愛環保
EnvironmentalCare

齊注重 齊受用
We care We share

Indoor Environmental Health Risk Management:

A Titania Nanotechnology-based Photocatalytic Oxidation Pollutant -remediation Approach

Sai C Chan, MD, PhD

EnvironmentalCare Limited, Hong Kong SAR, China

Parameters determining Indoor Environmental Quality (IEQ)

Physical Parameters

a. Sound
b. Light
c. Temperature
d. Moisture
e. Particulate matter
f. Radiation
g. Interior Design

Chemical Parameters

a. air-borne inorganic and organic chemicals
b. Food, garbage and waste-water derived chemicals
c. Household items VOC

Biological Parameters

a. Infectious agents
b. Human-human transmitted disease pathogens
c. Fungi/Molds, Pests

We spend over 70% of our time indoor. Reducing it to 25% can significantly decrease the Indoor environmental health risk.

ESTIMATES OF POTENTIAL NATIONWIDE PRODUCTIVITY AND HEALTH BENEFITS FROM BETTER INDOOR ENVIRONMENTS: AN UPDATE

William J. Fisk, M.S.
Indoor Environment Department
Lawrence Berkeley National Laboratory
Berkeley, California

TABLE 4.2 Percentage Reduction in Respiratory Illness or Surrogate Metrics before and after Adjustment for Time Spent in Building

Setting	Estimated % time in building	Outcome (observed % reduction*)	Adjusted % reduction in outcome assuming 25% time in building
U.S. Army barracks (Brundage 1988)	66	Respiratory illness (33)	12.5
U.S. Navy barracks (Langmuir 1948)	66	Respiratory illness (23)	9
Finnish office (Jaakkola 1993)	25	Common colds (17)	17
Antarctic station (Warshauer 1989)	66	Respiratory illness (50)	19
N.Y. state schools (N.Y. State Commission on Ventilation 1923)	25	Illness (41)	Illness (41)
		Absence (15)	Absence (15)
Four U.S. nursing homes (Drinka 1996)	100	Influenza (76)	Influenza (19)
		Total respiratory illness (50)	Total respiratory illness (12.5)
Gulf War troops (Richards 1993)	66	Cough (27)	Cough (10)
		Sore throat (16)	Sore throat (6)
U.S. jail (Hoge 1994)	100	Pneumococcal disease (49)	12
40 buildings with office, trade, manufacturing workers (Milton 1998)	25	Short-term absence with high Ventilation (17)	17 (high ventilation)
		Short-term absence without humidification (18)	18 (without humidification)
Dwellings in Finland (Husman 1993, 1996)	66	Respiratory illness (54)	20

*Some studies report the increase in the health outcome while other studies indicate the degree of reduction. All percentage increases have been converted to a percentage reduction, e.g., if some risk factor is associated with a 50% increase in illness, the percentage reduction from eliminating that risk factor is 33% [(1.5 − 1.0)/1.5].

Gain in Productivity in dollars by improving IEQ

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TABLE 4.5 Estimated Potential Productivity Gains from Improvements in Indoor Environments

Source of productivity gain	Potential annual health benefits	Potential U.S. annual savings or productivity gain (1996 $US)
Reduced respiratory disease	16 to 37 million avoided cases of common cold or influenza	$6–$14 billion
Reduced allergies and asthma	10 to 30% decrease in symptoms within 53 million allergy sufferers and 16 million asthmatics	$2–$4 billion
Reduced sick building syndrome symptoms	20 to 50% reduction in SBS health symptoms experienced frequently at work by approximately 15 million workers	$15–$38 billion
Improved worker performance from changes in thermal environment and lighting	Not applicable	$20–$200 billion

Hong Kong

Lung Diseases

Risk Factor

Depends on

“Where you live”

- the indoor environment quality

(IEQ)

全港18區肺癆發病率

地區	2000–02年 平均發病率*	01年排名** (低至高)	96年排名** (低至高)
東區	82.71	1	10
西貢	73.14	2	1
荃灣	86.98	3	15
沙田	88.45	4	3
九龍城	105.15	5	9
屯門	84.69	6	4
北區	87.61	7	6
元朗	90.26	8	11
觀塘	113.32	9	8
南區	103.94	10	5
葵青	107.11	11	12
中西區	106.28	12	13
大埔	96.39	13	7
離島	117.31	14	2
深水埗	142.08	15	16
黃大仙	150.99	16	14
灣仔	165.52	17	18
油尖旺	187.58	18	17
發病率最高與最低地區比率	2.56	—	—

• 2003年全港肺癆呈報數字：6,083宗

發病率： 89.2

死亡率： 3.3

男性發病率：120.2

女性發病率： 60.2

註：*發病率即每年每10萬人中發病人數，死亡率亦然

**排名按人口結構（如年齡性別等）調整的標準呈報比率釐定，排名愈高發病率愈低

Hong Kong SAR 2003 Infectious Disease Statistics

Disease		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Cholera							1	2	2	1			1	7
Plague														0
Yellow Fever														0
Acute Poliomyelitis														0
Amoebic Dysentery			3						1		1	2	9	16
Bacillary Dysentery		8	11	8	5	9	5	10	17	8	8	16	11	116
Chickenpox		1376	1084	783	265	214	94	149	145	242	495	864	1069	6780
Dengue Fever		5	5		1	4	4	4	12	6	3	1	4	49
Diphtheria														0
Food Poisoning	Outbreaks	39	37	10	8	19	34	43	57	49	41	31	55	423
	Persons affected	131	205	116	37	70	114	165	240	432	300	174	209	2193
Legionnaires' Disease				1		1					1			3
Leprosy		2						3			1		1	7
Malaria		2	2	3	4	3	2	1	4	4	2	1		28
Measles		3	8	2	2	1	2	1	5	1	5	3		33
Meningococcal Infections		1							2					3
Mumps		9	6	12	8	11	7	11	6	15	15	10	11	121
Paratyphoid Fever		3	2	3	4	7	11	13		5	3	4	5	60

Transmission Air , Water

About 1/3 of infectious diseases can be linked to environmental pollutants, transmitted through air and water, mostly indoor.

Rabies(Human)													0
Relapsing Fever													**0**
Rubella	**3**	**2**		**3**			**1**	**2**	**1**	**2**	**2**	**3**	**19**
Scarlet Fever	**15**	**12**	**12**	**5**	**1**	**2**	**1**	**2**	**3**	**3**	**1**	**6**	**63**
Severe Acute Respiratory Syndrome (SARS)	**NA**	**NA**	**610**	**979**	**150**	**16**							**1755**
Tetanus		**1**	**1**							**1**			**3**
Tuberculosis	**437**	**450**	**608**	**468**	**466**	**556**	**518**	**514**	**456**	**565**	**512**	**533**	**6083**
Typhoid Fever	**10**	**6**	**6**	**4**	**5**	**4**	**3**	**3**	**5**	**3**			**49**
Typhus Fever						**1**	**1**	**1**		**4**	**5**	**2**	**14**
Viral Hepatitis	**21**	**18**	**28**	**11**	**11**	**24**	**12**	**24**	**17**	**25**	**21**	**20**	**232**
-A	***3***	***11***	***16***	***4***	***5***	***14***	***7***	***15***	***7***	***9***	***11***	***5***	***107***
-B	***15***	***5***	***6***	***6***	***3***	***8***	***4***	***7***	***9***	***14***	***9***	***12***	***98***
-C													***0***
-E	***2***	***2***	***4***	***1***	***3***	***2***	***1***	***1***		***1***		***1***	***18***
-Unclassified	***1***		***2***					***1***	***1***	***1***	***1***	***2***	***9***
Whooping Cough			**4**				**1**						**5**
Total*	**1934**	**1647**	**2091**	**1767**	**902**	**763**	**774**	**797**	**813**	**1178**	**1473**	**1730**	**15869**

An example of environmental health cost

The Next Flu Pandemic

H5N1 transmitted thru' human ?

Avian BioSecurity

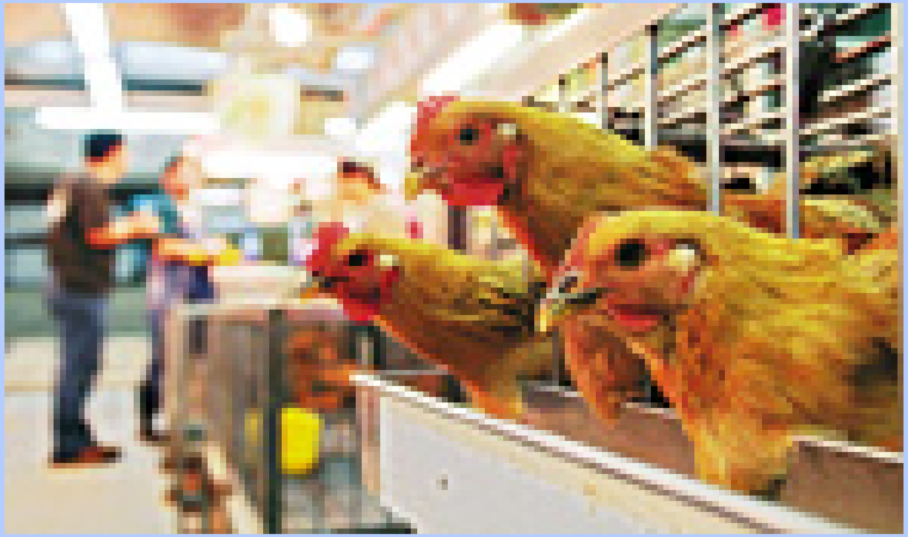


Figure 1: **Poultry wet-market in mainland China**
Removal of ducks and geese (original source of influenza viruses) from live-poultry markets in Hong Kong reduced number of subtypes of influenza viruses found there. Similar changes have not been made on the mainland.

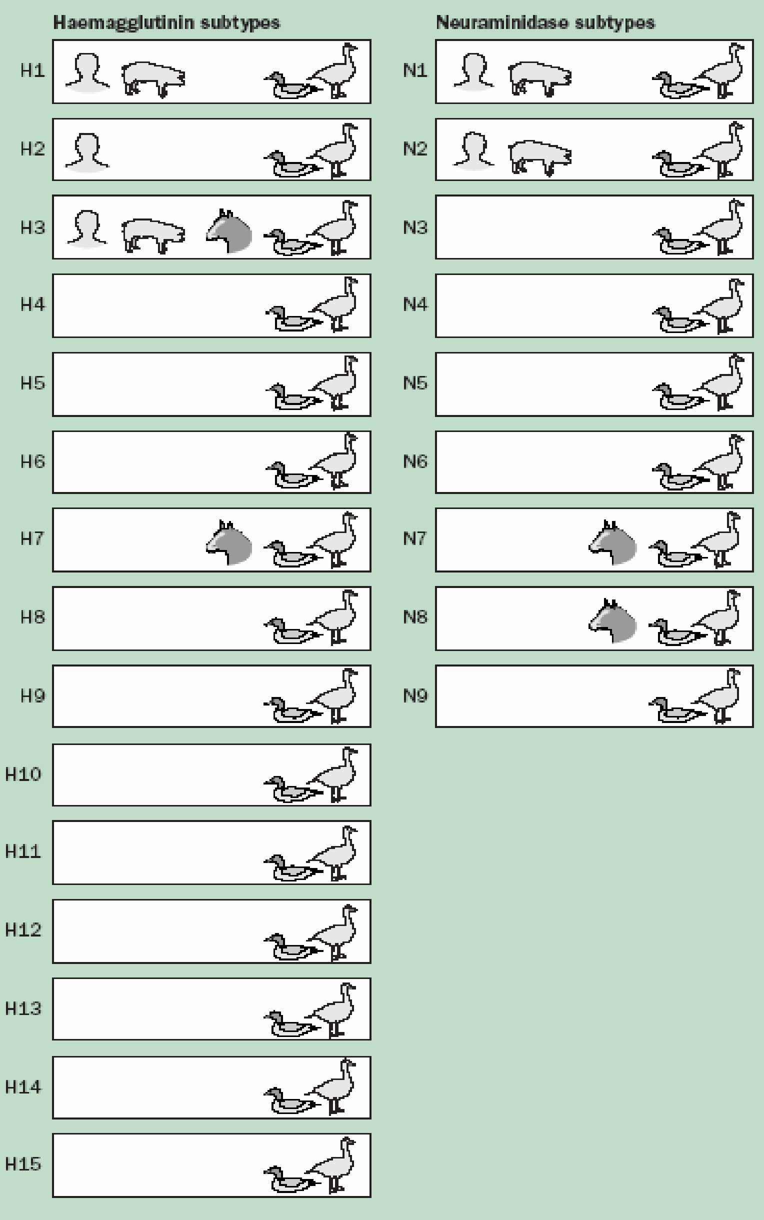


Figure 1: **Natural hosts of influenza viruses**

H N

Avian Genomics

The NS1 gene of H5N1 influenza viruses circumvents the host anti-viral cytokine responses

Sang Heui Seo[a,b], Erich Hoffmann[a,c], Robert G. Webster[a,*]

[a] Division of Virology, Department of Infectious Diseases, St. Jude Children's Research Hospital, 332 North Lauderdale, Memphis, TN 38105-2794, USA
[b] Department of Microbiology, College of Veterinary Medicine, Chungnam National University, 220 Kung-Dong Yusong-Ku, Taejeon 305-764, South Korea
[c] MedImmune Vaccines, Inc., 297 North Bernardo Avenue, Mountain View, CA 94043, USA

Available online 22 April 2004

Abstract

The H5N1 influenza viruses transmitted to humans in 1997 were highly virulent, but the mechanism of their virulence in humans is largely unknown. Here we show that lethal H5N1 influenza viruses, unlike other human, avian, and swine influenza viruses, are resistant to the anti-viral effects of interferons and tumor necrosis factor α. The nonstructural (NS) gene of H5N1 viruses is associated with this resistance. Pigs infected with recombinant human H1N1 influenza virus that carried the H5N1 NS gene experienced significantly greater and more prolonged viremia, fever, and weight loss than did pigs infected with wild-type human H1N1 influenza virus. These effects required the presence of glutamic acid at position 92 of the NS1 molecule. These findings may explain the mechanism of the high virulence of H5N1 influenza viruses in humans and provide insight into the virulence of 1918 Spanish influenza.

Keywords: H5N1; Influenza; Cytokines; Virulence

K. Shinya et al. / Virology 320 (20

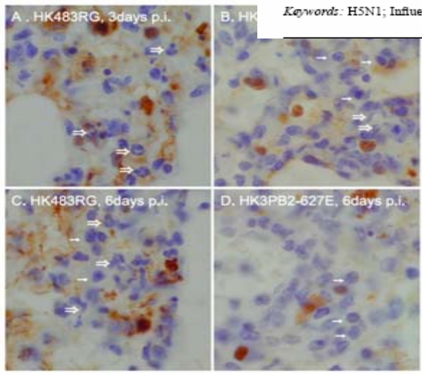


Fig. 2. Histologic changes in the lungs of mice intranasally infected with the virulent HK483RG virus or the avirulent HK3PB2-627E virus. Promi differences were observed in the pattern of neutrophil (□) and lymphocyte (□) recruitment: in mice infected with HK483RG (A, C), persistent infiltratic neutrophils was characteristic during the entire experimental period (from days 2 to 7), while the lungs of mice intranasally infected with avirulent HK3I 627E (B,D) showed transient neutrophilic inflammation followed by rapid infiltration of lymphocytes by day 3 p.i.

Virulence of NS1 reassortants in pigs

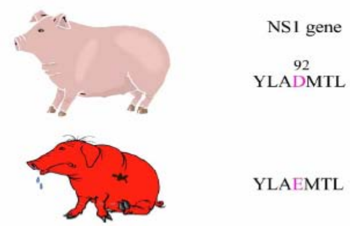


Fig. 2. Virulence of NS1 ressortants in pigs. Diagram representing the response of pigs to infection with influenza virus containing the NS gene of H5N1 virus. Groups of pigs were infected with A/PR/8/34 (H1N1) or with recombinant A/PR/8/34 (H1N1) containing H5N1/97 NS gene. The pigs infected with the latter virus developed high fever for an extended period, shed virus for an extended period and lost up to 40% of their body weight (Seo et al., 2002). The amino acid sequence of the NS1 genes of A/PR/8/34 (H1N1) and H5N1/97 in the region of residue 92 is shown.

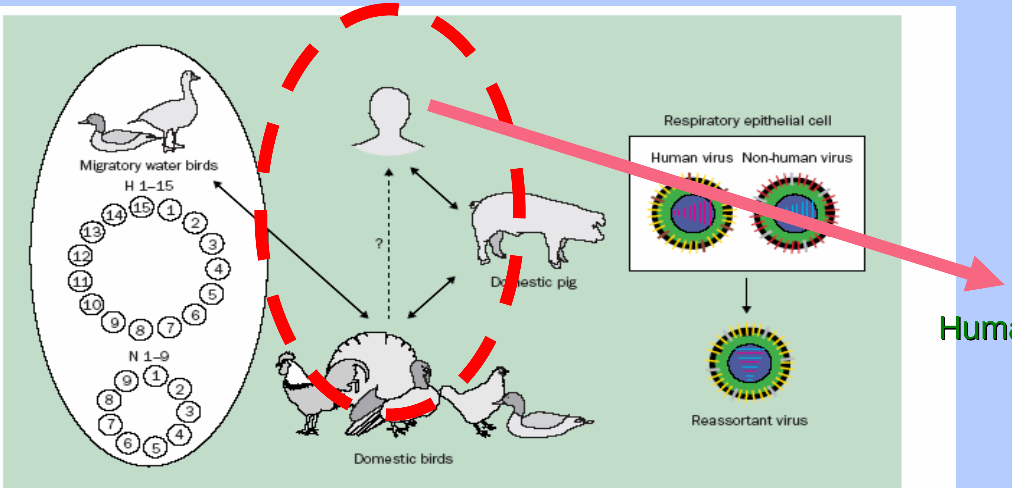


Figure 2: **Origin of antigenic shift and pandemic influenza**
The segmented nature of the influenza A genome, which has eight genes, facilitates reassortment; up to 256 gene combinations are possible during coinfection with human and non-human viruses. Antigenic shift can arise when genes encoding at least the haemagglutinin surface glycoprotein are introduced into people, by direct transmission of an avian virus from birds, as occurred with H5N1 virus, or after genetic reassortment in pigs, which support the growth of both avian and human viruses.

Human to human transmission

By new mutations –

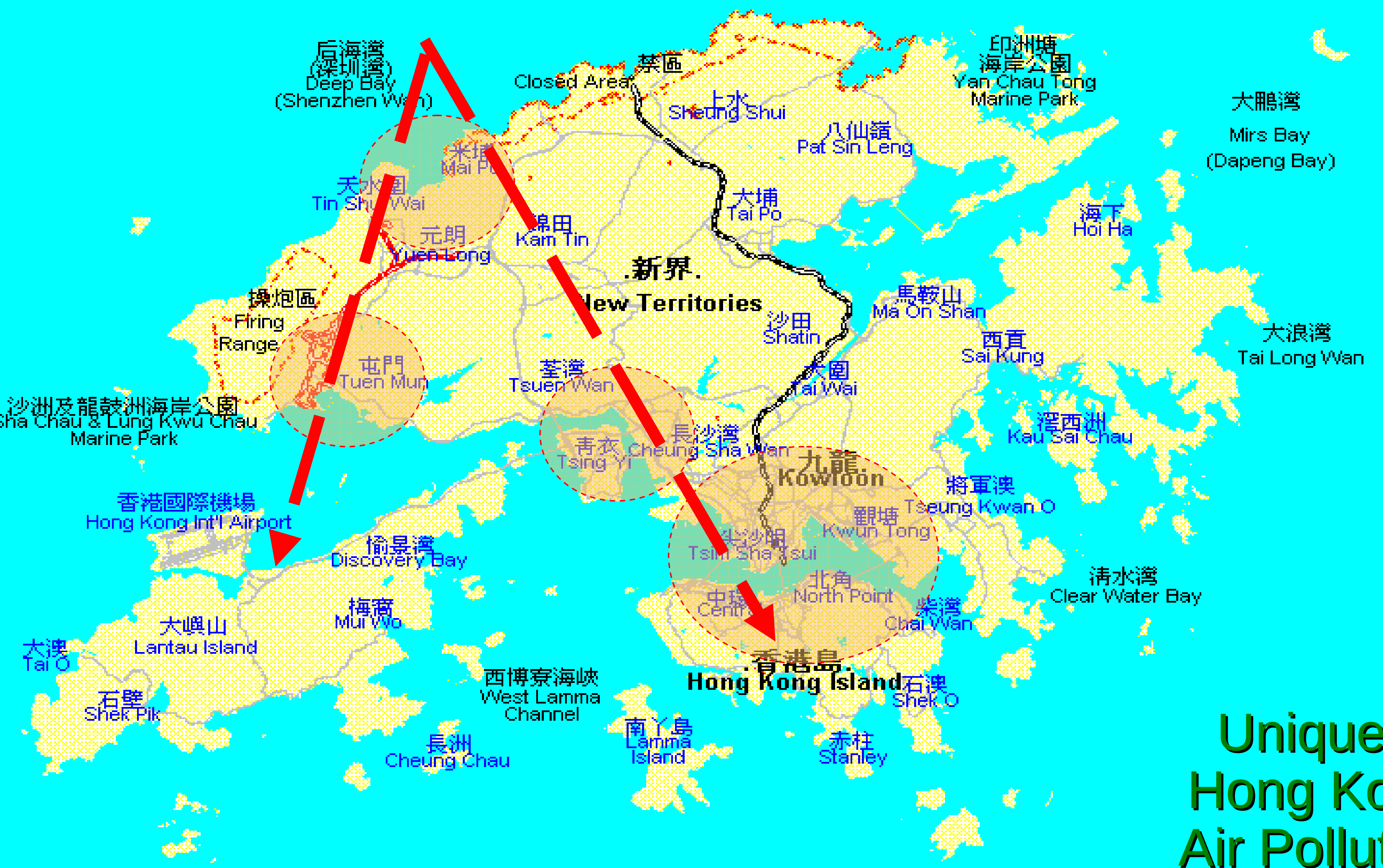
No immunity

Economic Costs of Influenza Outbreak

- Total annual costs of influenza are estimated at $14.6 billion in the US
- 10%: Direct costs of increased medical care
- 90%: Indirect costs (lost productivity, employee absenteeism)

American Lung Association. Fact Sheet – Influenza.
Available at http://www.lungusa.org/diseases/influenza_factsheet.html.

PRD pollutants



Uniquely Hong Kong Air Pollution


Manulife
Manulife
PCCW

空氣 污染

室外

室內

Hong Kong pollutant-based health cost:

1999, 46 Billion USD

Masking the Problem
Hong Kong residents protest excessive air pollution. In 1999, health costs related to water and air pollution totaled over US$46 billion, nearly 7% of China's GDP. Environmental degradation's first impacts are on a society's well-being and economic development, but also can exacerbate domestic and regional political tensions.

Comparing Outdoor Air / Cabin Air Pollutants

Selected In-Vehicle Pollutants [redacted]

Staying indoor safer ?

Pollutant	In-Vehicle	Ambient
	(min–max/mean value ranges for all driving scenarios)	
MTBE	20–90/31–60	10–26 (μg/m³)
Benzene	10–22/13–17	3–7 (μg/m³)
Toluene	23–58/30–51	10–40 (μg/m³)
Formaldehyde	<MQL–24/7–20	7–21 (μg/m³)
$PM_{2.5}$	23–107/32–83	21–64 (μg/m³)
PM_{10}	23–111/36–89	54–103 (μg/m³)
Carbon Monoxide	<MQL–1 (ppm), average	<MQL-4

Adapted from: Rodes C, Sheldon L, Whitaker D, Clayton A, Fitzgerald K, Flanagan J, DiGenova F, Hering S, Frazier C. Measuring concentrations of selected air pollutants inside California vehicles. Sacramento, CA:California Air Resources Board, 1998.
Abbreviations: <MQL, below quantification limit

IAQ Pollutant Class	Potential Indoor Sources
Environmental Tobacco Smoke	Lighted cigarettes, cigars, pipes
Combustion Contaminants- the oxides of carbon, nitrogen and sulfur	Furnaces, generators, gas or kerosene space heaters, tobacco products, outdoor air, vehicles.
Biological Contaminants	Wet or damp materials, cooling towers, humidifiers, cooling coils or drain pans, damp duct insulation or filters, condensation, re-entrained sanitary exhausts, bird droppings, cockroaches or rodents, dustmites on upholstered furniture or carpeting, body odors.
Volatile Organic Compounds (VOCs)	Paints, stains, varnishes, solvents, pesticides, adhesives, wood preservatives, waxes, polishes, cleansers, lubricants, sealants, dyes, air fresheners, fuels, plastics, copy machines, printers, tobacco products, perfumes, dry cleaned clothing.
Formaldehyde	Particle board, plywood, cabinetry, furniture, fabrics.
Soil gases (radon, sewer gas, VOCs, methane)	Soil and rock (radon), sewer drain leak, dry drain traps, leaking underground storage tanks, land fill
Pesticides	Termiticides, insecticides, rodenticides, fungicides, disinfectants, herbicides.
Particulate Matter (PM10, PM2.5 etc)	Printing, paper handling, smoking and other combustion, outdoor sources, deterioration of materials, construction/renovation, vacuuming, insulation.

Common Indoor Airborne Bacteria in Hong Kong (air samplings at CUHK)

1. Micrococcus (10[a])	luteus (10) ~20%[b]	8. Kocuria (5)	rosea (2)
	lylae (10) >95%		kristinae (2) ~50%
2. Bacillus (10)	pumilus (8) ~60%	9. Stenotrophomonas (4)	maltophilia (4) ~95%
	cereus (4)	10. Arthrobacter (4)	spp. (4) ~30%
	megaterium (2)	11. Microbacterium (4)	imperiale (1) ~85%
	licheniformis (1)	12. Chryseobacterium (3)	spp. (3)
	circulans (1)	13. Sphingomonas (2)	capsulata (1) ~70%
	thuringiensis (1)	14. Chryseomonas (2)	luteola (2)
3. Staphylococcus (9)	saprophyticus (4) ~70%	15. Brevibacterium (2)	casei (1) ~20%
	hominis (3)	16. Paenibacillus (2)	spp. (2) ~15%
	haemolyticus (2)	17. Curtobacterium (2)	sp. (1)
	arlettae (1)	18. Deinococcus (2)	spp. (2) ~10%
	cohnii (1)	19. Enterobacter (1)	cloacae (1)
	epidermidis (1)		agglomerans (1)
	warneri (1)	20. Kytococcus (1)	sedentarius (1)
4. Pseudomonas (9)	stutzeri (6) >95%	21. Aerococcus (1)	virdians (1)
5. Moraxella (7)	osloensis (6) ~60%	22. Marcrococcus (1)	caseolyticus (1) ~80%
	catarrhalis (1)	23. Rhodobacter (1)	sp. (1)
6. Acinetobacter (6)	lwoffii (5) ~65%	24. Paracoccus (1)	sp. (1)
7. Brevundimonas (6)	diminuta (6) ~20%	25. Enterococcus (1)	faecalis (1)
	vesicularis (3)	26. Rhodococcus (1)	sp. (1)

(N) = number of samples ; a+ N= 10; b= UVA sensitivie

Signs and Symptoms	Environmental Tobacco Smoke	Combustion Products	Biological Pollutants	Volatile Organics	Heavy Metals	Sick Building Syndrome
RESPIRATORY						
Rhinitis, nasal congestion	YES	YES	YES	YES	NO	YES
Epistaxis	NO	NO	NO	YES[1]	NO	NO
Pharyngitis, cough	YES	YES	YES	YES	NO	YES
Wheezing, worsening asthma	YES	YES	NO	YES	NO	YES
Dyspnea	YES[2]	NO	YES	NO	NO	YES
Severe lung disease	NO	NO	NO	NO	NO	YES[3]
OTHER						
Conjunctival irritation	YES	YES	YES	YES	NO	YES
Headache or dizziness	YES	YES	YES	YES	YES	YES
Lethargy, fatigue, malaise	NO	YES[4]	YES[5]	YES	YES	YES
Nausea, vomiting, anorexia	NO	YES[4]	YES	YES	YES	NO
Cognitive impairment, personality change	NO	YES[4]	NO	YES	YES	YES
Rashes	NO	NO	YES	YES	YES	NO
Fever, chills	NO	NO	YES[6]	NO	YES	NO
Tachycardia	NO	YES[4]	NO	NO	YES	NO
Retinal hemorrhage	NO	YES[4]	NO	NO	NO	NO
Myalgia	NO	NO	NO	YES[5]	NO	YES
Hearing loss	NO	NO	NO	YES	NO	NO

Basic Methods for Technology-based Remediation

Environmental life-cycle analysis ranking:

Physical Separation: HEPA ;

Processing by charge: Activated Carbon, electrostatic, ion-clusters, plasma-clusters;

Processing by radiation energy : UV, Laser, Sound, radiation (gamma);

Processing by chemicals : Ozone, chlorine (halogens), peroxides;

PhotoCatalytic Oxidation: Suspension-based, solid-composites and immobilized Nano-coating surfaces.

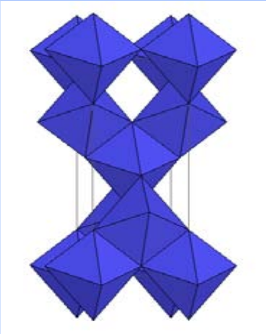
NANO-FOTOCIDE™

The Technology – the TiO_2–based Photocatalytic Oxidation (developed at CUHK)

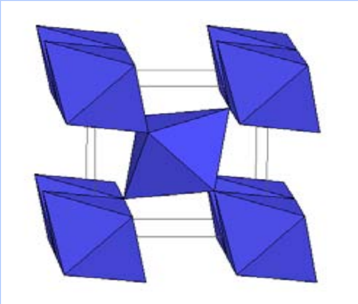
- **Rea[illegible] take place under ambient temperature and press[illegible]**
- **[illegible]water are used to generate the main oxidant, hyd[illegible]yl r[illegible]als**
- **The final oxidation products are environmentally acceptable**
- **Can treat a wide range of pollutants**

Anatase TiO_2 – an ideal photocatalyst

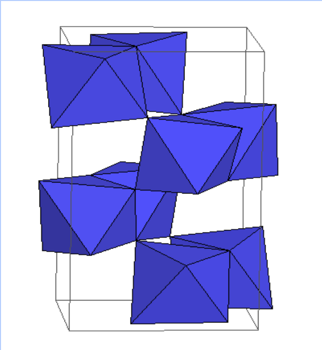
- Chemically stable and non-toxic
- Relatively inexpensive
- Generates highly reactive •OH



Anatase

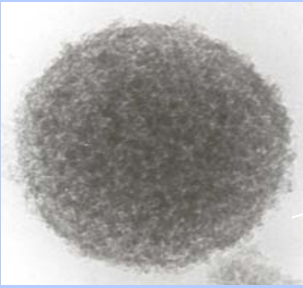


Rutile

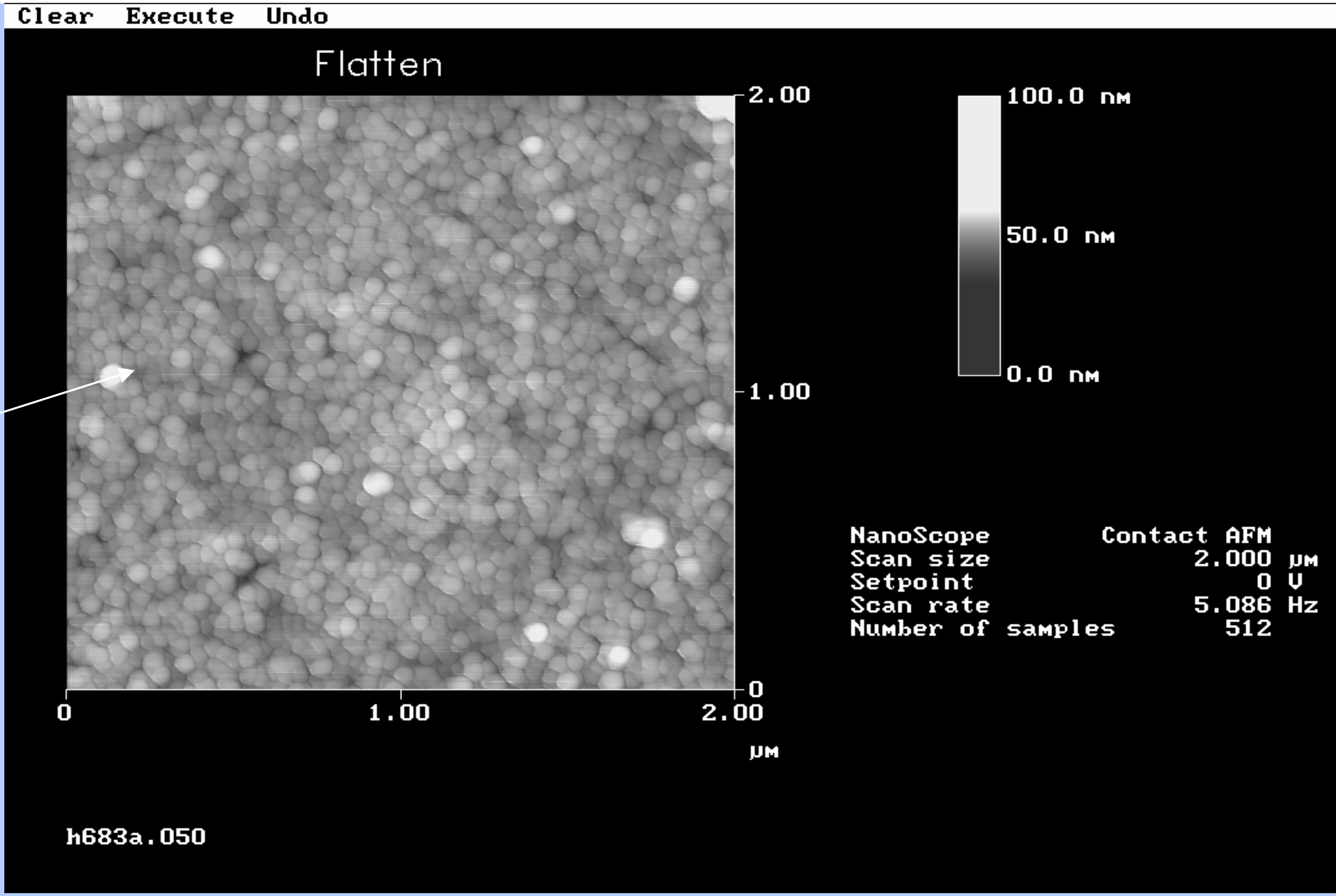


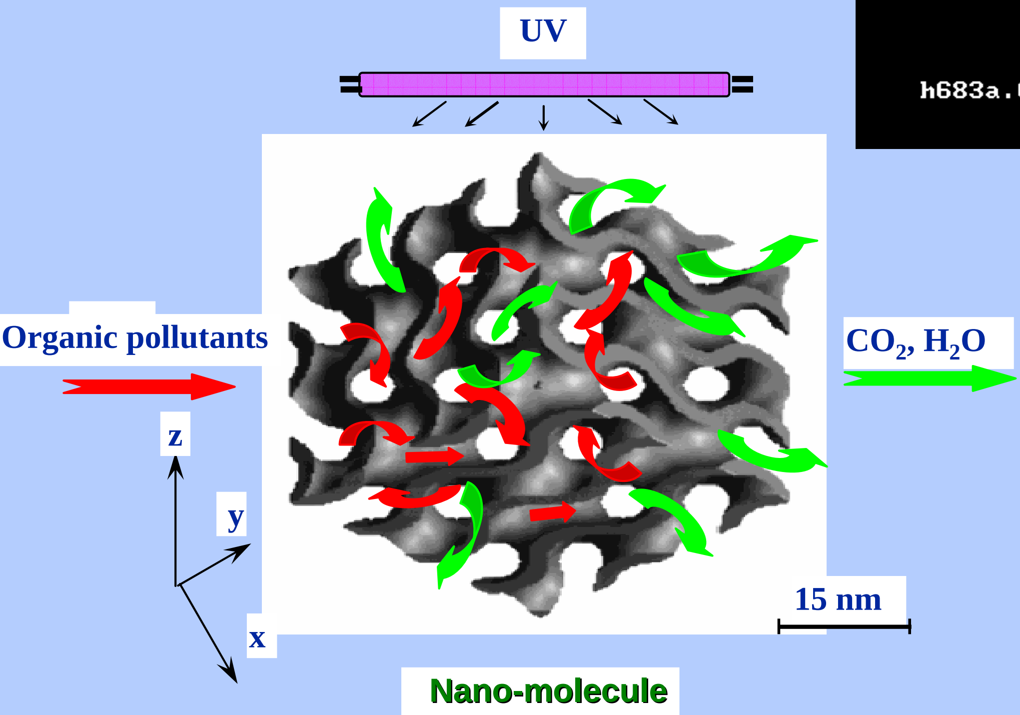
Brookite

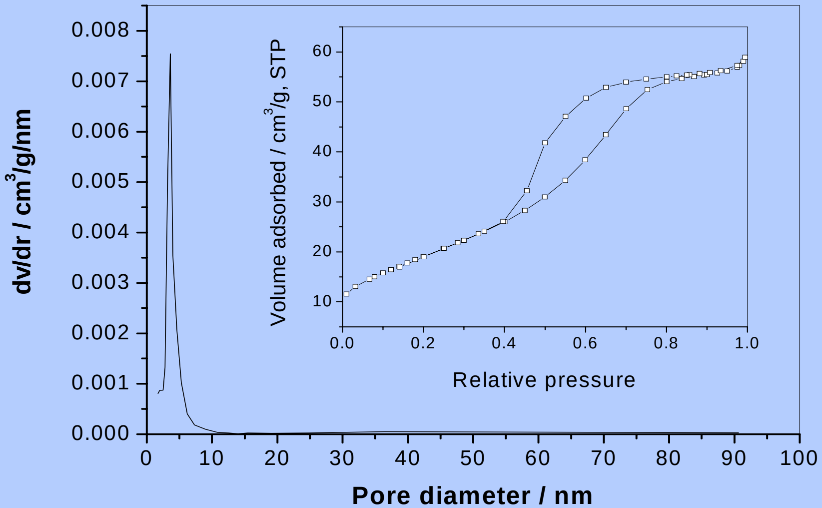
The Nano-coating



Mesoporous TiO_2







EnvironmentalCare Branding

納米富途

NANO-FOTOCIDE™

Commercialization of a Nano-coating technology

developed at the

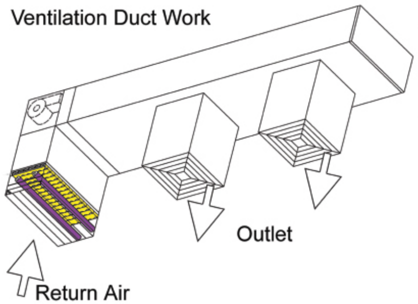
Chinese University Hong Kong

Total IAQ compliance by installation of Nano-Fotocide chemical and biological controls at the:

1. Fresh-air inlets/outlets
2. Ventilation ducting
3. Energy-exchange Units
4. Air Re-circulator inlet/outlet (diffusers)
5. Toilets and bathrooms
6. Waste-water drainage
7. Kitchens (food- and garbage-derived pollutants)
8. Bedrooms (extended stay)
9. Offices (extended stay)
10. Air-conditioning units

NANO-FOTOCIDE™

Indoor Air Quality (IAQ) Systems

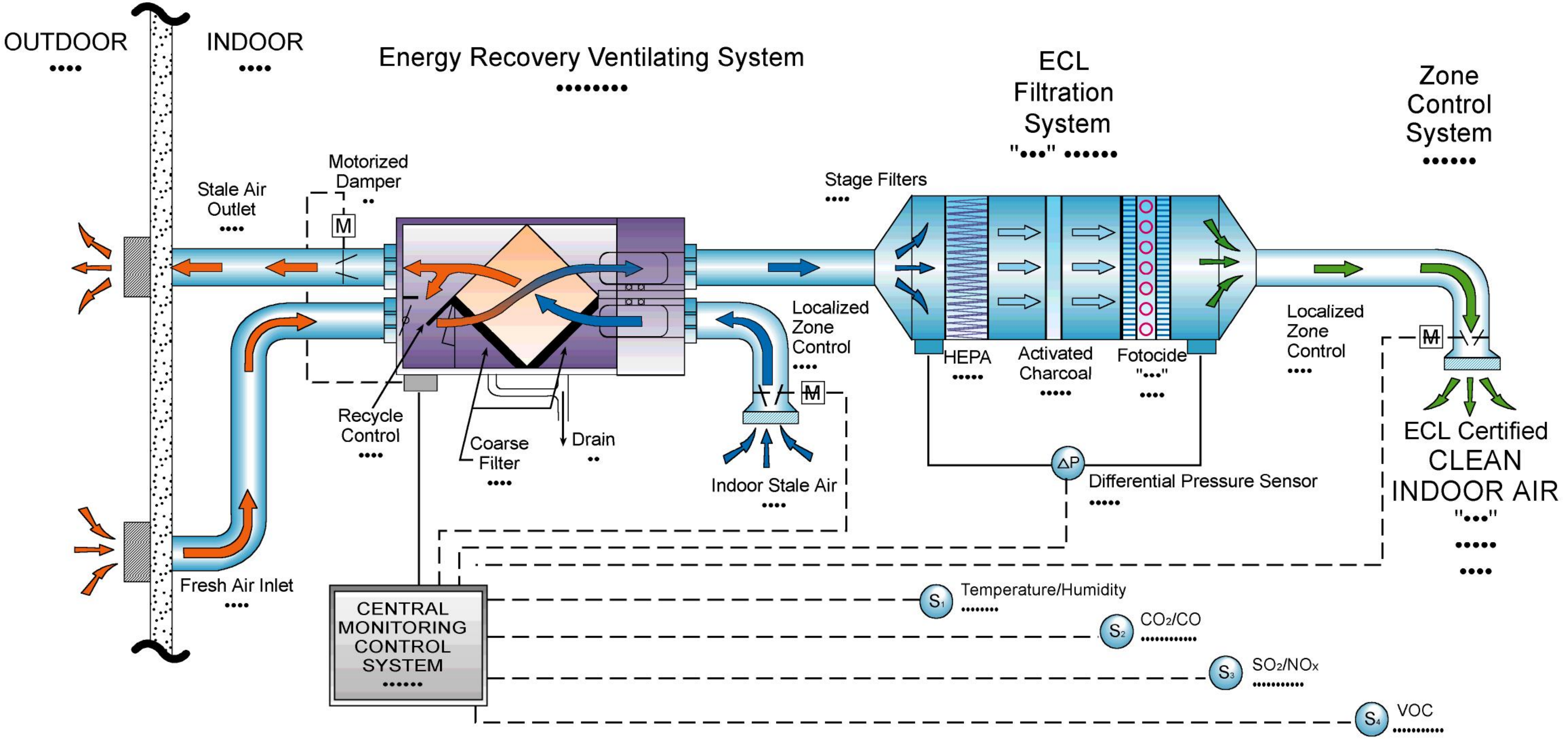


Patents Pending

Integrated *total compliance* Indoor Air Quality Control System

Total IAQ Solution

•••••••••••



For best IAQ, target Zero VOC products.

Zero VOC "Truly Environmental" paints and cleaners

The next generation of PCO-applications : coupling with other environmental technologies

1. Bio-filters and PCO-reactor for odors

Bio-filters can introduce odor-specificity in the removal mechanism for the PCO reactors, and the PCO units can reciprocate the bio-safety control for bio-filter applications;

2. Electrostatic precipitator and PCO-reactor for air

Some air-borne chemicals are associated with particulate and the ventilated at very high flow-rate with high concentrations. A pretreatment with electrostatic precipitator, prior to PCO-reactor processing would enhance the capacity of the PCO units to efficiently process these specific restaurant pollutants; and

3. Ion-exchange based systems and fluidized bed PCO-reactor for the effluent wastes

At high effluent flow-rate and high concentration, the effluence can be pretreated by concentrating the pollutants at the coupled ion-exchange based electrophoretic systems prior to the processing at the fluidized bed PCO-reactors. These systems target COD and BOD compliance for the local waste-water discharge ordinance standards.

愛環保
EnvironmentalCare

齊注重 齊受用

We care We share