Achieving IAQ & Energy Conservation Goals with ASHRAE 62.1-2004 Requirements, Applications and Case Studies

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บริษัท ชัยมิตร เอ็นจิเนียริ่ง อินเตอร์เนชั่นแนล จำกัด

ASHRAE Definition of Acceptable IAQ

Air in which there are no known contaminants at harmful concentrations as determined by cognizant authorities and with which a substantial majority (80% or more) of the people exposed do not express dissatisfaction.

- **IAQ is a function of many parameters:**
  - Outdoor air quality
  - Automobile / diesel exhaust
  - Various gases, vapors and smoke
  - Smog
- **Interior sources**
  - Building materials and furnishings
  - Surface activities
  - Indoor activities
  - Human occupants

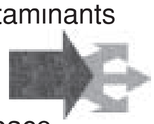
An important challenge today is how to improve and maintain IAQ in buildings while, at the same time, reducing their overall energy consumption. As energy conservation measures have been implemented, and energy consumption has decreased, IAQ has suffered, this one-sided trade off is no longer acceptable. One cannot discuss the issue of IAQ without giving some attention to the role that energy conservation measures may play. Public sector energy conservation efforts have been primarily voluntary, the government facilities have been mandated to reduce overall energy consumption. The quest to reduce energy costs has been criticized as the main cause of IAQ problems. Ventilation standards and mechanical codes have evolved to the point that those currently in place allow building designers/engineers the opportunity to address both IAQ and energy conservation.

Air cleaning technologies have similarly developed to the point that they may be used in conjunction with there standards to provide healthy and comfortable indoor environments while continuing to conserve energy. There are ever-increasing numbers of applications for both particulate and chemical (or gas-phase) air filtration in HVAC system designs such as Indoor Air Quality, odor control and energy conservation. Selecting and specifying the appropriate control strategies requires special consideration, air cleaning for both particulate and gas-phase contaminants can be a critical component in achieving acceptable. Indoor Air Quality as well as implementing energy conservation measures with ASHRAE Standard 62.1-2004.

This paper will tell about air cleaning with respect to gaseous contaminants and how it can be used as part of an overall IAQ strategy in addition to how the proper use of an the appropriate air cleaning technology streamlines the implementation of the IAQ Procedure for both improved IAQ and energy conservation.

Control Strategies

- Source Control
  - Remove the source(s) of contaminants

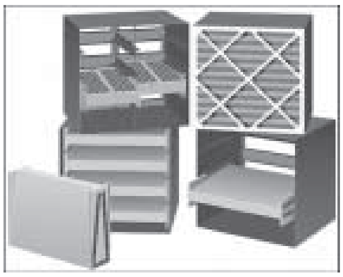


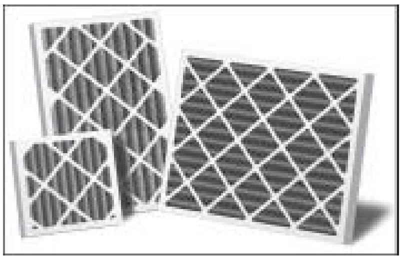
- Ventilation Control
  - Introduce clean air into the space

- Removal Control
  - Control contaminants by physical or chemical means

General Applications

- Gas-phase air filtration systems are used in commercial applications for:
  - Improving indoor air quality (IAQ)
  - Improving worker productivity
  - Reducing energy costs





Most common type of equipment employs the chemical filtration media in disposable or refillable modules in front or side-access systems or as adsorbent-loaded non-woven filters. Various standards and codes allow for the reduction of outside ventilation air and/or the recirculation of normally exhausted air.

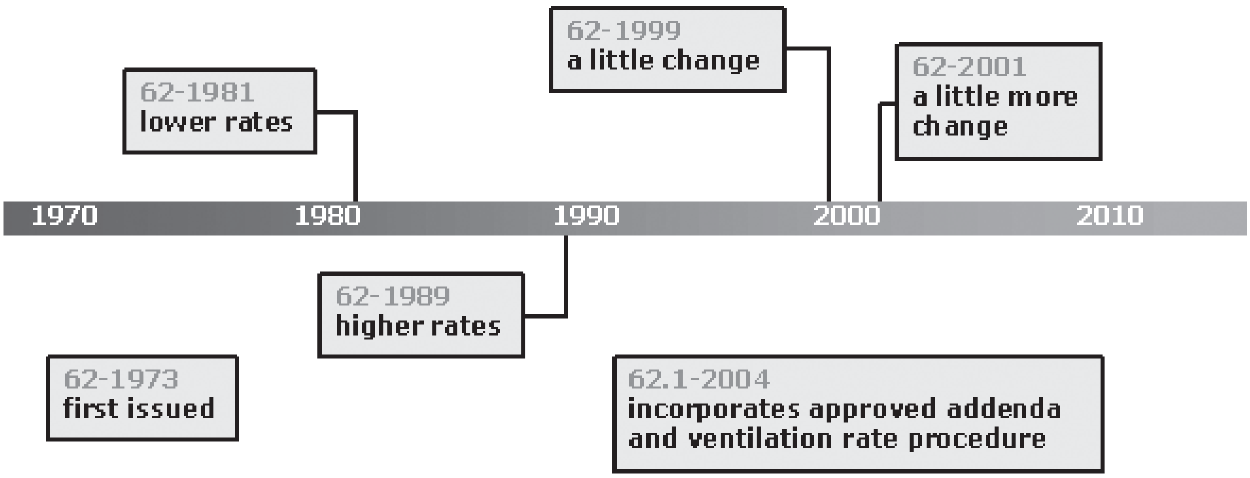
ASHRAE Standard 62.1-2004: "Ventilation for Acceptable Indoor Air Quality."

- Ventilation Rate Procedure - prescribes minimum amount of outdoor air required based on occupancy.
- Indoor Air Quality Procedure - allows the reduction in the amount of outdoor air used for ventilation through the use of FILTRATION and RECIRCULATION.

ASHRAE Standard 62 History

ASHRAE Standard 62

What Is Its History?



ASHRAE Standard 62-1973

Standard for Natural and Mechanical Ventilation

Provided a prescriptive approach to ventilation by specifying both minimum and recommended outdoor air flow rates to obtain acceptable IAQ for a variety of indoor applications. Specified both minimum and recommended ventilation rates.

ASHRAE Standard 62-1981

Ventilation for Acceptable Indoor Air Quality

"Recommended" rate category deleted. Two categories became smoking and non-smoking. Recommended outdoor air flow rates for both categories. Added alternate "IAQ" procedure to allow for the use of innovative energy conservation practices. Allowed for the use of whatever amount of outside air if shown that levels of indoor air contaminants could be maintained below recommended limits.

ASHRAE Standard 62-1989

Ventilation for Acceptable Indoor Air Quality

Tripled and quadrupled 1981 minimum non-smoking ventilation rates; did not distinguish between smoking and non-smoking. Retained the Ventilation Rate (VRP) and Indoor Air Quality Procedures (IAQP) for ventilation design.

- VRP - provided an indirect solution for the control of indoor air contaminants.
- IAQP - provided a direct solution by reducing and controlling the concentrations of contaminants through air cleaning. Endeavored to achieve the necessary balance between energy consumption and indoor air quality.

ASHRAE Standard 62.1-2001

Ventilation for Acceptable Indoor Air Quality

Converted from Standard 62-1999.

- Minimum requirements code-language, not a code.
- Working under "Continuous Maintenance".

Previous versions of Standard 62 strived to achieve a balance between energy consumption and IAQ. Whereas the VRP focused primarily in assuring acceptable IAQ, the IAQP was intended to provide a way to reduce HVAC system operating costs while still providing a healthy environment. Limited the applicability of the VRP for energy conservation purposes to the use of recommended ventilation rates and measures other than reducing outside air. Includes efficient location of supply and return air devices, variable ventilation rates based on occupancy indicators, insulation of HVAC system components, subcooling of refrigerants, etc. The IAQP provided an alternate, performance-based design approach

Outdoor air intake rates and other system design parameters are based on an analysis of contaminant sources, contaminant concentration targets, and perceived acceptability targets.

The IAQP allowed credit to be taken in the form of a reduction of the outside air intake rate (s) for contaminant controls or for other design techniques that can be reliably demonstrated to result in indoor contaminant concentrations equal to or lower than those achieved using the VRP.

ASHRAE Standard 62.1-2004

Ventilation for Acceptable Indoor Air Quality

- Since 2001, the last time the standard was published in its entirety, Standard 62.1-2004 contains only mandatory language.
- User's Manual
  - Published in 2005.
  - Provides information on how to use and apply Standard 62.1 with practical examples of compliance.
- Developing a guideline on ventilation & IAQ
  - Title, purpose and scope approved (Guideline 19P).
- Standard 62.1 was written to be code-enforceable containing only mandatory language and has been updated and revised in a number of significant ways.
  - The IAQ Procedure was modified.
  - The Ventilation Rate Procedure was revised.
  - The Minimum Ventilation Rate table has been revised.
  - Appendix G entitled "Application and Compliance," was added.
  - Requirements concerning indoor air humidity and the building envelope were added.
  - Requirements were added to ensure that air distribution systems are capable of delivering outdoor air to the occupied spaces.
  - A requirement was added for particle filtration when outdoor air particulate levels are deemed harmfully high.
  - Gaseous air cleaning requirements have been added for ozone in outdoor air.
  - Air is classified with respect to contaminant and odor intensity, and limits are placed on the recirculation of lower-quality air into spaces containing air of higher quality.
  - Appendix B, renamed to "Summary of Selected Air Quality Guidelines" and updated and clarified.
  - The purpose and scope of the standard were revised.

IAQ is based upon subjective criteria.

- Comfort based on the absence of odors.
- Carbon dioxide widely used as a surrogate indicator of IAQ.
- Increasing outside air may only substitute one (group of) contaminant (s) for another.

<u>Ventilation Rate Procedure establishes:</u>

- Minimum acceptable outdoor air quality.
- Outdoor air treatment, when necessary.
- Ventilation rates for residential, commercial, institutional, vehicular, and industrial spaces.
- Criteria for reduction of outdoor air quantities.
- Criteria for variable ventilation when air is used to dilute contaminants.

IAQ Procedure establishes:

- Acknowledges that air-cleaning, along with recirculation, is an effective means of controlling contaminants.
- Allows for both quantitative and subjective evaluation of the effectiveness of the air cleaning methods employed.
- Allows the amount of outside ventilation air to be reduced when air quality criteria is met.
- Allows a balance to be struck between IAQ and energy conservation.
- Energy savings due to decreased load on the HVAC system.
- Grants / rebates available for the implementation of energy-saving measures.

ASHRAE Standard 62...What is Its Future?

Standard 62.1-2004

- Mandatory language, minimum requirements
- Commercial, institutional, high-rise residential

User Manual for Std 62.1

Standard 62.1-2006 Supplement

Guideline 19 (informative design guidance)

Code change proposal support

Section 4.0-Outdoor Air Quality

General Requirements

4.1.1 Regional Air Quality. Assess regional outdoor air quality (EPA NAAQS).

- Must determine NAAQS compliance status.

4.1.2 Local Air Quality.

- Survey site.
- Must visit site and look around.

Section 6.2-Ventilation Rate Procedure

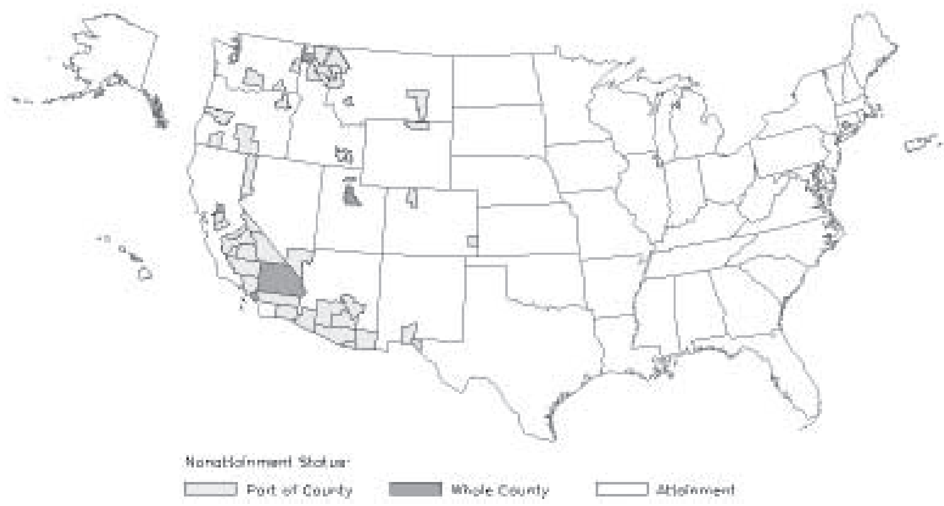
Ventilation Requirements

6.2 Ventilation Rate Procedure. Prescribes rates and procedures for finding outdoor air intake flow.

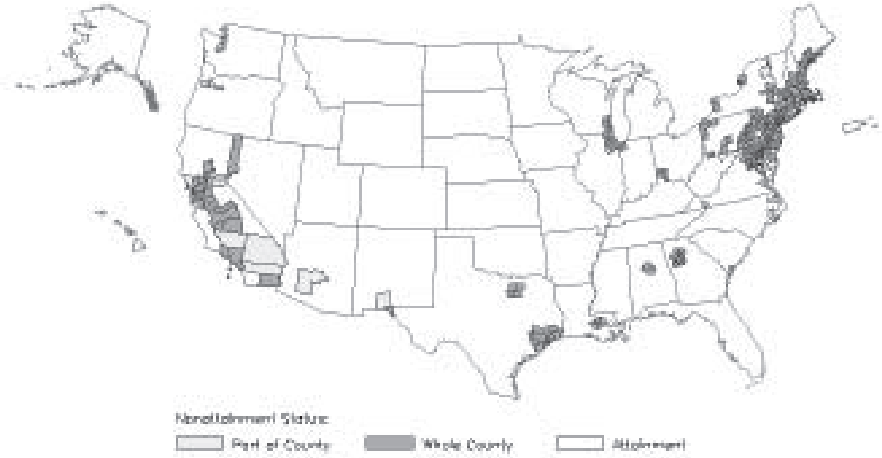
6.2.1 Air Treatment. If outdoor air is judged to be unacceptable per Section 4.1 assessment.

- Use MERV 6 filter in PM10 non-attainment regions.
- Use 40% efficient ozone filter in some O3 non-attainment regions.

Air Data: PM10

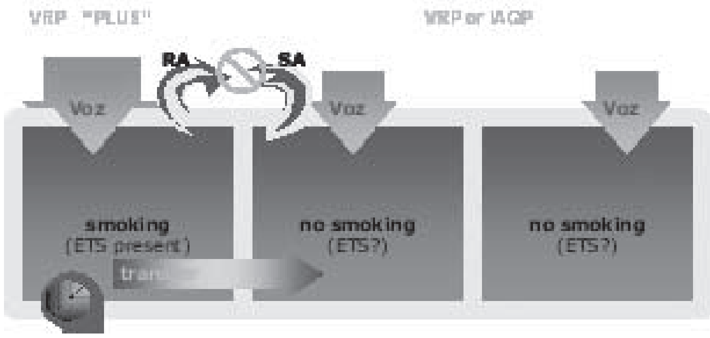


Air Data: Ozone (120 ppb)



Smoking-Permitted Areas

To comply with Std 62.1-2004



<u>Section 6.3-IAQ Procedure</u>

Ventilation Requirements

6.3.1.1 Contaminant Sources. Must identify contaminants of concern, along with sources and source strength.

6.3.1.2 Contaminant Concentration. Must specify target concentration and exposure time, referencing cognizant authority, for each C of C.

6.3.1.3 Perceived IAQ. Must specify target perceived air quality in terms of percent satisfied.

6.3.1.4 Design Approaches. Must follow an acceptable design procedure to find required airflow values. May be used:

- To take ventilation-credit for low-emitting materials.
- To take ventilation-credit for air cleaning.
- To achieve specific target concentrations of one or more contaminants.
- To achieve specific target levels of perceived IAQ (percent satisfied).

Standard 62-2001 defines cognizant authority as:

"An agency or organization that has the expertise and jurisdiction to establish and regulate concentration limits for airborne contaminants; or an organization that is recognized as authoritative and whose scope includes the establishment of guidelines, limit values, or concentrations levels for airborne contaminants."

ASHRAE 62.1 Update next publication, early 2006 "supplement" :

62.1a (clean up Section 5.10-dehumidification)
62.1b (occupancy category rationalization)
62.1c (Appendix B update)
62.1d (Table 4-1 update to NAAQS)
Probably 62g (ETS separation)

- Two more PPR cycles until mid-2007 publication
- Guideline in the works
- IMC Code proposal in the works The IAQ Procedure Today
- The standard acknowledges that air cleaning, along with recirculation, is an effective means for controlling indoor levels of contaminants.
- Employing the IAQP allows for the amount of outside ventilation air to be reduced be low levels prescribed by the Ventilation Rate Procedure.
- Ventilation system designs based on the IAQP will now have to comply with specified requirements.
  - Contaminant Sources
  - Contaminant Concentration
  - Perceived Indoor Air Quality
  - Design Approaches
  - Documentation
- Designing for compliance using the IAQP requires four steps:
- Identifying contaminants of concern (COC);
- Determining acceptable concentrations of these contaminants;
- Specifying the perceived indoor air quality criteria; and
- Applying an acceptable design approach to achieve the performance criteria.

Application Of The IAQ Procedure

One or a combination of the following design approaches can be selected to determine minimum space and system outdoor airflow rates and all other design parameters deemed relevant.

- The steady-state equations in Appendix D, which describe the impact of air cleaning on outdoor air and recirculation rates, may be used as part of a mass balance analysis for ventilation systems serving a single space.

- Design approaches that have proved successful in similar buildings.

- Approaches validated by contaminant monitoring and subjective occupant evaluations in the completed building.

- Application of one of the design approaches listed above to specific contaminants and the use of the VRP to address the general aspects of indoor air quality in the space being designed.

Of the four design approaches described for compliance with the IAQP, the mass balance analysis is the most frequently used method. Mass balance analysis equations for calculating the space contaminant concentrations or the volumetric airflow rate of outdoor air on single zone systems are provided in Appendix D and limited to the steady-state analysis of a single zone.

The U.S. National Institute of Standards and Technology (NIST) developed software to aid in contaminant-based design of ventilation systems, such as when using the IAQP. Indoor Air Quality Design Tool (IAQDT) software is for single zone systems that does not assume steady state conditions exist.

CONTAM 2.1 is a multi-zone indoor air quality and ventilation analysis computer program.

The IAQ Procedure and Energy Savings

For many buildings, the IAQP is an option that provides improved indoor air quality as well as reduces the amount of energy used to condition the ambient air. It also provides direct control of indoor air contaminants that is not possible under the Ventilation Rate Procedure. Many different applications can be designed using the IAQP.

- The most common applications, and those with the greatest potential for capital cost savings and operational cost reductions, involve new construction and renovation.

Example 1-Movie Theater

New Construction, Single Zone Modeling

- An engineer applied the IAQP in the construction of a movie theater where air cleaning (filtration) and recirculation would be used in an effort to reduce the outdoor air below the 20 cfm per person prescribed by the VRP.
- Design criteria showed that a reduction to 5 cfm per person would be possible.
- Resulted in a much smaller HVAC system being specified for the theater and an immediate capital savings of US$68,000.
- A reduction in the amount of outside air also meant that less air would have to be tempered by the HVAC system.
- Resulted in an additional operational savings of approximately US$ 15,000 /year.
- This savings takes into account an energy cost savings of US$ 23,000 /year (as compared to the VRP) and maintenance and energy costs for the air cleaning system of US$ 8,000 /year.

Example 2 - Office Building

Renovation, Single Zone Modeling

- An office building built in the mid-1970s was being renovated for a new owner.
- Applying current version of Standard 62, the VRP would have meant bringing in larger quantities of outdoor air to bring this building up to code.
- Would have required additional makeup

air handlers along with associated ductwork and controls at an estimated cost of US$ 300,000.00.

- The IAQP was recommended and a cost/ benefit analysis was performed.
- Owner could maintain current outdoor air intake rates and avoid the entire upgrade cost.
- There would be no retrofit or extra hardware requirements to add the additional filtration required.

• Item	• Amount
• Cost Avoided:	• US $300,000
• Energy Savings ($/yr):	• US $10,400
• Media Replacement ($/yr):	• + (US $21,000)
• Annual Operation:	• + (US $11,000)
• Time to Equalization:	• 28 years

Example 3-Lecture Hall

New Construction, Single Zone Modeling

- Design considerations:
- New construction
- Desired outdoor air intake rate of 5 cfm per person.
- Perceived IAQ acceptability of 80% of occupants.
- Air handler with constant outdoor and supply airflows.
- Filter (air cleaner) location in the supply (mixed) airstream .
- Supply airflow of 20,000 cfm.
- For all of the contaminants of concern, it was shown that 5 cfm per person complied with the requirements of the IAQP.
- Summary of savings for reduction of conditioned outside air.

Capital Equipment Savings: $8,643.00

Operational Savings: $1,136.00 /year

Example 4 - Retail Store

New Construction, Multizone Modeling

- A retail store design had the following space types: corridors, fitting rooms, and sales areas to be considered in the modeling of the IAQP.
- As in Example 3, all of the contaminants of concern were less than the target concentration limits when using a mass balance analysis design approach.
- - A total system outdoor airflow of 7 cfm per person based on total occupancy would comply with the requirements of Standard 62.1-2004.
- Summary of savings for reduction of conditioned outside air.

Capital Equipment Savings: $8,845.00

Operational Savings: $2,641.00 /year

Summary and Conclusions

- The Indoor Air Quality Procedure described in ASHRAE Standard 62.1-2004 may be used as an alternative to the Ventilation Rate Procedure.
- Using the VRP does not allow outdoor air ventilation rates to be reduced.

- The IAQP provides a direct solution for reducing and controlling contaminants to specified acceptable levels through air cleaning.
- Provides a way to reduce HVAC system operating costs while still providing a healthy environment.
- The IAQP is often neglected as a method for complying with the ventilation requirements of the standard.
- Practical applications of the IAQP have been presented to show that air cleaning can effectively achieve acceptable air quality as well as reduce outdoor air requirements saving energy required to condition ambient air.

Whereas the Ventilation Rate Procedure of ASHRAE Standard 62.1-2004 focuses primarily on assuring acceptable indoor air quality, the IAQP provides a way to reduce HVAC system operating costs while still providing a healthy environment.

- The IAQP can allow for a more cost-effective solution to providing good air quality since all design strategies may be considered and compared.
- In times when energy conservation is at the forefront of many peoples' minds, the IAQP should be considered as a proven option to achieve these goals.

Applying the IAQ Procedure shows that using as little as 5 cfm/person of outdoor air can reduce the total space contaminant concentration to levels low enough to be below published guidelines, provide BETTER indoor air quality, and meet the requirements of ASHRAE Standard 62-2001-2004.

What About Thailand?

- The previous examples were taken from installations in the United States.
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- Can this approach to improving IAQ and decreasing energy costs be applied in Thailand?
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- Thai Air Quality Monitoring Network
- The Pollution Control Department (PCD) began monitoring air quality in Thailand in 1983.
- Air pollution monitoring assesses compliance with air quality standards.
- The Pollution Control Department has 71 air quality monitoring sites across Thailand.
- PCD's monitoring network collects information on a variety of pollutants, such as CO, NO2, SO2, and ground-level ozone (O3).

Thailand NPAAQS*

Pollutants	Averaging time	Standard
Carbon monoxide (CO)	1 hr	Not to exceed 30 ppm. (34.2 mg/m3)
	8 hr	Not to exceed 9 ppm. (10.26 mg/m3)
Nitrogen dioxide (NO2)	1 hr	Not to exceed 0.17 ppm. (0.32 mg/m3)
Ozone (O3)	1 hr	0.10 ppm. (0.20 mg/m3)
Sulfur dioxide (SO2)	1 year	Not to exceed 0.04 ppm. (0.10 mg/m3)
	24 hr	Not to exceed 0.12 ppm.(0.30 mg/m3)
	1 hr	Not to exceed 0.3 ppm.(780 μg/m3)
Lead (Pb)	1 month	Not to exceed 1.5 μg/m3
Particulate matter (PM10)	24 hour	Not to exceed 0.12 mg/m3
	1 year	Not to exceed 0.05 mg/m3
Particulate matter (<100 μm)	24 hour	Not to exceed 0.33 mg/m3
	1 year	Not to exceed 0.10 mg/m3

*National Primary Ambient Air Quality Standard

U.S. EPA NAAQS*

Pollutants	Averaging time	Standard
Carbon monoxide	1 hr	35 ppm (40 mg/m3)
	8 hr	9 ppm (10 mg/m3)
Nitrogen dioxide	Annual (Arithmetic Mean)	0.053 ppm (100 μg/m3)
Ozone	1 hr	0.12 ppm (0.24 mg/m3)
	8 hr	0.08 ppm (0.16 mg/m3)
Sulfur oxides	Annual (Arithmetic Mean)	0.03 ppm (0.08 mg/m3)
	24 hr	0.14 ppm (0.37 mg/m3)
	3 hr	0.5 ppm (1.3 mg/m3)
Lead	Quarterly average	1.5 μg/m3
Particulate matter (PM10)	24 hr	150 μg/m3
	Annual (Arithmetic Mean)	50 μg/m3
Particulate matter (PM2.5)	24 hr	65 μg/m3
	Annual (Arithmetic Mean)	15 μg/m3

Comparison of Air Quality Standards

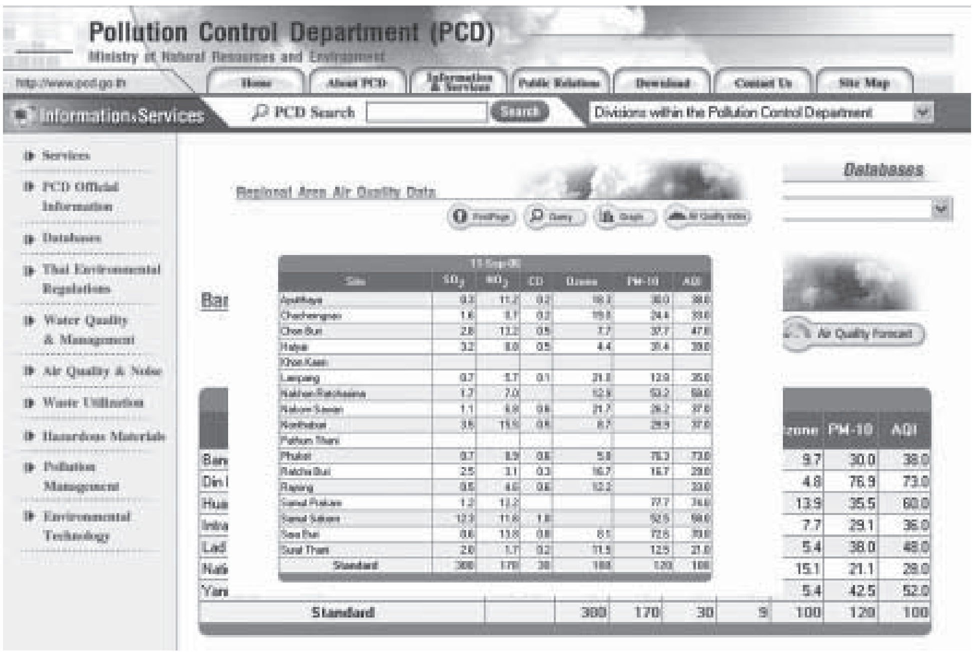
Country	SO2			NO2			CO		O3		TSP		PM10		Pb		
	1hr	24 hr	Annual	1 hr	24 hr	Annual	1 hr	8 hr	1 hr	8 hr	24 hr	Annual	24 hr	Annual	1 hr	24 hr	Annual
Australia	0.44	0.16	-	0.30	0.12	-	34.3	11.4	0.24	0.10	-	-	-	-	-	-	-
Canada	0.82	0.27	-	0.40	0.20	-	15.0	6.0	0.10	-	-	-	-	-	-	-	-
Germany	-	0.27	-	0.20	-	0.80	30.0	-	-	-	-	-	-	-	-	-	2.00
Japan	0.26	0.11	-	-	0.08	-	-	22.8	0.12	-	-	-	-	-	0.10	-	-
Mexico	-	-	-	0.40	-	-	-	15.0	-	-	-	-	-	-	-	-	-
Netherlands	0.76	0.23	-	0.18	-	-	40.0	6.0	0.12	-	-	-	-	-	2.00	-	-
Taiwan	0.78	0.26	-	-	0.10	-	22.9	-	-	-	-	-	-	-	-	-	-
Thailand	0.78	0.30	0.04	0.32	-	-	34.2	10.3	0.20	-	0.33	0.10	0.12	0.05	-	1.50	-
USA	-	0.37	-	-	-	0.10	40.0	10.0	0.24	0.16	-	-	0.15	0.05	-	-	-
WHO	0.35	0.13	0.05	0.40	0.15	-	30.0	10.0	0.15	0.10	-	-	-	-	-	-	0.05

Thai Environmental Regulations

Air Quality and Noise Standards http://www.pcd.go.th/info_serv/en_reg_std_airsnd01.html

Bangkok Daily Air Quality Data http://www.pcd.go.th/AirQuality/Bangkok/Default.cfm

Regional Air Quality Data http://www.pcd.go.th/AirQuality/Regional/Default.cfm



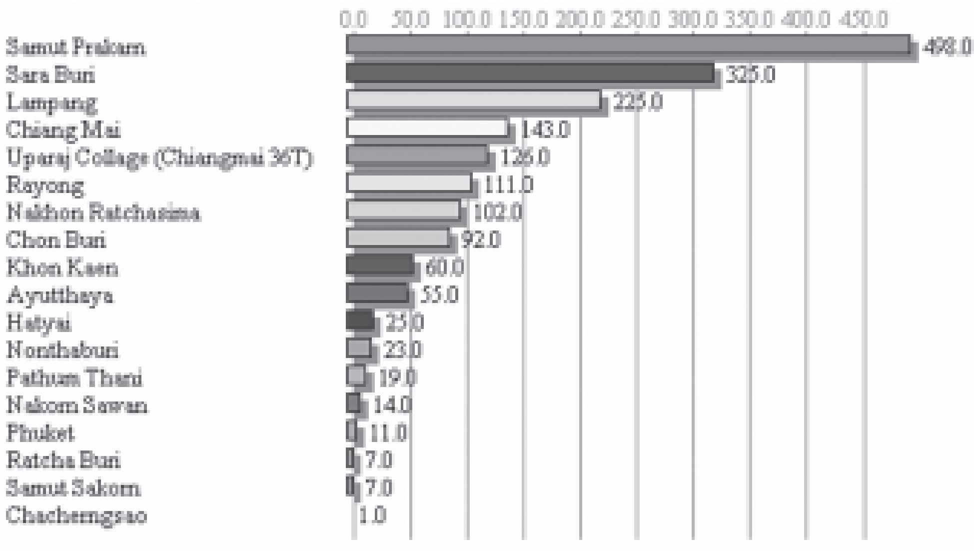
AQI for Thailand

PM10 Information

So far in 2006, the PM10 standard has been exceeded almost 300 times.

- One site in Bangkok - Din Daeng
- 13 other regional sites

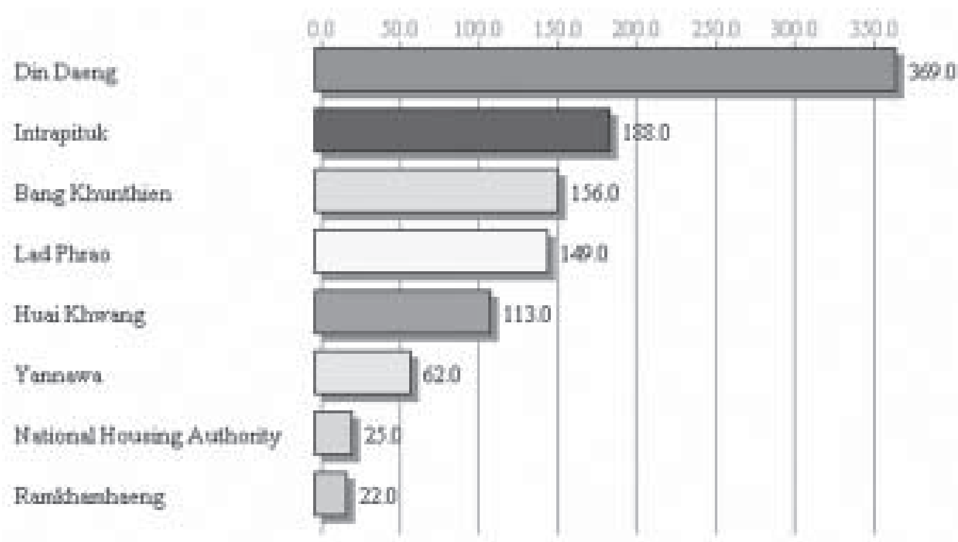
PM10 levels normally peak during the months of October through February, The number of respiratory outpatients seem to peak during the same period.



Days Exceeding Particulate Matter Standard

Ozone Information

The ozone standard has been exceeded in 2 sites in Bangkok (Lad Phrao and Bang Khunthien) and one regional site (Samut Prakarn). It has been observed that as much as 0.3 per cent of hourly ambient O3 concentrations exceed the ambient air quality standard of 100 ppb - mostly in the areas downwind from the center of Bangkok. This indicates that Bangkok may start to experience a photochemical smog problem



Days Exceeding Particulate Matter Standard

Air Quality in Bangkok

Air Pollutant Concentrations

Pollutants	Range	95th Percentile	Annual Average	Standards	Exceeding Standards (%)
TSP (24-hr) mg/m3	0.03 - 0.49	0.29	0.14	0.33	(1.87) 17/910
PM10 (24-hr) ug/m3	6.6 - 233.9	123.7	54.5	120	(5.4) 171/3164
CO (1-hr) ppm	0.0 - 22.0	4.0	1.41	30	(0) 0/118611
CO (8-hr) ppm	0.0 - 12.0	3.7	1.41	9	(0.03) 39/120416
Pb (24-hr) ug/m3	0.01 - 1.32	0.33	0.12	--	(0) 0/753
Pb (monthly) ug/m3	0.02 - 0.69	0.32	0.12	1.5	(0) 0/202
O3 (1-hr) ppb	0.0 - 183.0	44.0	12.1	100	(0.096)75/78378
SO2 (1-hr) ppb	0.0 - 109.0	16.0	5.9	300	(0) 0/91304
SO2 (24-hr) ppb	0.0 - 54.3	12.9	5.9	120	(0) 0/3845
NO2 (1 hr) ppb	0.0 - 197.0	61.0	25.6	170	(0.01) 10/97018

Additional Air Quality Information

Air Quality Management in Bangkok: Air Quality Management in Bangkok: Trends and Challenges http://www.cse.polyu.edu.hk/~activi/BAQ2002/BAQ2002_files/Proceedings/Subworkshop1sw1a5Wangwongwatana_Final.pdf#search=%22air%20quality%20monitoring%20in%20Bangkok%22

Air Pollution Management in Thailand

http://www.asiairnet.org/publications/pubs/panya.pdf#search=%22air%20quality%20monitoring%20in%20Bangkok%22

http://www.asiairnet.org/publications/11-Thailand.pdf#search=%22air%20quality%20monitoring%20in%20Bangkok%22

Real-World Possibilities

How can the IAQ Procedure from ASHRAE Standard 62.1-2004 be used in Thailand?

The following are examples using climate data and utility rate information for Thailand and comm on building types.

- Airflow is listed in cubic meters/hour (cmh).
- Costs and savings are listed in Thai Baht.

Building Type – Airport Terminal

System Type		VAV
Filter & Airflow Information	Filtration Type	PK-18s & CK-12s
	Annual Filter Changes	0
	Supply air (cmh)	507,398
	O/A VRP (cmh)	140,961
	O/A IAQP (cmh)	88,110
	O/A Difference (cmh)	52,851
Annual Energy Requirements & Savings	Annual run hours	4,380
	Electricity (kwh)	287,505
	Electricity (THB)	972,399.41
	Fuel (therms)	6920
	Fuel (THB)	252,251.99
	Total Savings (THB)	1,224,651.40
	Costs (THB)	0.00
	Net Savings (THB)	1,224,651.40
Capital Savings	Chiller (Tons)	158
	Chiller (THB)	2,375,056.00
	Boiler (Mbtuh)	1,501
	Total (THB)	2,544,278.74

Building Type – Conference Center

System Type		Constant	VAV
Filter & Airflow Information	Filtration Type	2" Purafilter	2" Purafilter
	Annual Filter Changes	4	4
	Supply air (cmh)	7,209	1,019,400
	O/A VRP (cmh)	2,243	305,820
	O/A IAQP (cmh)	1,121	101,940
	O/A Difference (cmh)	1,121	203,880
Annual Energy Requirements & Savings	Annual run hours	2,380	2,380
	Electricity (kwh)	1,223	222,282
	Electricity (THB)	4,136.43	751,802.18
	Fuel (therms)	334	60662
	Fuel (THB)	12,175.17	2,211,287.62
	Total Savings (THB)	16,311.60	2,963,089.80
	Costs (THB)	(17,530.10)	(2,478,911.71)
	Net Savings (THB)	(1,218.50)	484,178.09
Capital Savings	Chiller (Tons)	3	566
	Chiller (THB)	45,096.00	8,508,112.00
	Boiler (Mbtuh)	61	11,023
	Total (THB)	51,973.14	9,750,845.02

Building Type – High School

System Type		VAV & Constant	VAV OA
Filter & Airflow Information	Filtration Type	2" Purafilter	2" Purafilter
	Annual Filter Changes	4	4
	Supply air (cmh)	282,513	576,496
	O/A VRP (cmh)	87,555	168,570
	O/A IAQP (cmh)	28,246	56,478
	O/A Difference (cmh)	59,309	112,092
Annual Energy Requirements & Savings	Annual run hours	2,380	2,380
	Electricity (kwh)	106,475	201,235
	Electricity (THB)	360,119.75	680,617.02
	Fuel (therms)	10112	19111
	Fuel (THB)	368,608.69	696,645.64
	Total Savings (THB)	728,728.44	1,377,262.66
	Costs (THB)	-686,997.36	-1,401,886.53
	Net Savings (THB)	41,731.07	-24,623.87
Capital Savings	Chiller (Tons)	152	287
	Chiller (THB)	2,284,864.00	4,314,184.00
	Boiler (Mbtuh)	2,490	4,707
	Total (THB)	2,565,586.60	4,844,851.18

Building Type – Museum

System Type		VAV
Filter & Airflow Information	Filtration Type	2 pass PK-18s
	Annual Filter Changes	0
	Supply air (cmh)	129,124
	O/A VRP (cmh)	49,543
	O/A IAQP (cmh)	23,038
	O/A Difference (cmh)	26,504
Annual Energy Requirements & Savings	Annual run hours	4,380
	Electricity (kwh)	26,490
	Electricity (THB)	89,594.48
	Fuel (therms)	17728
	Fuel (THB)	646,231.69
	Total Savings (THB)	735,826.17
	Costs (THB)	0.00
	Net Savings (THB)	735,826.17
Capital Savings	Chiller (Tons)	52
	Chiller (THB)	781,664.00
	Boiler (Mbtuh)	1,452
	Total (THB)	945,362.48

Building Type – Office Building

System Type		VAV	VAV	VAV	VAV
Filter & Airflow Information	Filtration Type	2" Purafilter	2" Purafilter	2" Purafilter	2" Purafilter
	Annual Filter Changes	4	4	4	3
	Supply air (cmh)	156,308	820,784	531,787	2,300,964
	O/A VRP (cmh)	26,844	99,497	84,712	268,306
	O/A IAQP (cmh)	5,097	29,840	21,178	67,077
	O/A Difference (cmh)	21,747	69,657	63,534	201,230
Annual Energy Requirements & Savings	Annual run hours	4,380	4,380	4,380	4,380
	Electricity (kwh)	101,734	60,632	127,478	412,154
	Electricity (THB)	344,084.73	205,069.55	431,156.09	1,393,987.26
	Fuel (therms)	4693	51377	34789	94784
	Fuel (THB)	171,072.05	1,872,825.23	1,268,149.50	3,455,123.24
	Total Savings (THB)	515,156.79	2,077,894.78	1,699,305.59	4,849,110.50
	Costs (THB)	-400,319.07	-2,102,101.26	-1,361,954.82	-5,892,978.38
	Net Savings (THB)	114,837.72	-24,206.48	337,350.77	-1,043,867.89
Capital Savings	Chiller (Tons)	70	150	176	475
	Chiller (THB)	1,052,240.00	2,254,800.00	2,645,632.00	7,140,200.00
	Boiler (Mbtuh)	751	3,914	3,435	9,090
	Total (THB)	1,136,907.74	2,696,064.36	3,032,893.90	8,165,006.60

Building Type – Retail Store

System Type		Constant	VAV & Constant
Filter & Airflow Information	Filtration Type	2" Purafilter	2" Purafilter
	Annual Filter Changes	12	4
	Supply air (cmh)	188,589	164,803
	O/A VRP (cmh)	64,083	45,193
	O/A IAQP (cmh)	16,990	16,480
	O/A Difference (cmh)	47,093	28,713
Annual Energy Requirements & Savings	Annual run hours	8,760	4,380
	Electricity (kwh)	512,365	94,865
	Electricity (THB)	1,732,920.90	320,852.40
	Fuel (therms)	12,332	9,009
	Fuel (THB)	449,533.46	328,401.47
	Total Savings (THB)	2,182,454.37	649,253.88
	Costs (THB)	-1,395,555.85	-422,075.64
	Net Savings (THB)	786,898.52	227,178.24
Capital Savings	Chiller (Tons)	141	74
	Chiller (THB)	2,119,512.00	1,112,368.00
	Boiler (Mbtuh)	1,337	1,206
	Total (THB)	2,270,245.38	1,248,332.44

Building Type – University

System Type		VAV
Filter & Airflow Information	Filtration Type	2" Purafilter
	Annual Filter Changes	4
	Supply air (cmh)	223,614
	O/A VRP (cmh)	75,777
	O/A IAQP (cmh)	22,648
	O/A Difference (cmh)	53,129
Annual Energy Requirements & Savings	Annual run hours	2,380
	Electricity (kwh)	157,048
	Electricity (THB)	531,167.75
	Fuel (therms)	3780
	Fuel (THB)	137,790.83
	Total Savings (THB)	668,958.57
	Costs (THB)	-543,769.92
	Net Savings (THB)	125,188.65
Capital Savings	Chiller (Tons)	159
	Chiller (THB)	2,390,088.00
	Boiler (Mbtuh)	1,509
	Total (THB)	2,560,212.66

Concluding Remarks

Air quality in Bangkok and the rest of Thailand is generally good, however, PM10 and ozone levels have been trending upward. Pollution levels are still low enough to make the use of air cleaning along with recirculation an effective and economical option for improving IAQ and reducing energy costs.

The IAQ Procedure is especially applicable in the hot, humid climate of Thailand.

- It's use can reduce the amount of energy used cool the air.
- It's use will provide better IAQ than if using the VRP by direct control of airborne contaminants-both particulate and gaseous.
- It's use will make it easier to control indoor humidity levels and reduce the potential for mold growth-further improving IAQ.