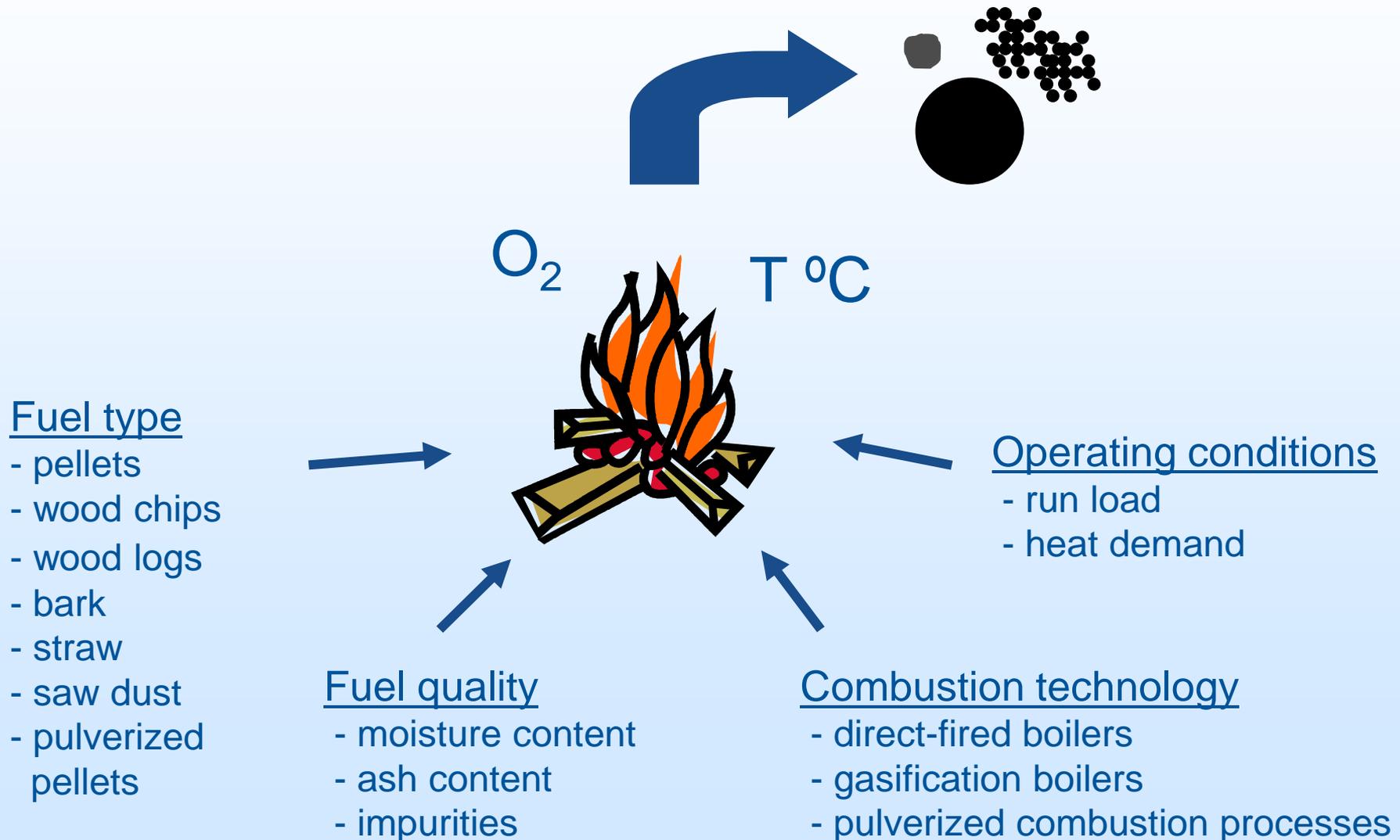


# Toxicity of wood smoke particles generated under different combustion conditions

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# Factors influencing the combustion conditions



## Physicochemical properties

Wood smoke particles may be divided into three classes based on physicochemical properties and combustion conditions

### Organic carbon

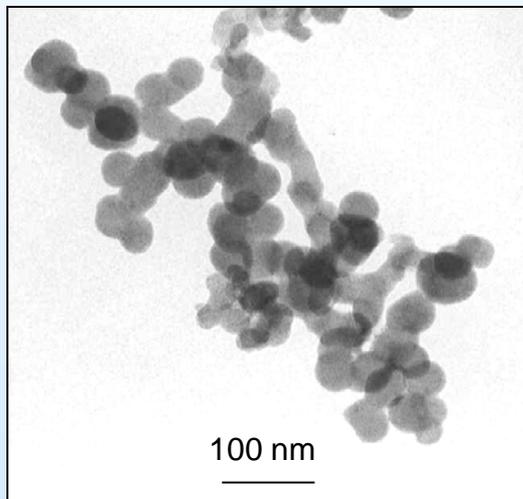
Air starved combustion



(Kocbach, 2008)

### Soot

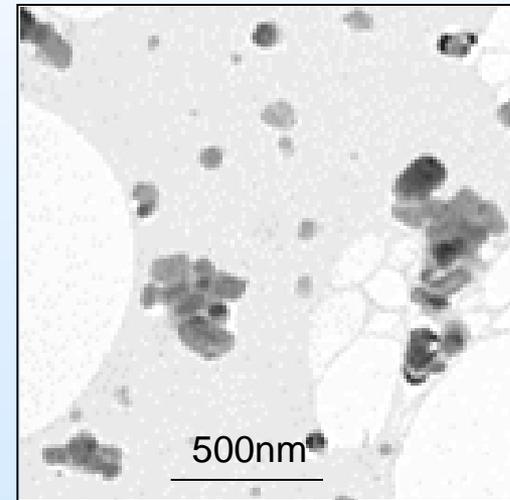
Flaming combustion



(Kocbach, 2008)

### Inorganic ash

Complete combustion

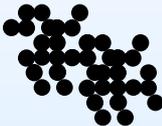


(Mavrocordatos *et al.*, 2002)

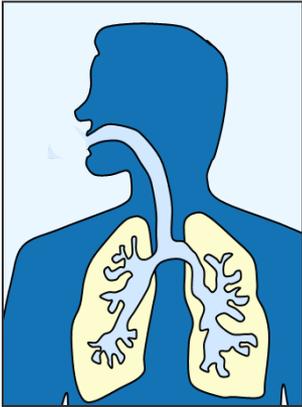
Real life emissions contain a mixture of these three particle classes

## Physicochemical properties

The three particle classes differ considerably with respect to physical and chemical properties that may influence their toxicity

	Organic carbon	Soot	Inorganic ash
			
<b>Particle size</b>	50-600 nm	20-50 nm	50-125 nm
<b>Solubility</b>	Depends on ageing	Insoluble	Soluble
<b>Chemical composition</b>	Organic compounds like hydrocarbons	Elemental carbon, and condensed organics	Alkali salts, e.g KCl and $K_2SO_4$ , metals

# Toxicity of wood smoke particles



- Human inhalation studies  
inflammation in distal airways  
increased oxidative stress ?  
systemic inflammation  
blood coagulation



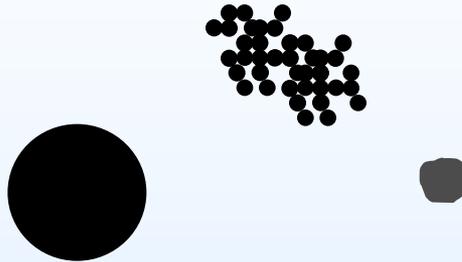
- Animal inhalation studies  
decreased lung function  
mild airway inflammation  
systemic immunotoxicity  
increases in platelet levels



- Cell culture studies  
increased release of inflammatory markers  
toxic effects

No consistent difference in magnitude of effect compared to particles from other combustion sources ?

# How does the toxicity vary with the combustion conditions?



The majority of these studies only use one type of particles

The physical and chemical properties of wood smoke particles depend on the combustion conditions

Show examples of studies comparing the inflammatory and toxic potential of particles from varying combustion conditions

# Inflammation - varying combustion conditions



Modern wood stove  
- low oxygen supply  
- high oxygen supply



Intratracheal instillation

Expression of inflammatory markers in the lung

Particles from low oxygen supply were more potent



Cell culture study using human cell lines

Same conclusion

# Inflammation - complete combustion conditions



Particles from large biomass combustion plants:

- wood chips
- straw
- bark
- waste wood



Human epithelial cell line → release of inflammatory markers

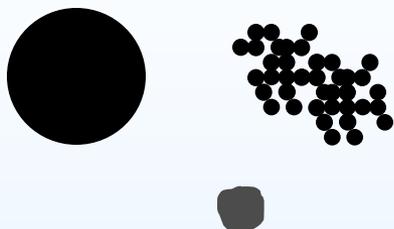


Rats, inhalation → no inflammatory response

→ insoluble reference particles induced inflammatory response

Hypothesis; soluble particles are dissolved and cleared from the lung, but clearance is not possible in the cell culture system

## Toxicity - varying combustion conditions



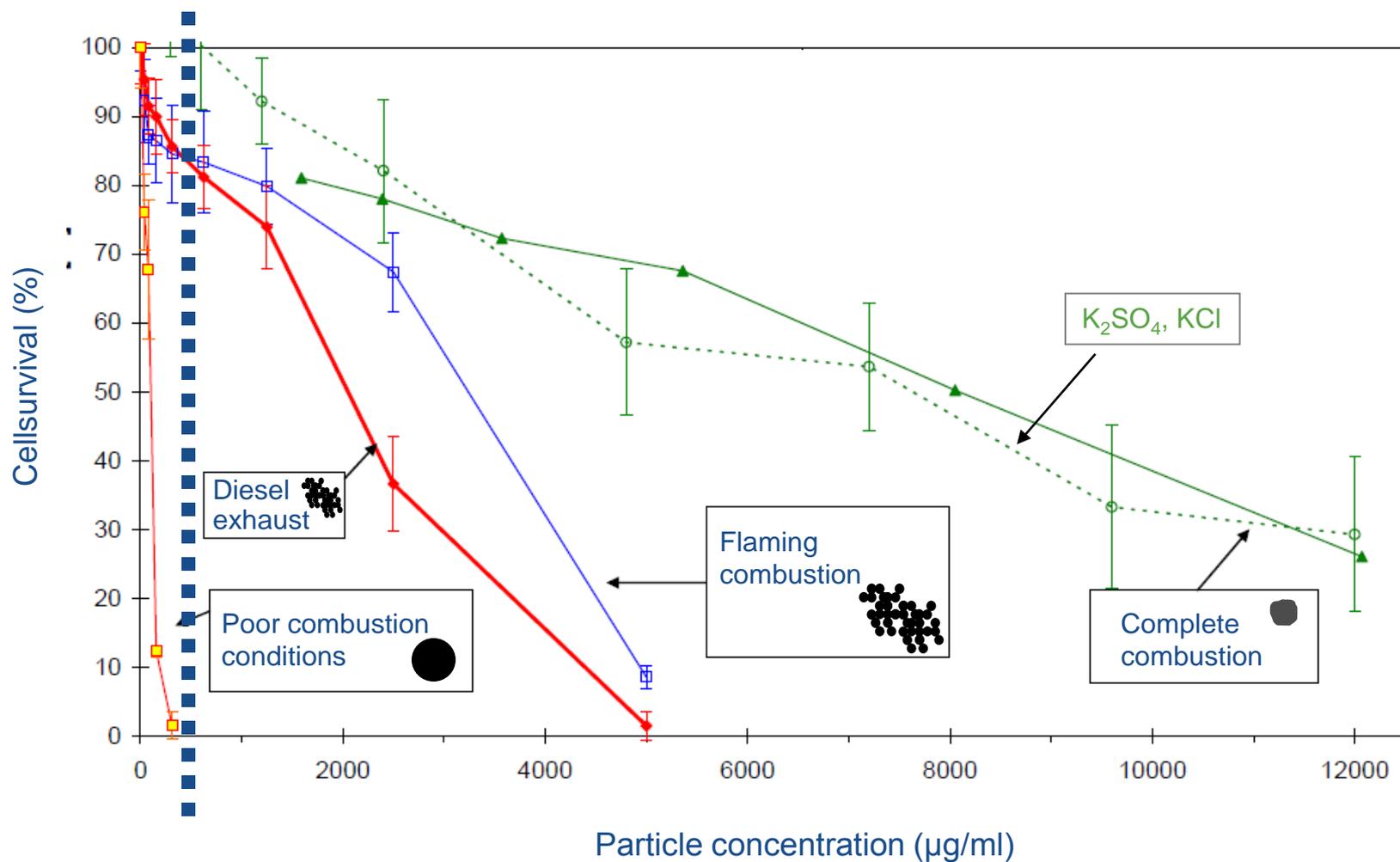
Particles from different types of stoves

- old wood stove
- modern stove
- two stage combustion

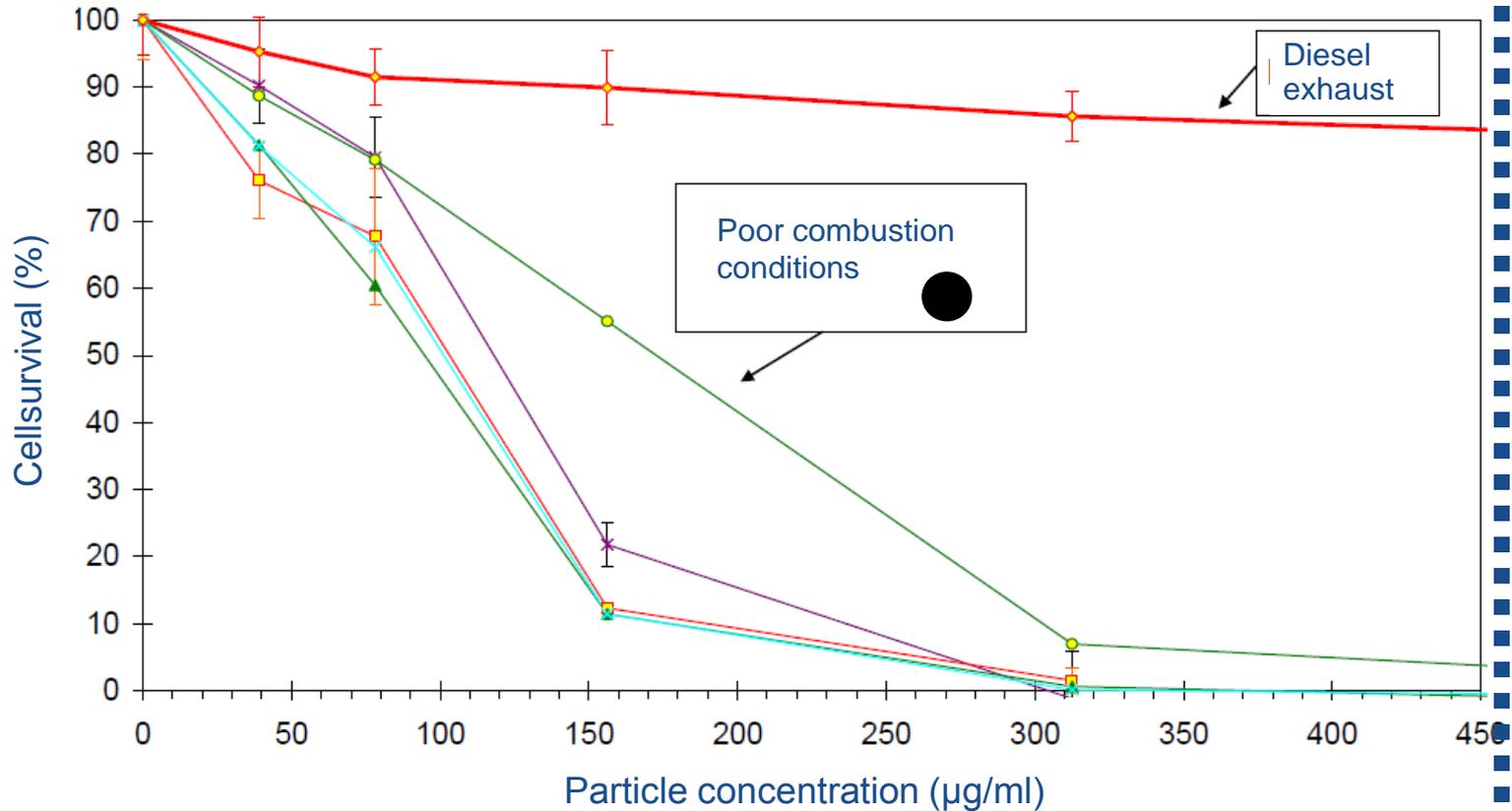


Cell culture study → cell death (toxicity)

# Toxicity - varying combustion conditions



# Toxicity - varying combustion conditions



# How does the toxicity vary with the combustion conditions?

- Overall impression:

Inflammation

poor comb.  $\geq$  flaming comb.

Toxicity

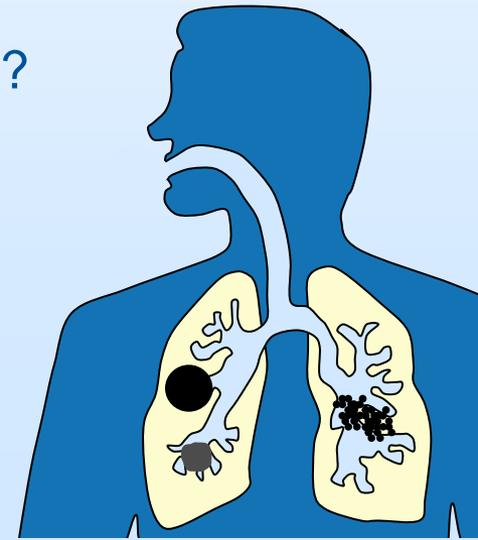
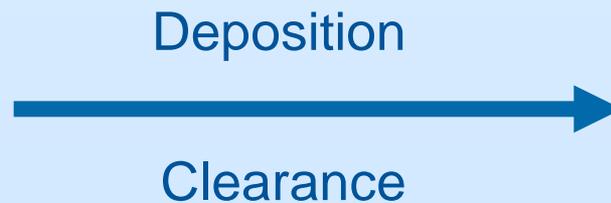
poor comb.  $>$  flaming comb.  $>$  complete comb.

- Limitations

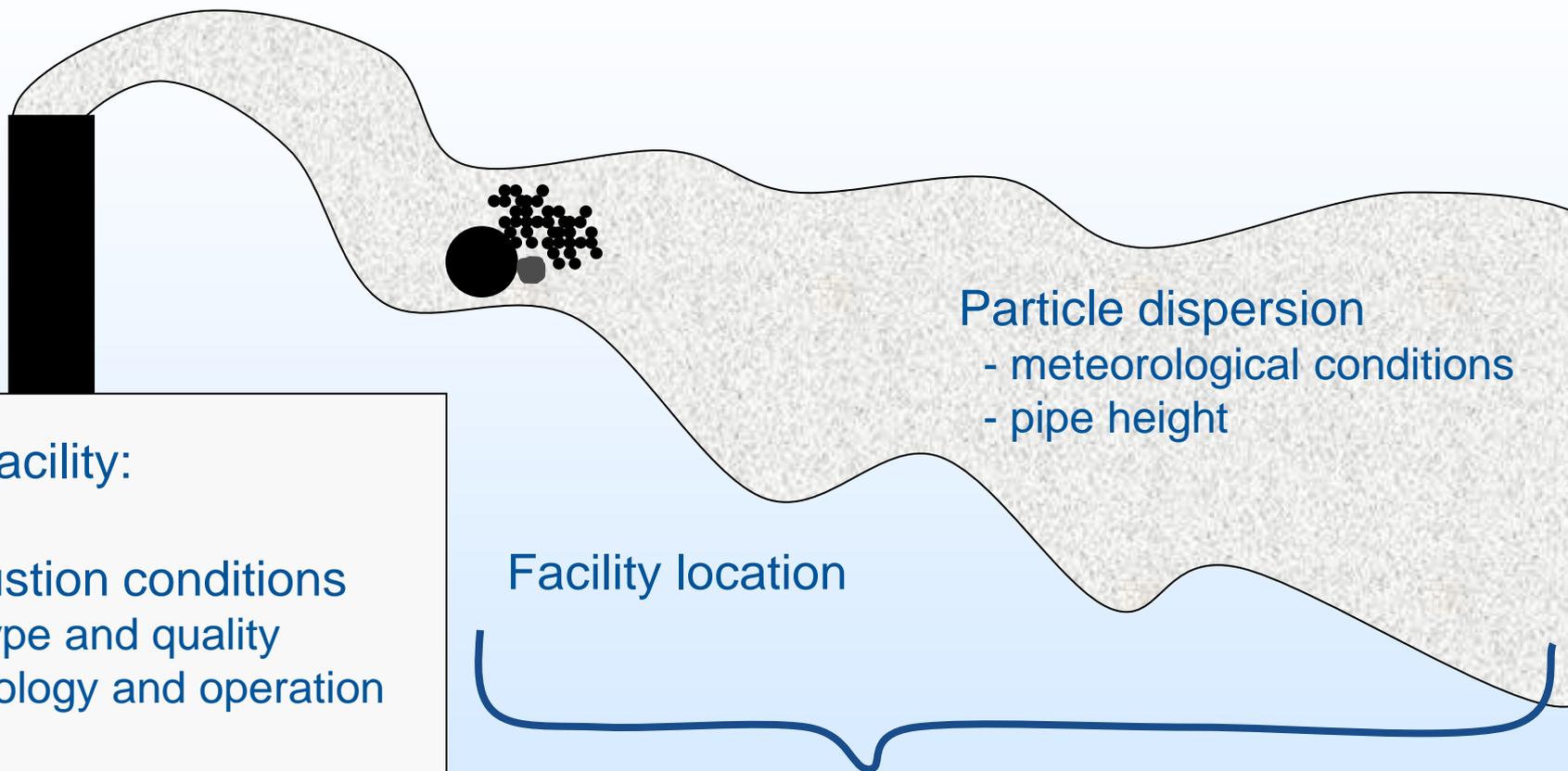
Most studies only include samples from two different combustion conditions

Mostly cell culture studies

- From experimental studies to human health effects ?



# ICI-scale facilities : From emissions to health impact



## In the facility:

### Combustion conditions

- fuel type and quality
- technology and operation

### Particle removal

- shrubbers
- cyclons, multicyclons
- electrostatic precipitators

## Particle dispersion

- meteorological conditions
- pipe height

## Facility location

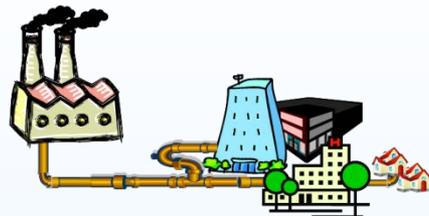
## These factors influence:

- ambient concentrations
- human exposure

# Emissions: different sizes combustion facilities



Small scale  
'in-house' facilities,  
schools and hospitals



Medium scale  
district heating



Large scale  
power plants  
industrial facilities

Technology

Poor/Good/Advanced

Good/Advanced

Good/Advanced

Particle  
removal

Poor/Good/Advanced

Good/Advanced

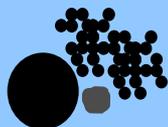
Good/Advanced

Emissions

Organic, soot, ash

Soot, inorganic ash

Inorganic ash



+ heavy metals

## Conclusions :

- Particle toxicity does not only depend on amount, but also on physicochemical properties

### Research status:

- Particles from complete combustion seem to be less harmful
- Insufficient knowledge about relative toxicity of particles from incomplete combustion conditions (organics vs. soot)

### ICI scale facilities:

- Small scale facilities (institutional) may be an area of concern since some facilities have poor technology and limited particle removal

- Improved combustion conditions → reduced health impact