)	4.3 ± 6.7 (n = 79, 0.1–43.8)	25.3 ± 17.9 (n = 181, 0.3–100.1)

Elemental composition

	Low	Inter-mittent	Frequent	Acid	P-Val ue	TRAP (Tsai 2015)
Filters (n)	2	4	4	2		
Mean net mass (μg)	826 \pm 695	1082 \pm 553	1685 \pm 411	2378 \pm 766	NS	*
Sulfur	580 \pm 501	777 \pm 361	1001 \pm 305	1572 \pm 478	NS	912.7
Sodium	45 \pm 1	85 \pm 23	110 \pm 80	95 \pm 35	NS	*
Potas-sium	9 \pm 1	33 \pm 28	47 \pm 27	18 \pm 6	NS	195.2
Silica	6 \pm 4	31 \pm 20	49 \pm 26	25 \pm 18	NS	137.7
Iron	5 \pm 2	21 \pm 8	31 \pm 2	16 \pm 9	NS	144.8

Elemental composition

	Low	Inter-mittent	Frequent	Acid	P-Value	TRAP (Tsai et al)
Zinc	0.4 ± 0.2	1.4 ± 0.3	2.5 ± 0.4	1.0 ± 0.2	< 0.001	26.4
Copper	0.2 ± 0.03	1.2 ± 0.2	1 ± 0.7	0.4 ± 0.2	< 0.01	6.4
Lead	0.2 ± 0.05	0.6 ± 0.05	1.47 ± 1	0.4 ± 0.2	< 0.05	*
Nickel	0.06 ± 0.06	0.41 ± 0.13	0.06 ± 0.03	0.14 ± 0.15	< 0.05	1.6
Vanadium	0.04 ± 0.07	0.81 ± 0.4	0.11 ± 0.16	0 ± 0	< 0.01	2.9

Beijing, January 2013



496 micrograms/m³

Traffic- Related Air Pollution

Industrial Air Pollution

- Primary
 - Gases (sulfur dioxide, nitrogen dioxide, nitric oxide, carbon monoxide, and more)
 - Particulates
 - Carbon-centered ultrafine (<100 nm)
 - PM 2.5, PM 10
- Secondary
 - Ozone
 - Particulates
 - Nitrates
 - Sulfates



RECRUITMENT & PARTICIPATION

2002-2003

2725 Children
Invited

```
graph TD; A[2725 Children Invited] --- B[Forms NOT Returned (543, 20%)]; A --- C["YES" Responses (1988, 73%)]; A --- D["NO" Responses (204, 7%)"];
```

Forms NOT Returned
(543, 20%)

"YES" Responses
(1988, 73%)

"NO" Responses
(204, 7%)

Participant Characteristics

	All	Low	Inter- mittent	Frequent	Acid	P-value
N	1957	531	584	112	730	
Age in yr (mean ± s.d.)	10.1 ± 0.66	10.1 ± 0.69	10.0 ± 0.63	10.1 ± 0.59	10.1 ± 0.67	0.11
Girls	993 (51)	259 (49)	282 (48)	57 (51)	395 (54)	0.14
Race						< 0.0001
White	310 (16)	78 (15)	40 (7)	12 (11)	180 (25)	
Asian	282 (15)	84 (16)	117 (20)	21 (19)	60 (8)	
Mixed	1218 (63)	334 (64)	395 (68)	66 (60)	423 (59)	
Pacific Isle	93 (5)	22 (4)	23 (4)	9 (8)	39 (5)	
Other	35 (2)	8 (2)	5 (1)	2 (2)	20 (3)	
Unknown	19 (1)	5 (1)	4 (1)	2 (2)	8 (10)	

Participant Characteristics

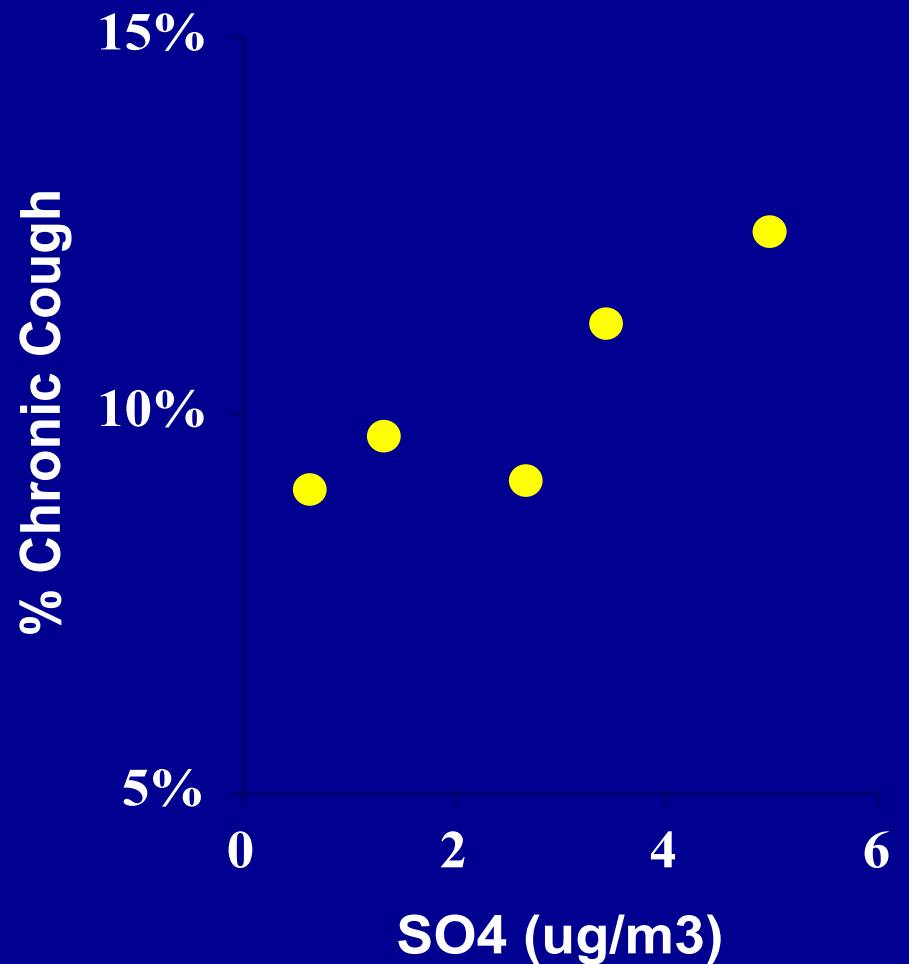
	All	Low	Intermittent	Frequent	Acid	P-value
N	1957	531	584	112	730	
Premature	187/1891 (10)	34/511 (7)	75/572 (13)	12/105 (11)	66/703 (9)	< 0.005
Family income >\$50,000	546/1614 (34)	156/452 (35)	119/482 (25)	15/81 (19)	256/599 (43)	< 0.0001
Mother smoked during pregnancy	296/1789 (17)	74/496 (15)	108/523 (21)	15/98 (15)	99/672(15)	< 0.05
Before 2 years old: other smokers in home	733/1789 (41)	197/490 (40)	239/525 (46)	45/98 (46)	252/676 (37)	< 0.05
Current smokers in home	395/1944 (20)	111/528 (21)	146/579 (25)	16/109 (15)	122/728 (17)	< 0.001
Mold in home in last 12 months	760/1759 (43)	220/488 (46)	265/531 (50)	28/94 (30)	247/654 (38)	< 0.0001

Participant Characteristics (%)

	All	Low	Intermittent	Frequent	Acid	P-value
N	1957	531	584	112	730	
Premature	10	7	13	11	9	< 0.005
Family income >\$50,000	34	35	25	19	43	< 0.0001
Mother smoked during pregnancy	17	15	21	15	15	< 0.05
Before 2 years old: other smokers in home	41	40	46	46	37	< 0.05
Current smokers in home	20	21	25	15	17	< 0.001
Mold in home in last 12 months	43	46	50	30	38	< 0.0001

Symptoms

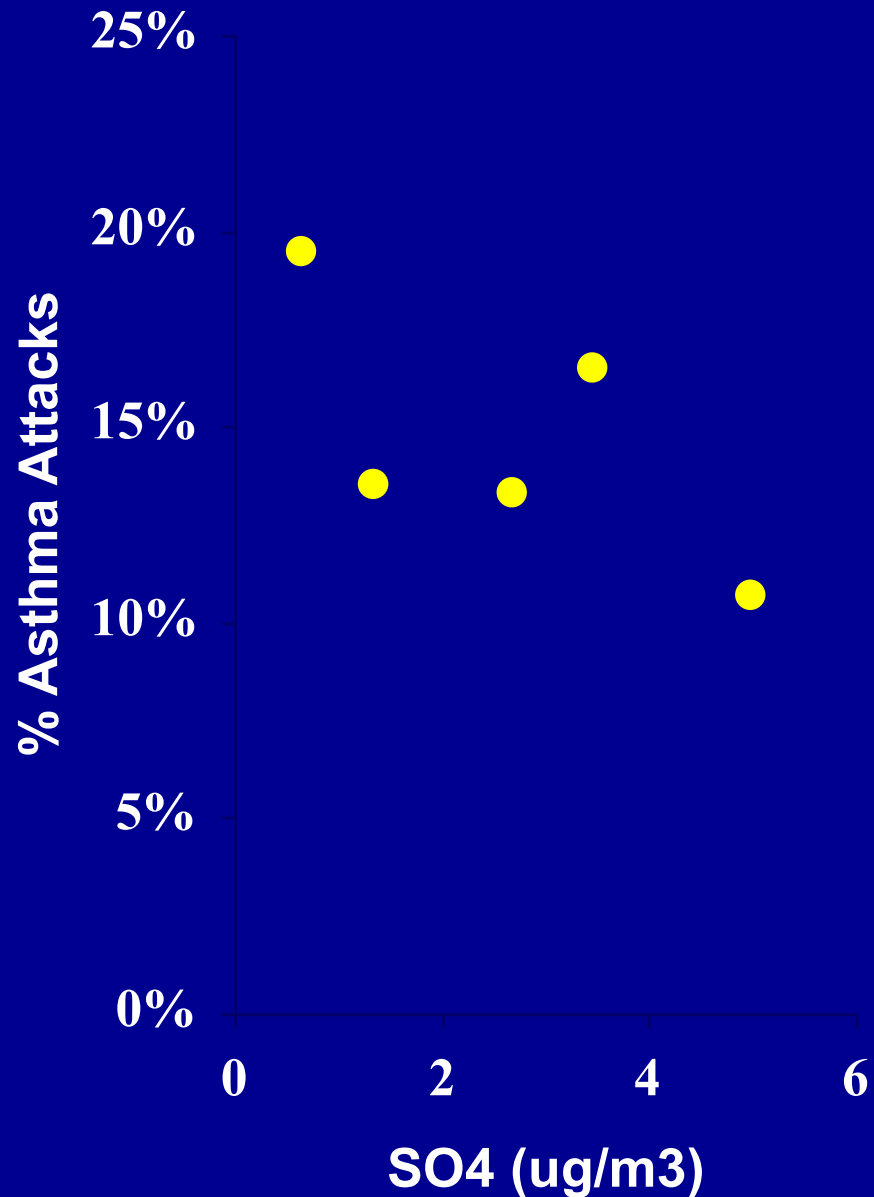
**Cough that
persists more
than 3
months**



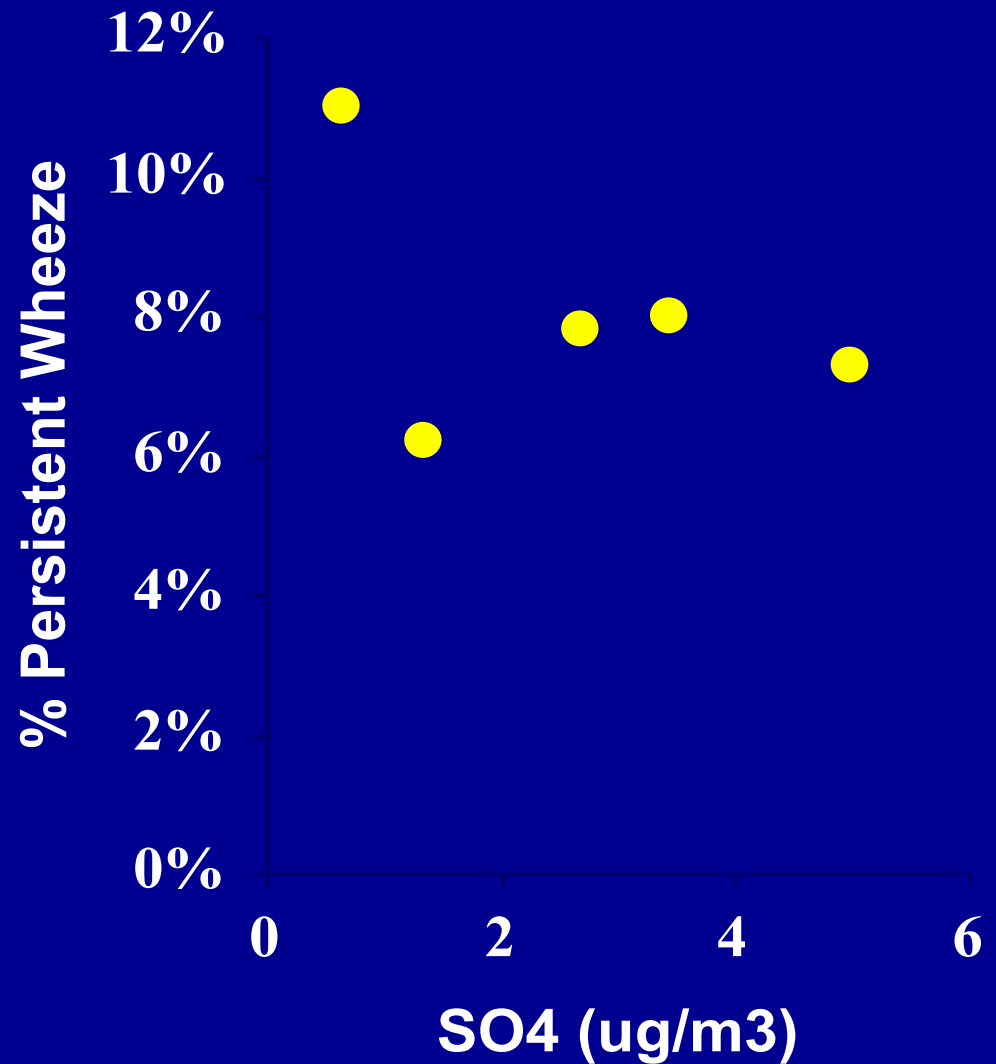
Respiratory Symptoms

	Vog exposure	n	% Yes	Adjusted OR ^a	95% CI
Chronic cough	Low	485	8		
	Intermittent	533	10	1.0	0.63–1.67
	Frequent	95	11	1.7	0.75–3.97
	Acid	683	11	1.5	0.98–2.38
Chronic Cough in Non-asthmatic	Low	407	5	1	
	Intermittent	421	5	0.93	0.47–1.84
	Frequent	81	7	1.5	0.49–4.77
	Acid	591	9	2.0	1.11–3.57

**Asthma
attack
within the
last 12
months**



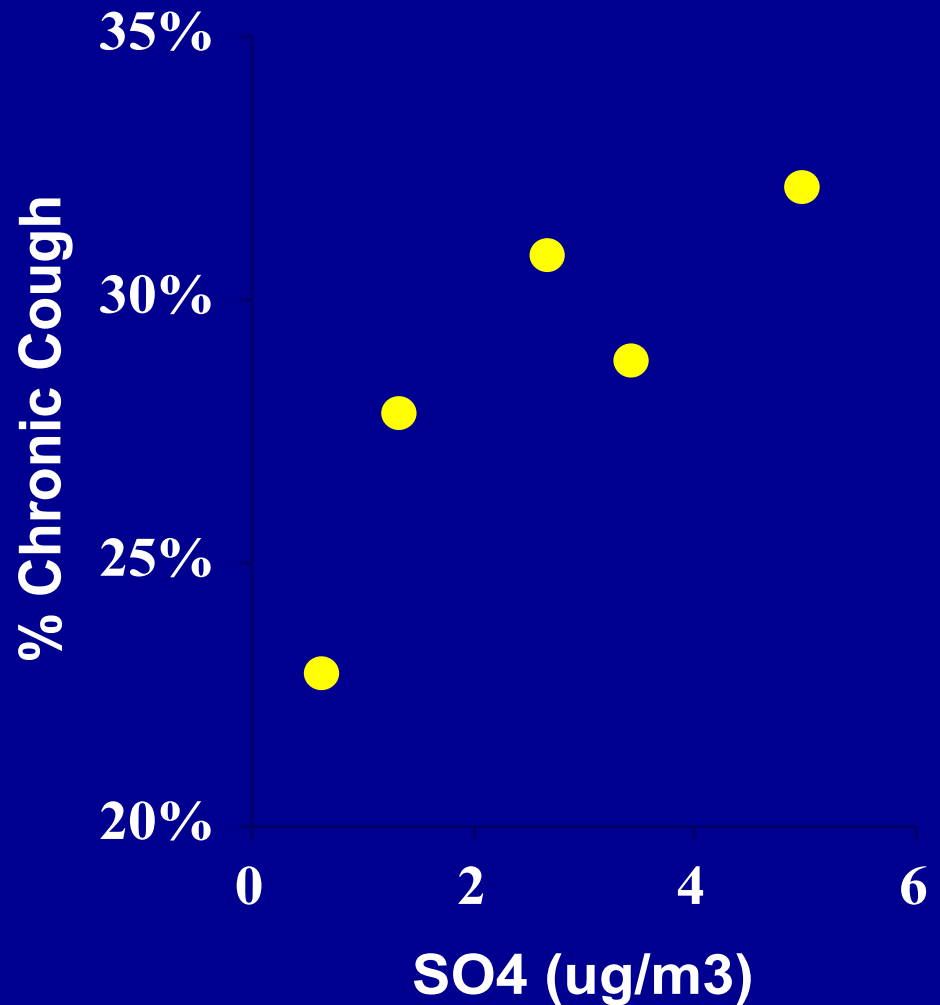
**Persistent
wheeze apart
from colds for
more than 3
months**



Respiratory Symptoms

	Vog exposure	n	% Yes	Adjusted OR ^a	95% CI
Physician-diagnosed Asthma	Low	529	16	1	
	Intermittent	575	21	1.1	0.77-1.54
	Frequent	111	14	0.9	0.43-1.76
	Acid	727	14	0.8	0.58-1.17
Persistent wheeze in last 12 months	Low	478	8	1	
	Intermittent	524	9	1.2	0.72-1.94
	Frequent	89	4	0.8	0.22-2.58
	Acid	650	6	0.8	0.50-1.38

Chronic cough among asthmatics



Respiratory Symptoms

	Vog exposure	n	% Yes	Adjusted OR ^a	95% CI
Chronic cough	Low	485	8		
	Intermittent	533	10	1.0	0.63–1.67
	Frequent	95	11	1.7	0.75–3.97
	Acid	683	11	1.5	0.98–2.38
Chronic cough in asthmatics	Low	76	25		
	Intermittent	106	28	1.1	0.50–2.38
	Frequent	14	29	2.8	0.63–12.4
	Acid	91	30	1.3	0.58–2.77

Respiratory Symptoms at Initial Test

	All	Low	Inter-mittent	Frequent	Acid	P-value
n	1895	523	562	103	707	
Diagnosed asthma (%)	23	23	29	18	19	< 0.001
Asthma, last 12 months (%) ^a	12	13	15	7	8	< 0.001
Head cold in last month (%)	53	47	59	52	52	< 0.005
Chest cold in last month (%)	34	33	36	31	34	0.65

Measurements

	All	Low	Inter-mittent	Frequent	Acid	P-value
Standing height (cm)	139.6 ± 8.3	139.1 ± 8.4	138.7 ± 8.3	137.4 ± 7.8	140.9 ± 8.2	< 0.0001
Sitting height (cm)	74.5 ± 4.4	74.3 ± 4.5	74.4 ± 4.5	73.0 ± 4.5	74.9 ± 4.2	< 0.0001
Weight (kg)	38.2 ± 12.0	37.5 ± 11.2	38.0 ± 11.5	36.3 ± 11.1	39.1 ± 13.0	< 0.05

Measurements

	All	Low	Inter- mittent	Frequent	Acid	P-value
BMI (mean)	19.3 ± 4.4	19.1 ± 4.3	19.5 ± 4.2	19.0 ± 4.5	19.4 ± 4.6	NS
BMI percentile						< 0.01
< 50th	63 (3)	23 (4)	14 (2)	9 (9)	17 (2)	
Normal	1150 (61)	322 (62)	327(58)	67 (63)	436 (62)	
> 85th	314 (17)	73 (14)	109 (19)	15 (15)	117 (17)	
> 95th	368 (19)	105 (20)	112 (20)	14 (14)	137 (19)	

Measurements

	All	Low	Inter- mittent	Frequent	Acid	P-value
	All	Low	Intermittent	Frequent	Acid	P-value
n	1836	504	551	103	678	
FEV ₁ (L)	1.92 ± 0.36	1.93 ± 0.36	1.89 ± 0.34	1.83 ± 0.34	1.95 ± 0.36	< 0.005
FVC (L)	2.26 ± 0.43	2.26 ± 0.44	2.23 ± 0.41	2.13 ± 0.41	2.29 ± 0.44	< 0.005
FEV ₁ /(sitting height) ²	3.44 ± 0.47	3.48 ± 0.45	3.41 ± 0.47	3.41 ± 0.46	3.44 ± 0.47	NS
FEV ₁ /FVC	0.85 ± 0.07	0.85 ± 0.06	0.85 ± 0.07	0.86 ± 0.07	0.85 ± 0.07	NS

FEV₁/FVC < 0.8

	Vog exposure	n	%yes	Adjusted OR ^a	95% CI
FEV ₁ /FVC < 0.80	Low	501	17.4	1	
	Intermittent	547	18.8	1.22	0.86-1.75
	Frequent	103	13.6	0.91	0.44-1.89
	Acid	670	19.7	1.32	0.94-1.86

Respiratory Symptoms 2010

Symptom	Vog Exposure	n	%	Adjusted OR	95% CI
Head cold	low	60	68	1	
	intermittent	121	77	1.2	.54-2.64
	frequent	7	43		
	acid	125	66	0.9	.39-1.91
Chest cold	low	59	25	1	
	intermittent	121	27	0.7	.33-1.60
	frequent	7	43		
	acid	125	34	1.5	.67-3.18

Respiratory Symptoms 2010

Symptom	Vog Exposure	n	%	Adjusted OR	95% CI
MD asthma	low	64	28	1	
	intermittent	121	43	1.5	.73-3.27
	frequent	7	29		
	acid	125	28	1	.47-2.28
FEV1/FVC < .80	low	58	17	1	
	intermittent	108	19	0.7	.26-1.84
	frequent	5	0		
	acid	121	18	1	.38-2.65

Highlights

- Kilauea volcano has erupted continuously since 1983; it released 1800 to 10000 metric tons of sulfur dioxide per day between 2000-2010.
- •Volcanic emissions, wind patterns, and mountains produce Low, Intermittent, Frequent, and Acid exposure zones on the island.
- •Acidic vog exposure was associated with increased cough, but not with physician-diagnosed asthma, persistent cough, bronchitis, or wheeze.
- Acidic vog exposure was (almost) associated with a higher prevalence of FEV1/FVC ratio < 0.8

References

- Tam et al, “Volcanic air pollution over the island of Hawai’i; Emissions, dispersal, and composition. Association with respiratory symptoms and lung function in Ha
- [http://www.science direct.com/science/article/pii/S0160412016301052](http://www.science.direct.com/science/article/pii/S0160412016301052)

3 types of air pollution, which has the lowest concentration of volatile organic compounds (VOC), metals, and Class A carcinogens?

Environmental Tobacco Smoke...

Traffic-Related Air Pollution (TRAP)

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10-year old Hawai'i Island schoolchildren born
after the eruption of Kilauea volcano, asthma prevalence
significantly increased in the area with volcanic air pollution than



Low
Intermittent
Frequent
Acid

Start the presentation to activate live content

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0%





10-year old Hawai'i Island schoolchildren born



in the first eruption of Kilauea volcano, the prevalence

of FVC < 0.80 was slightly increased in the area with vol

air pollution that was:

Low
Intermittent
Frequent
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