PARTICULATE POLLUTION ORIGINS, EFFECTS & COMMUNITY PROTECTION

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WHO AM I?

- **Professor of Geohealth**
- **Director of the International Volcanic Health Hazard Network (www.ivhhn.org)**
- Environmental scientist with an MSc & PhD in Volcanology.
- Research on hazards and impacts of airborne particles, ranging from volcanic ash through to industrial mineral dusts (crystalline silica dusts), urban particulates, desert dusts and combusted vegetation.
- Works across Earth sciences, toxicology, public health and medicine, psychology, social sciences and exposure science.
- Conducted 1st research on effectiveness of respiratory protection in volcanic settings. Now researching effectiveness of respiratory protection for children.
- Advises the World Health Organization and many GO/NGOs on preparing the health response for eruptions.
- Honorary position at Public Health England.
- Sits on the UK Government's SAGE panel for volcanic emergencies.

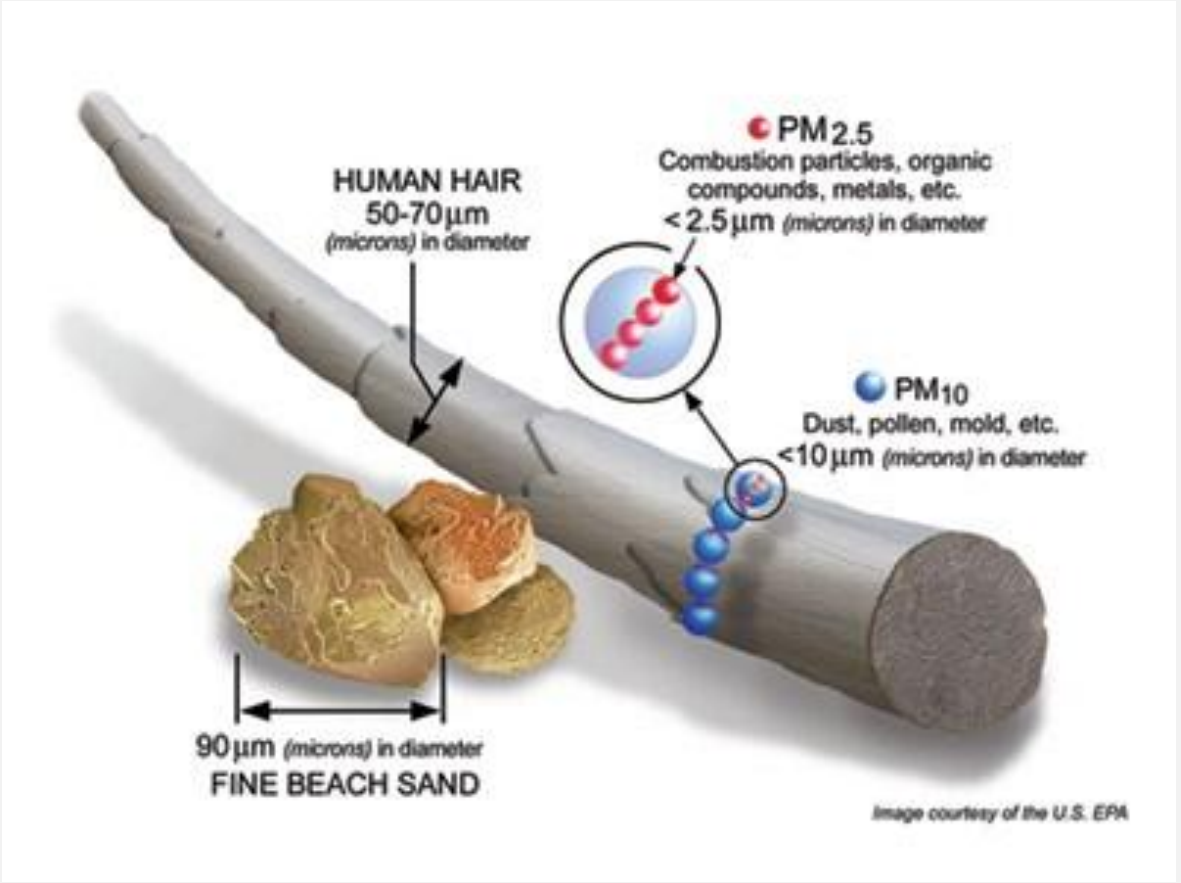
WHAT IS PARTICULATE POLLUTION?

- Also known as particulate matter or PM.
- General term for solid particles, in this case, suspended in the air.
- Made up different components: inorganic compounds (e.g. ammonium sulphate [from agriculture] and sodium chloride [sea salt]), organic matter (e.g. skin flakes), soot, smoke, vehicle exhaust, soil, mineral dust, tyre/brake wear and biological materials (e.g. pollen and mould spores).
- Secondary particles are formed in the air by chemical reactions with gaseous pollutants (e.g. sulphur dioxide to sulphate aerosol)
- The air we breathe, indoors and outdoors, always contains particles.
- Some particles are large enough to be seen with the naked eye. Others are so small they can only be detected analytically (microscopes, aerosol monitors etc.).

https://www.epa.gov/pmcourse/what-particle-pollution

PARTICLES COME IN DIFFERENT SHAPES AND SIZES

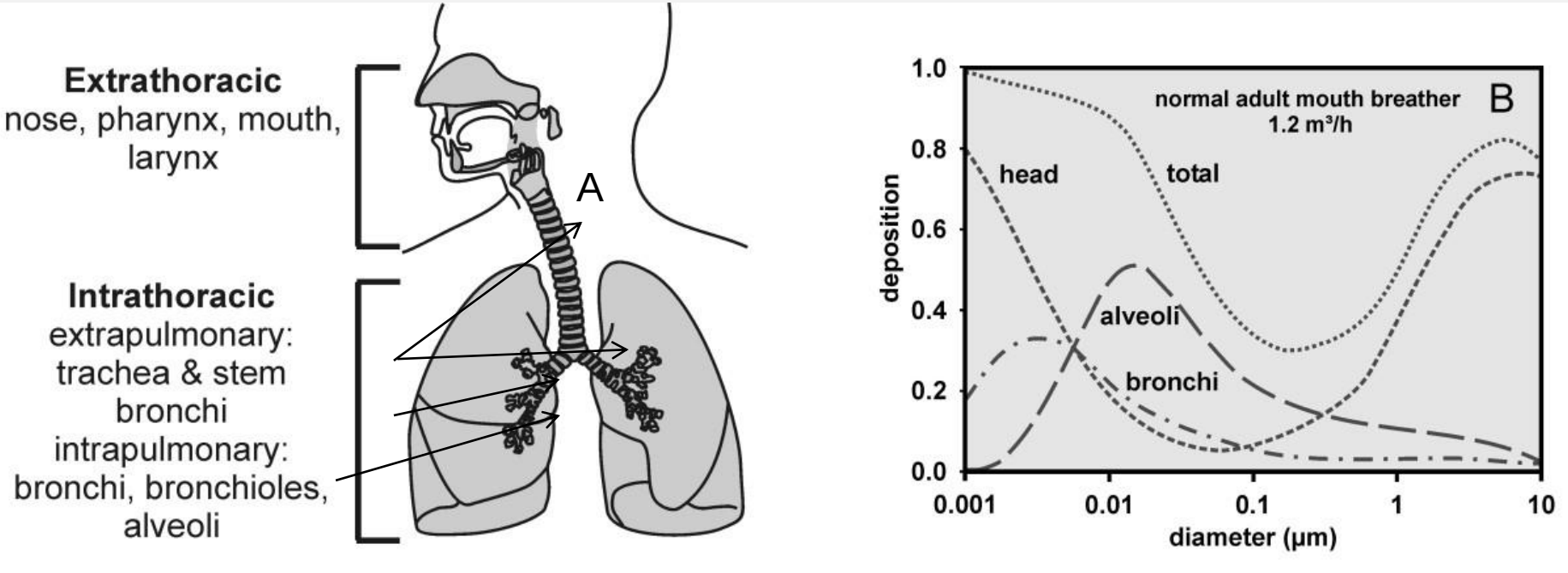
The size of particles is directly linked to their potential for causing health problems. Particles <10 µm diameter can get deep into your lungs, and some may even get into your bloodstream, affecting other organs.



PM between 0.1 µm and 1 µm in diameter can remain in the atmosphere for days or weeks and thus be subject to long-range transboundary transport in the air

https://nepis.epa.gov/Exe/ZyPDF.cgi/P1008KCP.PDF?Dockey=P1008KCP.PDF
https://www.euro.who.int/__data/assets/pdf_file/0006/189051/Health-effects-of-particulate-matter-final-Eng.pdf

PARTICULATE MATTER – SIZE MATTERS



The respiratory tract (A) and particle deposition in a normal, adult, mouth-breathing male human subject at rest, as a function of particle size (B). Data for bronchi are the sum of the deposition in bronchi and bronchioles.

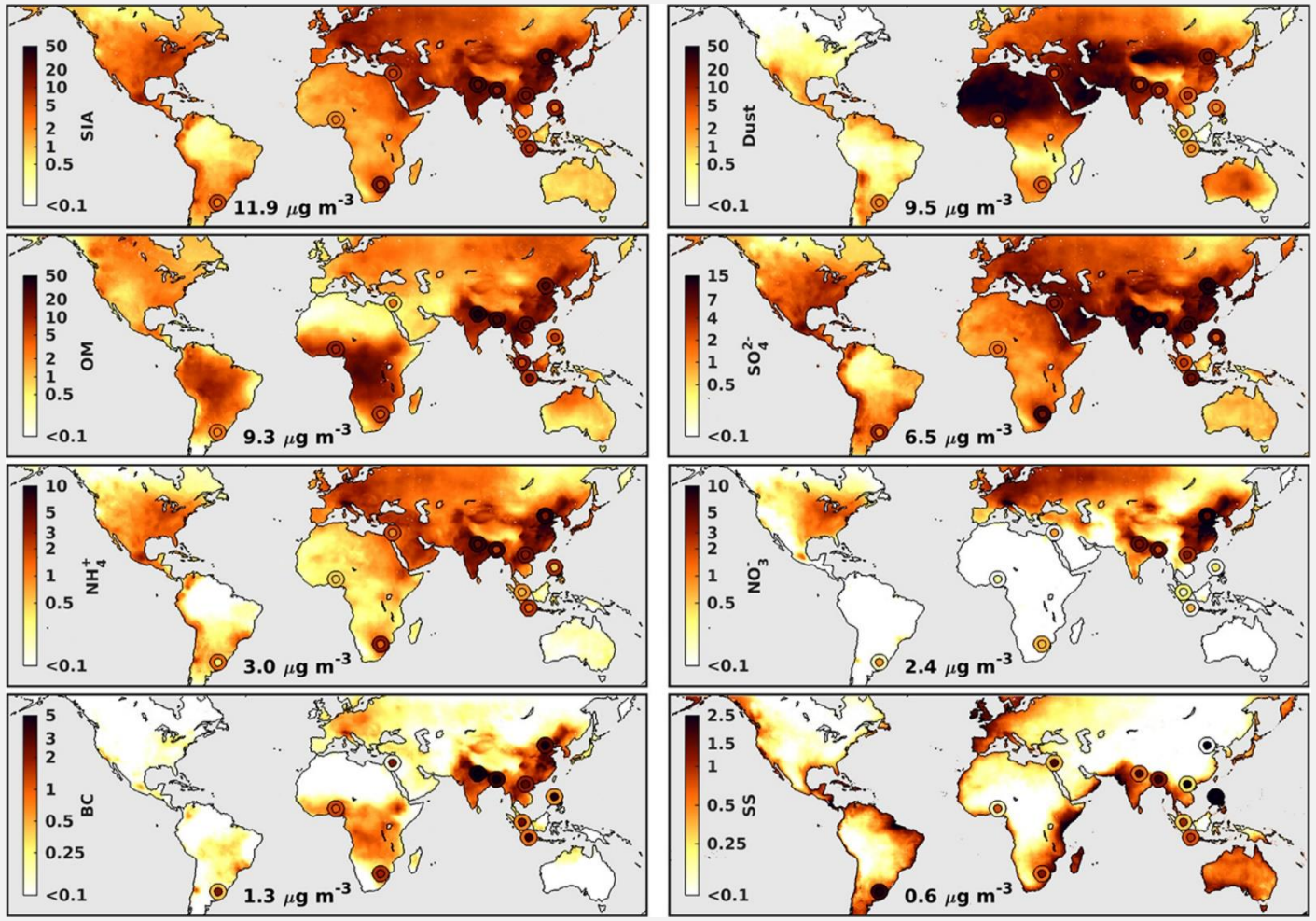
Geiser and Kreyling *Particle and Fibre Toxicology* 2010 **7**:2

WHERE IS PARTICULATE POLLUTION FOCUSSED?

Global simulated annual mean $PM_{2.5}$ composition.
Concentrations are shown at 35% relative humidity.

SIA = secondary inorganic aerosol (sum of SO_4^{2-}, NO_3^-, and NH_4^+)
OM = organic mass
BC = black carbon
SS = sea salt

Inset values indicate global population-weighted average $PM_{2.5}$ concentration resulting from each chemical component.

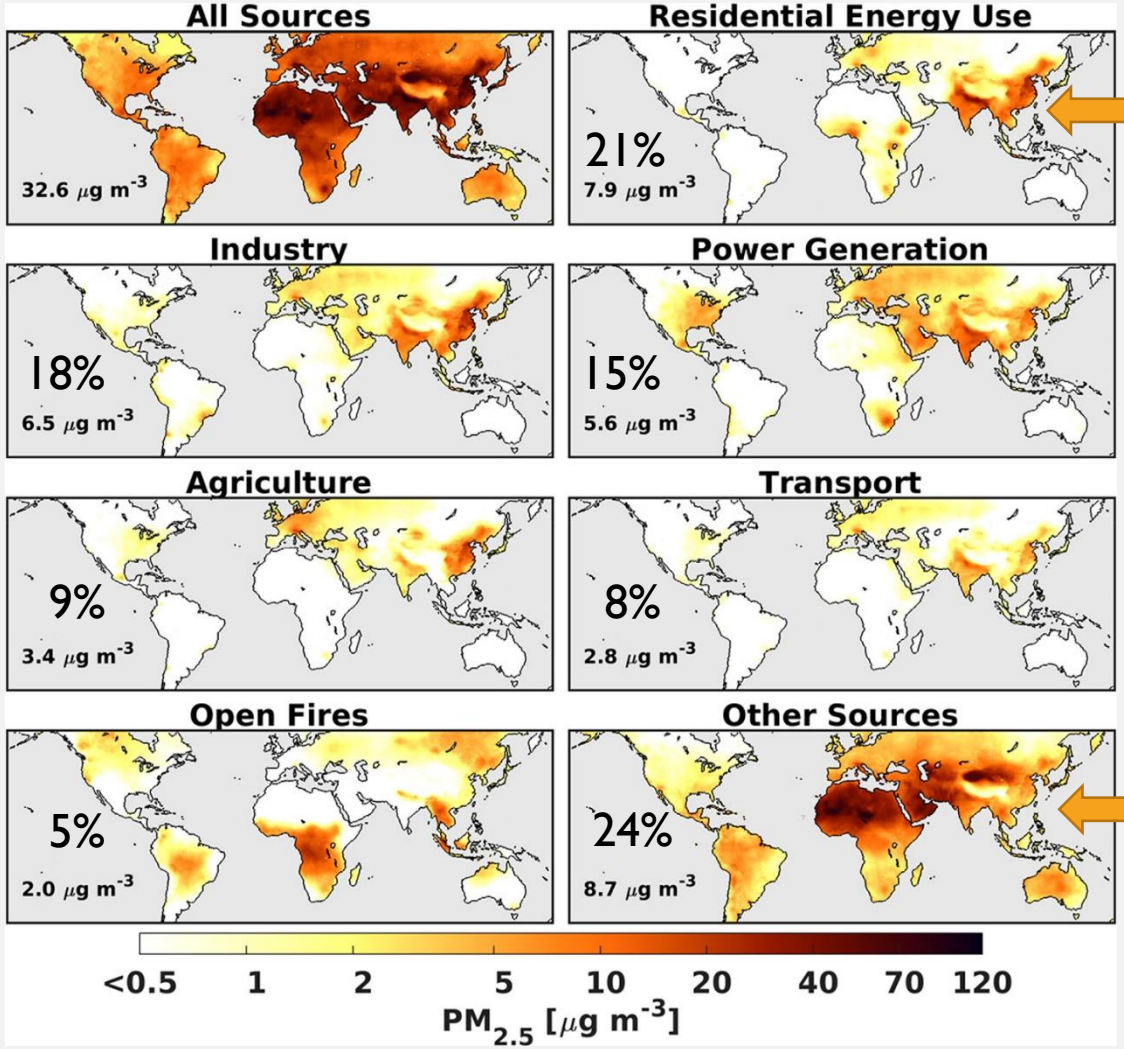


Weagle et al. Environ. Sci. Technol. 2018, 52, 20, 11670-11681

WHAT ARE THE GLOBAL SOURCES OF PM?

Global simulated annual mean total $PM_{2.5}$ mass (top left) and contribution from seven source categories at 35% RH.

Six primarily anthropogenic categories contribute 76% of global $PM_{2.5}$ exposure.
Inset values display the global population-weighted average $PM_{2.5}$ concentration from each source category.

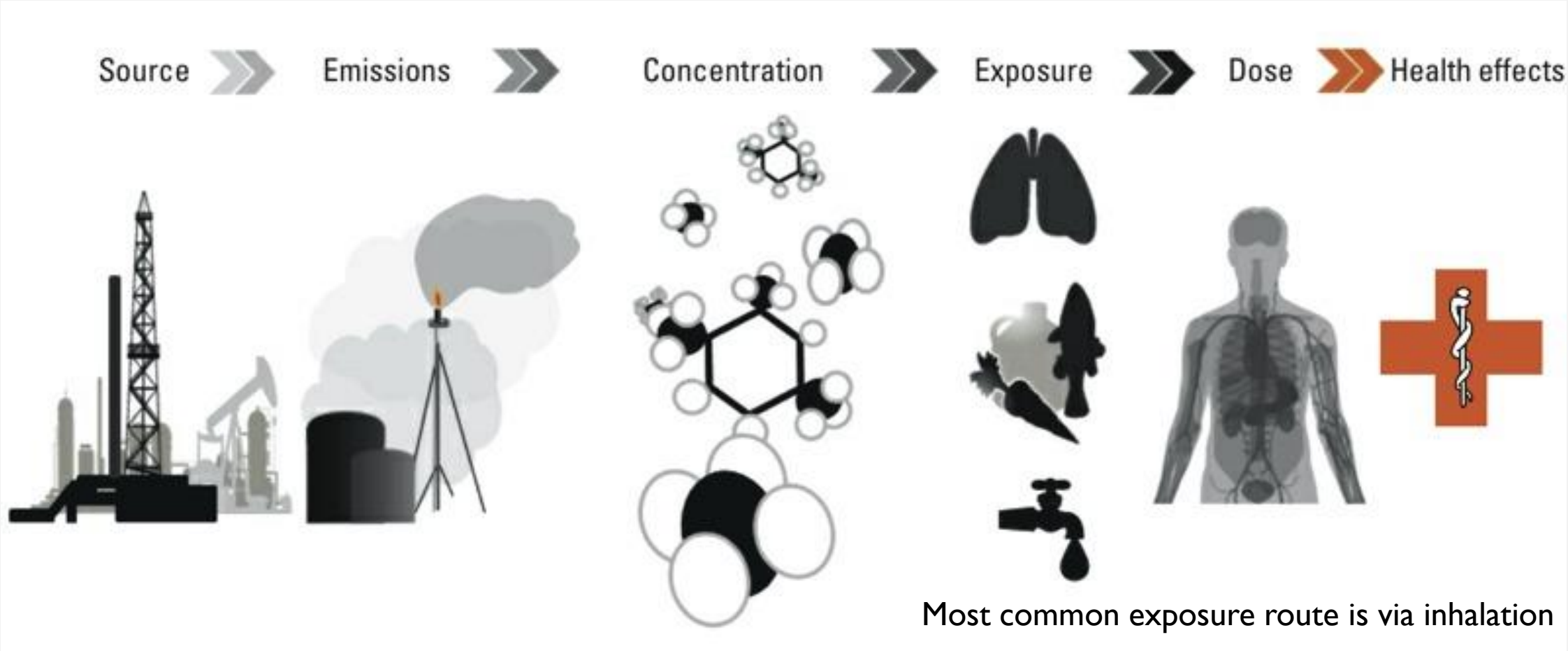


Biofuel sources, diesel generators and burning of household waste.
Elimination of solid fuel stoves over a 20-year period could avoid 22.5 million premature deaths associated with outdoor $PM_{2.5}$ between 2000-2100 (Lacey et al. 2017).

Other sources include mineral dust, which dominates $PM_{2.5}$ in arid and semiarid regions

Weagle et al. Environ. Sci. Technol. 2018, 52, 20, 11670-11681

EXPOSURE TO PARTICULATE MATTER



Most common exposure route is via inhalation

https://ehp.niehs.nih.gov/doi/10.1289/ehp.1307866

HEALTH EFFECTS OF PARTICULATE MATTER

- PM causes health effects after both short term (hours, days) and long term (months, years) exposures.
- **There is no evidence of a safe level of exposure or a threshold below which no adverse health effects occur.**
- $PM_{2.5}$ is a stronger risk factor than the coarse part of PM_{10} (2.5–10 μm).
- Respiratory and cardiovascular morbidity (illness), such as asthma, heart disease etc.
- Mortality (death) from cardiovascular and respiratory diseases and from lung cancer.
- All-cause daily mortality is estimated to increase by 0.2–0.6% per 10 $\mu g/m^3$ of PM_{10}.
- Susceptible groups with pre-existing lung or heart disease, as well as elderly people and children, are particularly vulnerable.
- Exposure to PM affects lung development in children, including reversible deficits in lung function as well as chronically reduced lung growth rate.
- At present, at the population level, there is not enough evidence to identify differences in the effects of particles with different chemical compositions or emanating from various sources.

https://www.euro.who.int/__data/assets/pdf_file/0006/189051/Health-effects-of-particulate-matter-final-Eng.pdf

MANAGEMENT AND MITIGATION

- Since, even at relatively low concentrations, the burden of air pollution on health is significant, effective management of air quality, and exposure reduction measures, are necessary to reduce health risks.
  - Emissions reduction (industrial and individual)
  - Emissions and concentrations regulations compliance
  - Monitoring of airborne concentrations
  - Personal protection

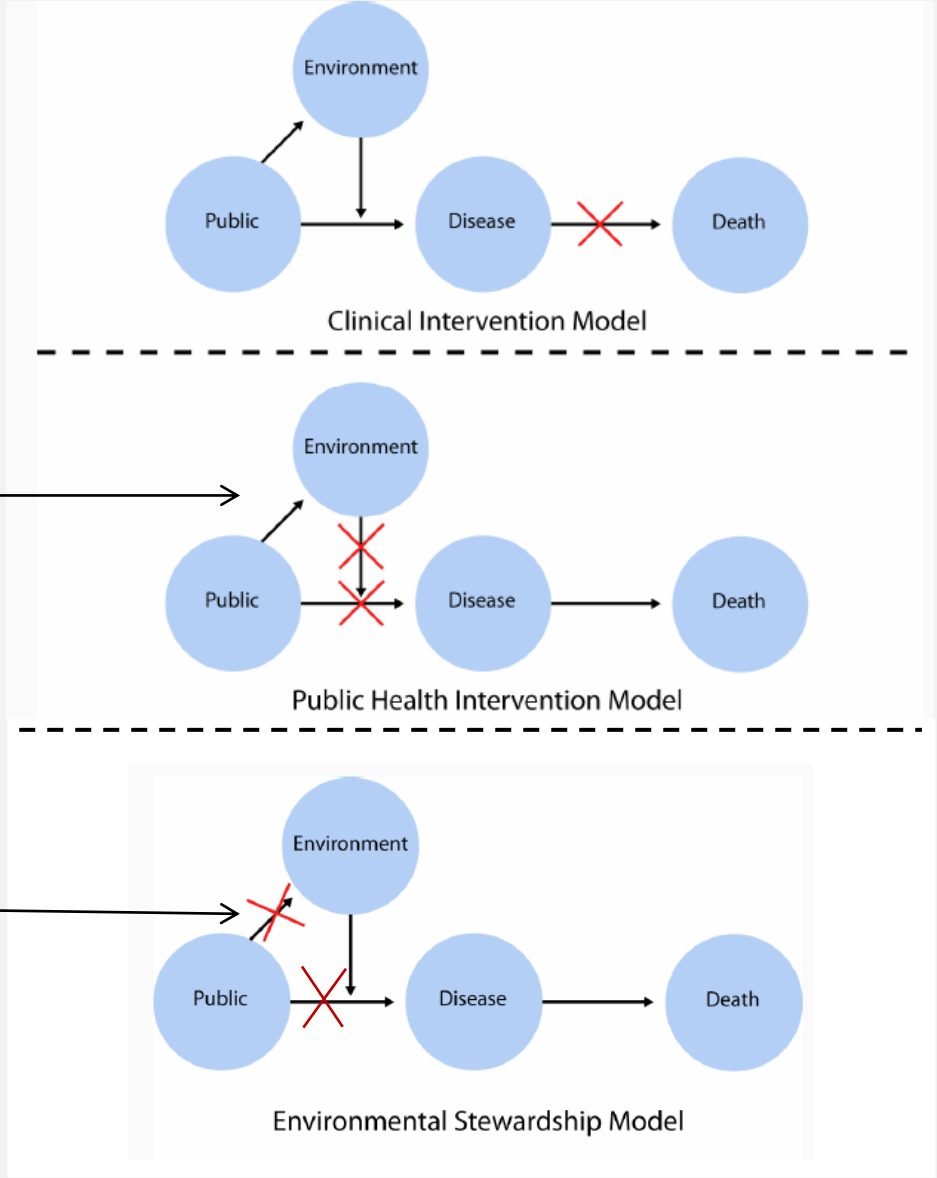


PUBLIC INTERVENTION MODELS

Prevention:
Process controls
Emissions reduction
Exposure reduction

SARS – China 2003
COVID-19 – Global 2020/21

Social & behavioural change:
Personal protection
Risk communication



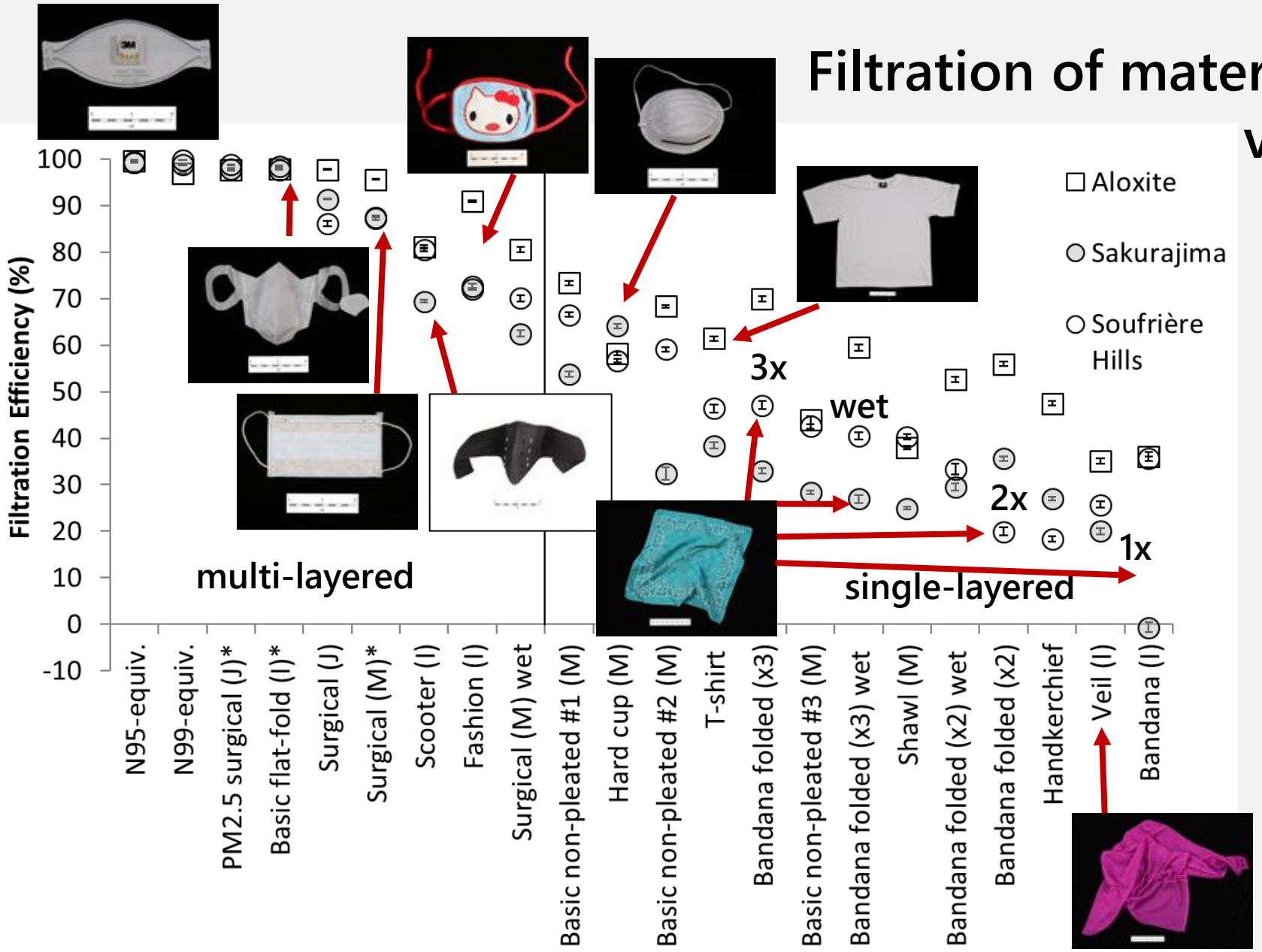
PUBLIC USE OF RESPIRATORY PROTECTION FOR PM CRISES

- The public in some Asian countries have been wearing respiratory protection/face coverings for some years.
  - Japan – infection control, fashion, social pressures
  - China – infection control, air pollution
  - Indonesia, Vietnam, Thailand – air pollution
- Mostly 'fashion' or 'scooter' masks for air pollution exposure reduction.
- Concern that public may take more risks – false sense of security. https://www.nature.com/articles/d41586-019-02938-1
- In non-anthropogenic PM crises (e.g. volcanic eruptions, wildfires)
  - NGOs/GOs distribute surgical or other cheap masks in LMICs (mostly pre-stockpiled for respiratory pandemics)
  - NGOs/GOs/mask manufacturers distribute N95/FFP2 masks in HICs
  - This inequality is slowly changing

HIVE

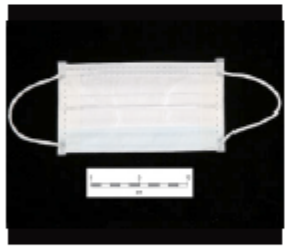
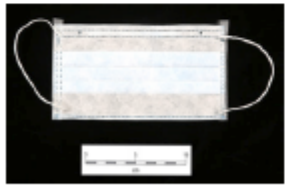
Health Interventions in Volcanic Eruptions

Filtration of materials against volcanic ash



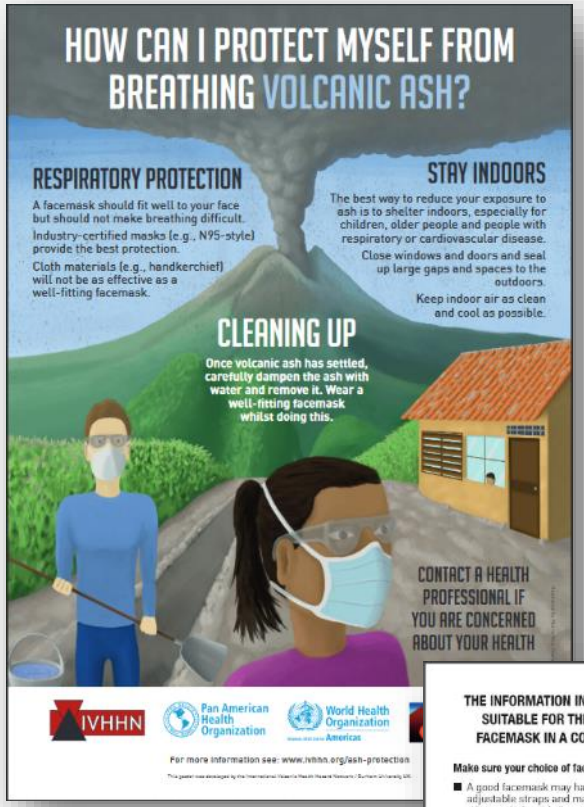
Mean FE (%) of each RP for all dusts for both flow rates (40 L/min and 80 L/min) and particle concentrations (1.5 and 2.5 mg/m^{-3}).
J = Japan; I = Indonesia; M = Mexico Mueller et al. International Journal of Hygiene & Environmental Health (2018).

SUMMARY TABLE OF FILTRATION EFFICIENCY AND TOTAL INWARD LEAKAGE

Mask Type	Mask Type	Features	Leakage	Filtration	Notes
	Industry-certified (N95/FFP2)	Nose clip, elasticated head- straps, foam/rubber edge seal	< 10 %	> 99%	Not very comfortable
	'Flat-fold' ('3D') mask (Japan)	No way of adjusting fit and not clear which orienta-tion it should be worn	35%	> 98%	Very comfortable but 'flimsy'
	PM2.5 surgical mask (Japan)	Cheek and chin 'flaps' which fold out. Nose clip, stretchy ear loops	22%	98%	Quite comfortable
	Surgical mask	Nose clips, stretchy ear loops	35%	~ 90%	Quite comfortable
	Surgical mask + bandage	Closes gaps around the face	24%	~90% + ?	Not comfortable

Steinle et al. International Journal of Hygiene & Environmental Health (2018).

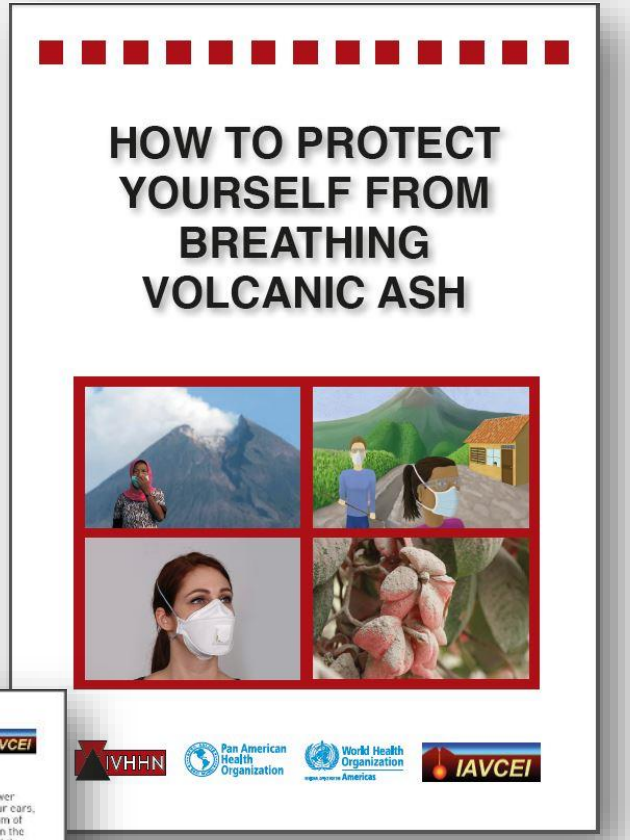
TRANSFORMING EVIDENCE INTO PRACTICE



Posters

And videos at:
www.ivhhn.org

Agency commitments to distribute in future eruptions



Booklets

Leaflets

World Health Organization

HIVE

IVHHN

RESEARCH UPTAKE

Train-the-trainer workshop, Indonesia. ISRP/3M trained stakeholder reps in how to fit a facemask. The reps then trained each other so that they, in turn, were then ready to train others. More than 1000 people are now trained.

CONCLUSIONS

- PM crises (e.g. wildfires) will worsen with climate change.
- Other PM sources will lessen with implementation of effective emissions reduction strategies (energy productions; transport).
- People won't put up with poor air quality until this happens. They are taking matters into their own hands with personal protection.
- COVID-19 has opened the world's eyes to respiratory protection. It has become an acceptable social norm.
- Efficacy for children still has no evidence base but use is now common. More research is required (e.g. 'FACE-UP' project).
- Better public information required to inform the world of efficacy of different types of respiratory protection for different purposes, and suitability for different susceptible groups.