Technology Selection Guide

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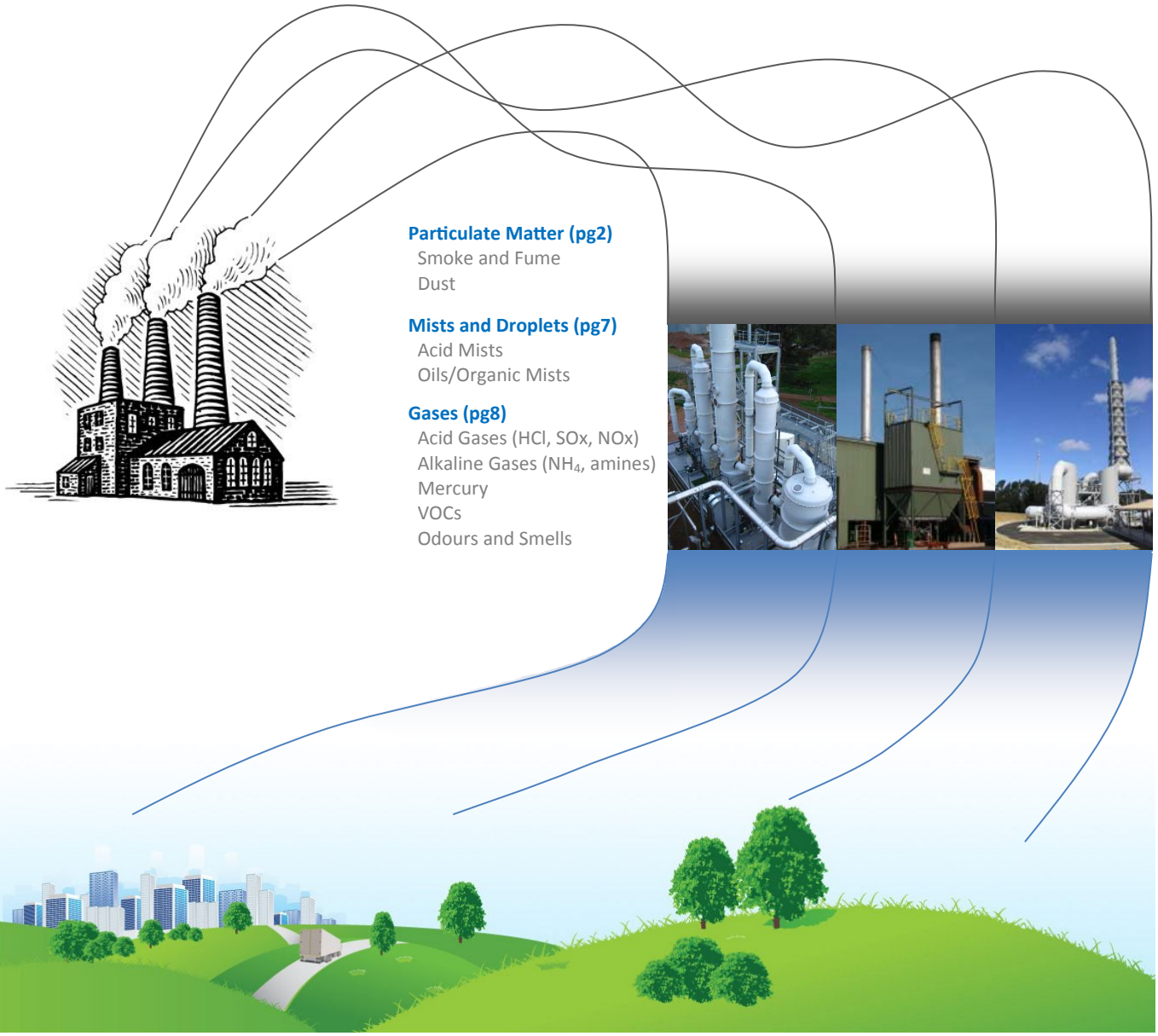

Australia's Leading Air Pollution Control Company.

With over 45 years of experience in air pollution control, TAPC has captured just about every type of airborne pollutant imaginable. This guide is designed to be an assistance to plant managers, engineers, technicians and scientists in selecting the appropriate abatement technology for various pollutants.

When you buy a TAPC gas cleaning plant you can be assured that you are buying the most advanced, most robust, and most efficient air pollution control device on the market today. We also have expert service crews and quality replacement parts for all types of air pollution control equipment - so no matter whether you need a new device or assistance with an existing one, we're there to help.

Total Air Pollution Control Pty. Ltd.
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TAPC

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Brochure ES01 rev A

Total Air Pollution Control

Dust and Particulate

Solid material conveyed in a gas stream can be referred to in numerous ways including "particulate", "dust", "fume" and "smoke". Typically, most visible emissions (if not steam) are a solid material which we refer to as particulate matter.

Fine Particulate matter definitions (PM_{10} and $PM_{2.5}$)

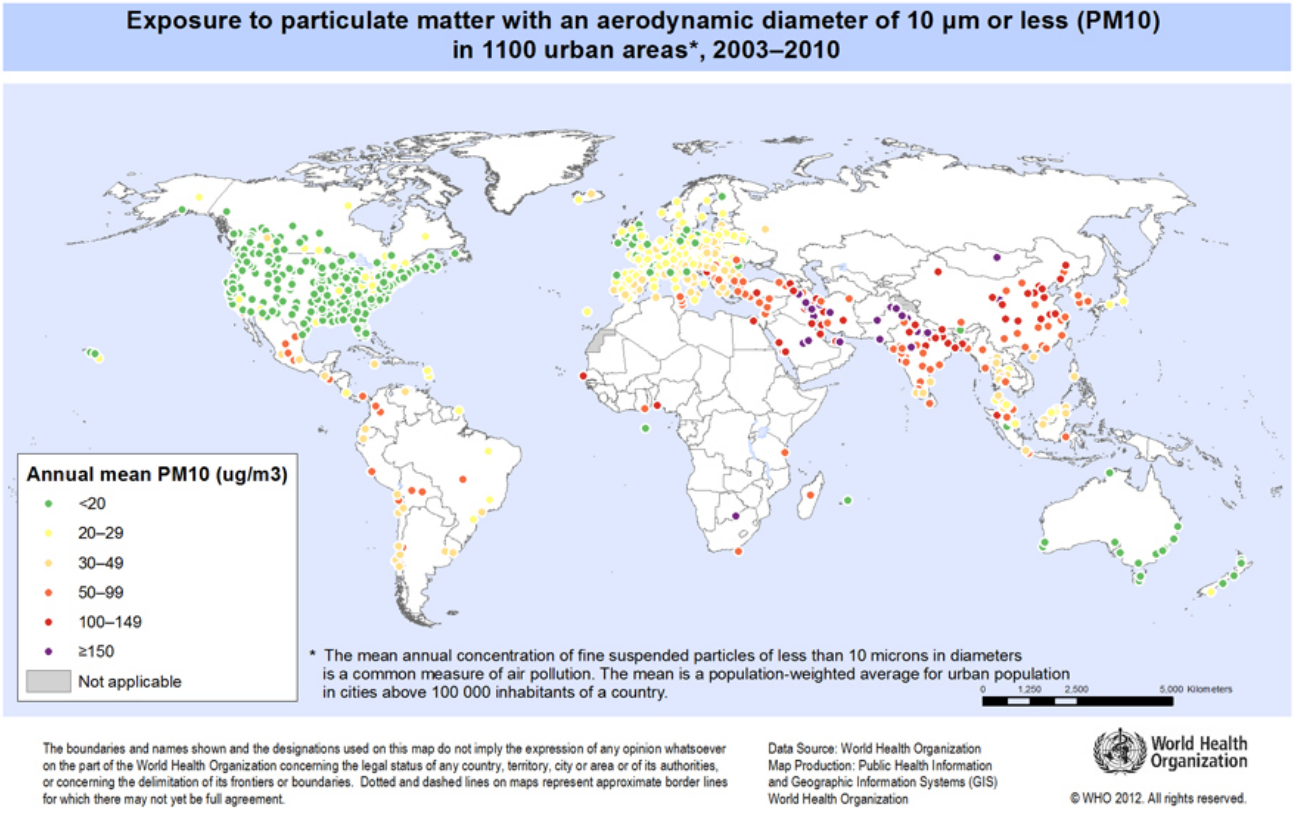
PM_{10} is particulate matter 10 µm or less in diameter, $PM_{2.5}$ is particulate matter 2.5 µm or less in diameter. $PM_{2.5}$ is generally described as ultrafine particles and is typically not visible to the human eye. By way of comparison, a human hair is about 100 µm, so roughly 130 fine particles could be placed end to end around one strand. Particles in this size range make up a large proportion of dust that can be drawn deep into the lungs, and into the blood stream causing detrimental health effects. The World Heath Organization (WHO) reports that fine particulate matter is associated with a broad spectrum of acute and chronic illness, such as lung cancer and cardiopulmonary disease. Worldwide, it is estimated to cause about 9% of lung cancer deaths, 5% of cardiopulmonary deaths and about 1% of respiratory infection deaths. Particulate matter pollution is an environmental health problem that affects people worldwide, but middle-income countries disproportionately experience this burden.

Under the National Environment Protection Measure (NEPM) for Ambient Air Quality, Australian governments have set a national ambient air quality standard for PM_{10} of 50 µg/m^3 in outdoor air averaged over a 24-hour period. The goal is for the standard to be exceeded no more than five days a calendar year.

The Measure was varied in 2003 to include advisory reporting standards for $PM_{2.5}$. These are 25 µg/m^3 averaged over 24 hours; and 8 µg/m^3 averaged over one year. The goal of the variation is to collect sufficient $PM_{2.5}$ monitoring data to allow the development of air quality standards.

Currently, the eight-hour time weighted average (TWA) exposure limits are 10 mg/m^3 of inspirable dust. Consult with your state or territory workplace safety authority to confirm current guidelines for particulate matter.

There are numerous styles of equipment for removing particulate, each with their own specific characteristics, advantages and disadvantages. The following pages provide a general guide of the particulate removal devices that we manufacture, with a brief outline of their relative capabilities. In all cases, please contact our engineers so that we can determine the correct solution to your air pollution control issues.

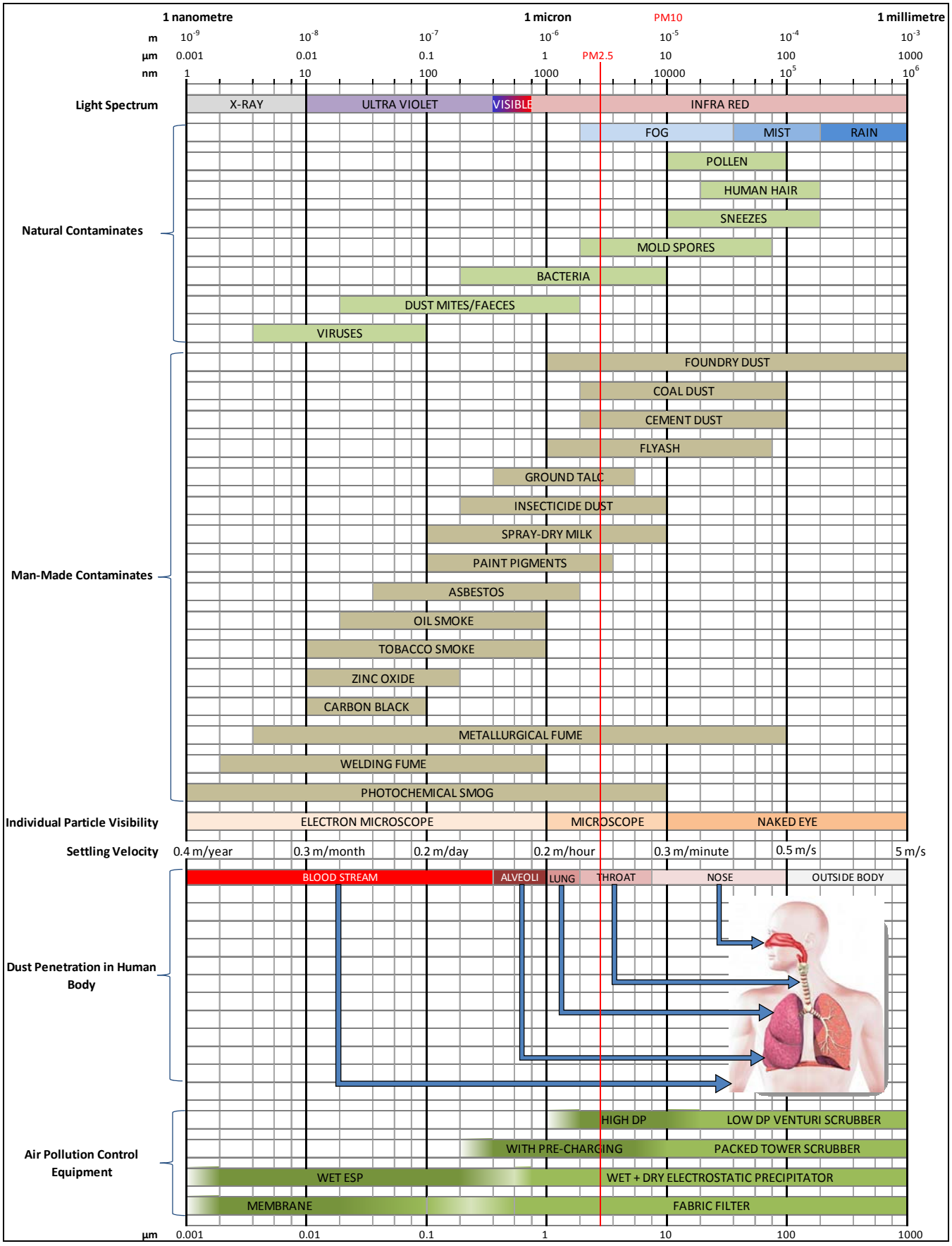


Courtesy World Health Organisation 2012

Dust and Particulate

Particulate Spectrum and Human Body Penetration

The following chart outlines the spectrum of typical airborne particulates and their ability to enter the human body. The lower section illustrates the various types of air pollution control equipment and their general removal capabilities.

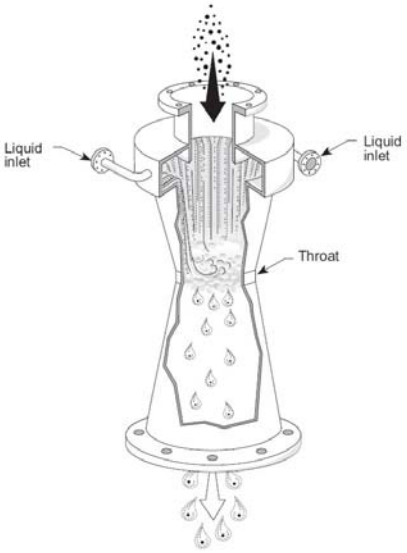


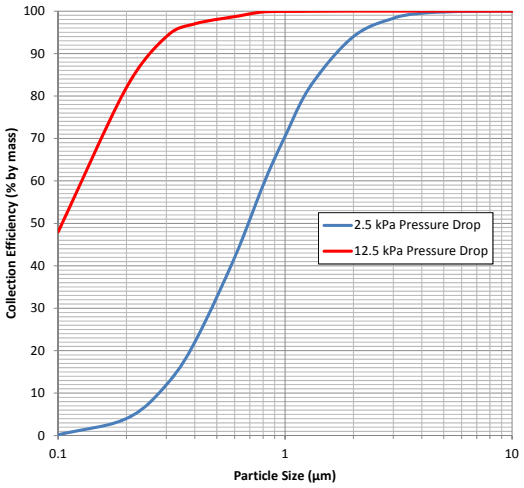
Adapted from "Characteristics of Particles and Particle Dispersoids" Stanford Research Institute Journal, 3rd Quarter (SRI, Mento Park, California 1961)

Wet Scrubbers

Venturi Scrubbers

A venturi scrubber consists of a converging throat section and a diverging and separating section. The inlet gas stream enters the converging section and, as the area decreases, gas velocity increases (in accordance with the Bernoulli equation). Liquid is introduced either at the throat or at the entrance to the converging section.





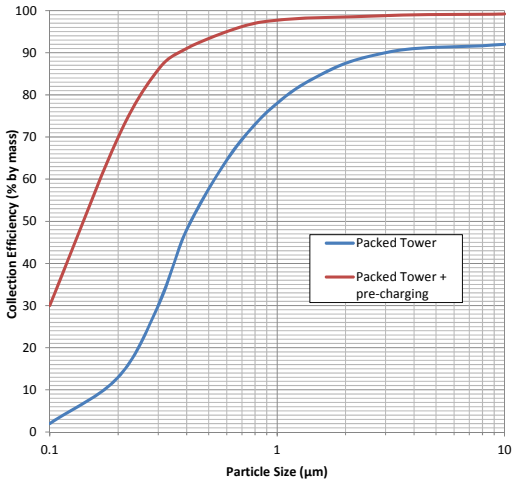
The inlet gas, forced to move at extremely high velocities in the small throat section, shears the liquid from its walls, producing an enormous number of very tiny droplets. The higher the pressure drop across the throat, the higher the velocities and the higher the removal efficiency.

Particle and gas removal occur in the throat section as the inlet gas stream mixes with the fog of tiny liquid droplets. The exhaust stream then exits through the diverging section, where it is forced to slow down and is separated from the gas stream.

Packed Tower Scrubbers

Packed tower scrubbers, like TAPC's **c-SORB™** range, are primarily used for gaseous pollutant control but have the capability of removing small amounts of particulate matter as well.

Particle and gas removal occur in the packed bed section as the inlet gas stream mixes with the tiny liquid droplets and liquid film. The clean gas stream then exits through the top of the packed tower where it passes through a mist eliminator to remove any entrained droplets.



As an additional enhancement, pre-charging can be added to make the particulate matter migrate to the liquid surface using electrostatic forces. This can aid in the removal of sub-micron particles.

TAPC v-SORB™
Venturi System
(WA)

TAPC Aeromix™
Low DP Scrubber
(NSW)

When to use a Venturi Scrubber:

- Gas temperatures between 10 and 1500°C
- Light to heavy dust loads
- Small to large gas volumes
- Particulate sizes above 1µm

When to use a Packed Tower:

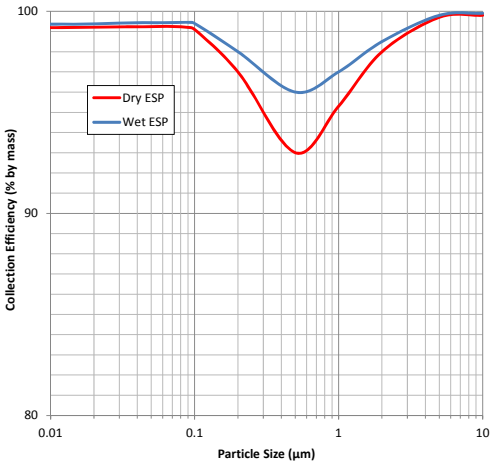
- When gases are the primary pollutant and there is a very light dust load.

Advantages:

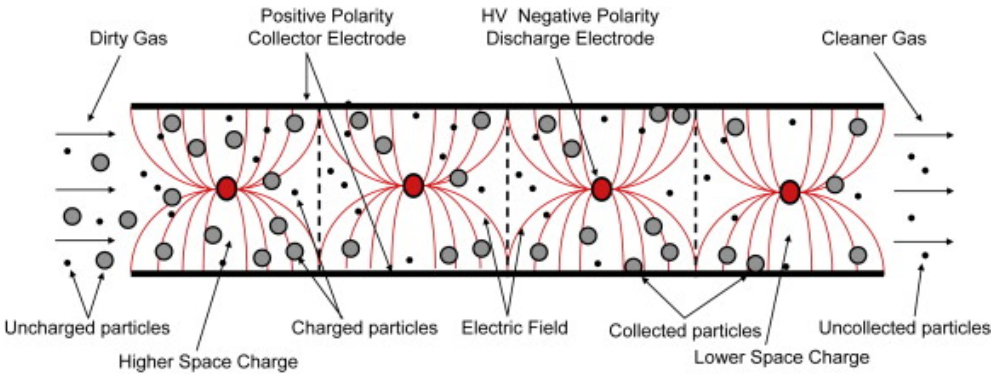
- Small footprint
- Low maintenance costs
- Can also be used to remove gaseous pollutants

Electrostatic Precipitators

An electrostatic precipitator (often abbreviated to "ESP", "EP" or "precip"), is a particulate collection device that removes particles from a gas stream using the force of an induced electrostatic charge. Electrostatic precipitators are highly efficient filtration devices that operate at a very low pressure drop, and can easily remove fine particulate matter such as dust and smoke from the air stream. In contrast to wet scrubbers and fabric filters, which apply energy directly to the flowing fluid medium, an ESP applies energy only to the particulate matter being collected and therefore is very efficient in its consumption of energy (in the form of electricity).



A very high voltage (typically 40,000 to 110,000 Volts) is developed across an air gap between a discharge electrode (in red below) and a flat metal collecting surface or plate (in black). The process gas (laden with dust) passes between these collecting surfaces and in so doing passes through the highly energised electric field. The dust particles are then charged negatively by cascading electrons and gas molecules. The strong electrical field then drives the dust to the collecting plates where it's deposited.



When to use a Dry ESP:

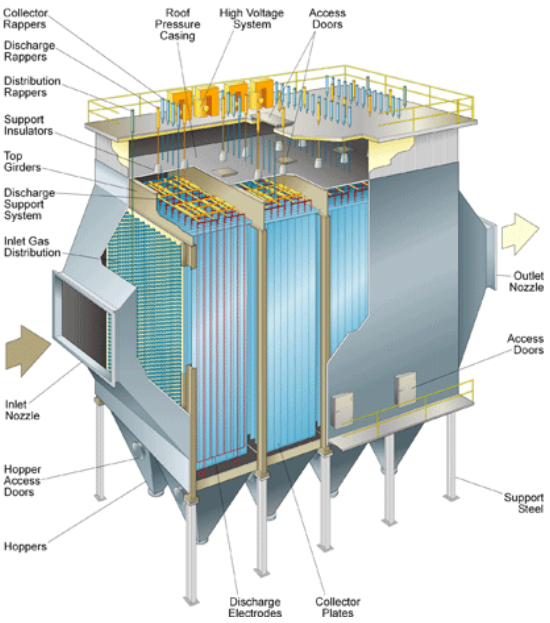
- Gas temperatures between 100 and 400°C
- Medium to heavy dust loads
- Large gas volumes with steady process conditions

When to use a wet ESP:

- Mixed stream of droplets and particulate

Advantages:

- High removal efficiencies
- Very low pressure drop (typically 0.4kPa)
- Low operating costs
- Low maintenance costs



TAPC ESP Projects

Cement (NZ)

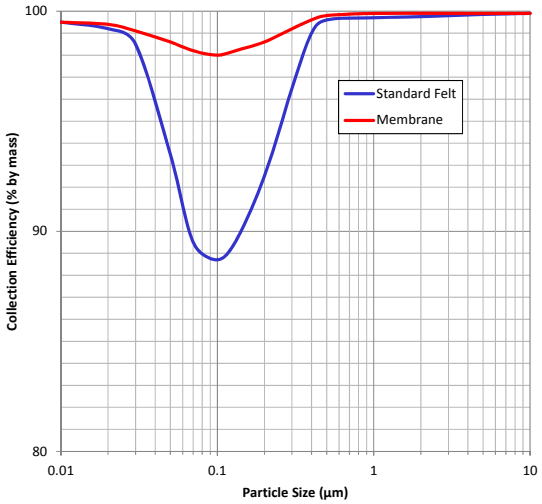
Steel Making (South Australia)

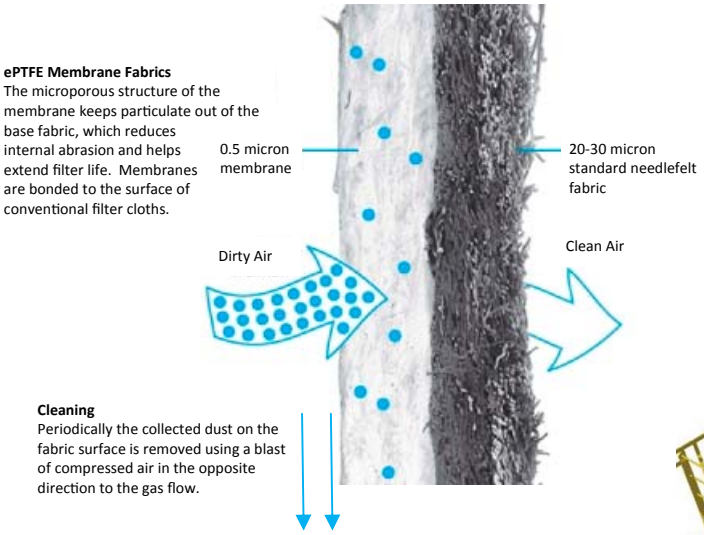
Nickel (Queensland)

Coal Fired Boiler (Western Australia)

Fabric Filters

Fabric Filters (also called baghouses and bagfilters) are air pollution control devices that remove particulate matter from a gas stream by passing the dirty air through a layer of cloth. The particulate matter deposits on the cloth surface and the clean air passes through. Of all the air pollution control technologies, fabric filters are the predominant particulate removal device used in industrial processes today.





When to use a Fabric Filter:

- Gas temperatures up to 260°C
- Light to heavy dust loads
- All gas volumes, even with varying process conditions

When to use Membrane Filter Elements:

- For ultrafine dusts (d_{50} <10µm)

Advantages:

- High removal efficiencies
- Moderate pressure drops (typically 0.8 to 2.0kPa)
- Dependable emissions
- Low capital costs

TAPC PowerJet™ Fabric Filter Installations

Cement Plant (NSW)	Alumina Refinery (Queensland)	Coal Processing (Indonesia)	Wood Fired Boiler (Tasmania)	Paint Manufacturer (Queensland)

Mists and Droplets

Liquid material conveyed in a gas stream can be referred to in numerous ways including "mist" and "droplets". There are a number of styles of equipment for removing mists, each with their own specific characteristics, advantages and disadvantages. Below is a general guide of the mist removal devices that we manufacture, with a brief outline of their relative capabilities. In all cases, please contact our engineers so that we can determine the correct solution to your air pollution control issues.

UltraFine Mist (<20 µm)

Acid Mist Electrostatic Precipitator

Acid Mist electrostatic precipitators (or MESPs) are one of the original styles of ESP developed over 100 years ago by Dr Frederick Cottrell to collect sulfuric acid fumes. The design has evolved significantly since then. Traditionally these units were built from lead to withstand the sulfuric acid mist, whereas today we build our units from advanced plastics with carbon and platinum earthing. These units are typically used in sulfuric acid plants to separate out fine particulate and sulfuric acid mist from the SO_2-rich gas stream, hence protecting the SO_2/SO_3 converter catalyst downstream.

Six-Cell Acid Mist ESP using advanced TAPC supplied internals (South Australia)

They have the following advantages:

- Very low pressure drop whilst maintaining high removal efficiencies of mists
- Can capture fine particulate without blocking
- Can be arranged in multiple parallel modules for larger gas volumes
- Can be arranged in series for higher collection efficiencies (>99%)

Brink Mist Eliminator Filters

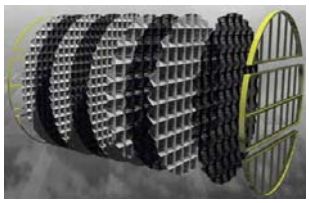
- Good for capturing ultrafine acid and organic mists from sources such as chlorine plants, asphalt plants, sulphuric and nitric acid plants, vinyl curing operations and other applications producing condensed organic mists.
- Good in applications involving smaller gas volumes without particulates present.

Fine Mists (20-100 µm)

Kimre B-GON® Mist Eliminators

Consist of multiple layers to allow for removal of different size materials at each stage

- Heavy loads of solid particulates or liquids can be stopped with coarse styles while less coarse styles eliminate small liquid droplets.
- Cross-flow of captured liquid helps flush particulates from the media.
- Each pad can be designed to achieve a given mist removal performance and liquid handling capability.



Kimre™ System (South Australia)

Chevron Mist Eliminators

Special chevron design allows for high velocity operation up to 5 m/s

- Existing towers with mesh pads can be retrofitted to minimize fouling and pad replacement
- Wide blade spacing provides excellent resistance against potential plugging in applications with high solids loading
- Effectively removes liquid droplets down to 25 microns
- Available in vinyl ester fiberglass reinforced plastic, polypropylene, carbon, and stainless steel

Chevron System (South Australia)

Acid Gases

Acid gases are a class of gaseous compounds that form an acidic solution when dissolved in water. By definition, they are all soluble in water but the degree of their solubility and their concentration can dictate the type of technology used in their capture.

Hydrogen Halides (HCl, HBr, HF)

Hydrogen halides (HCl, HF, HBr) often result from the burning of materials containing halide groups (plastics, salts, minerals, PCB etc.). Hydrogen Chloride (HCl) is highly soluble in water and forms hydrochloric acid. Hydrogen bromide is less soluble but forms hydrobromic acid. Hydrogen fluoride is only weakly soluble and forms only a weak acid. Because of these varying solubilities, the size and type of gas scrubbing varies with each.

HCl and HBr are generally captured using an alkaline water solution in a **TAPC c-SORB™** packed tower. HF, however, is typically captured using a dry scrubber with lime powder injection and a **TAPC PowerJet™** fabric filter.

TAPC c-SORB™ Scrubber plant removing HCl (NSW)

TAPC PowerJet™ Dry Scrubber for HF removal

Sulfur Oxides (SOx)

Sulfur dioxide and sulfur trioxide often result from the burning in oxygen of materials containing sulfur compounds (coal, oil, metallurgical ores.). Typically sulfur trioxide and sulfur dioxide co-exist in an exhaust stream with a ratio of around 20 to 25:1 SO_2:SO_3. Both SO_2 and SO_3 are highly soluble in water, making water based scrubbing desirable.

We have two technologies for removing SOx from a gas stream. The first is the **MECS Dynawave®** system which uses a reverse jet scrubbing action. This system is designed for large gas volumes containing high concentrations of SOx. Additionally, we also build advanced **TAPC c-SORB™** packed tower scrubbers which use an alkaline (typically caustic) scrubbing solution. Removal efficiencies are typically >98%.

SO_2 Scrubbing **Dynawave®** Plant on a steel process in Western Australia

TAPC c-SORB™ Scrubber removing SO_2 on a coal fired power boiler in Queensland

Nitrogen Oxides (NOx)

NOx is typically a general term for a mixture of nitric oxide (NO) and nitrogen dioxide (NO_2). Both are formed in burning processes where oxygen is present, especially at high temperatures. NOx is one of the prime constituents of photochemical smog.

Nitric oxide is low in solubility, hence it must be oxidised to nitrogen dioxide to be effectively scrubbed in a water-based chemical scrubber. In this case, a multiple-stage approach is required to remove NOx with a **TAPC c-SORB™** chemical scrubber.

At higher temperatures (above 340°C), Catalytic Destruction of NOx is the preferred option. Ammonia or urea is injected into the gas stream prior to the catalyst, and via a series of complex reactions, nitrogen (N_2) and water are produced.

NO, NO_2, HNO_3 Multistage **c-SORB™** scrubbing plant, Victoria

NOx **Catalytic Destruction** plant, Western Australia

Other Acid Gases

There are numerous other gases that can be defined as “acid gases”. Hydrogen Sulfide (H_2S) can be classed as an acid gas—please see our section on Odour Removal for more details of H_2S abatement. Other acid gases such as organic acids (phenolic, acetic etc.) have their removal systems defined by their relative solubility. We have various acid gas c-SORB™ scrubbing plants installed and pride ourselves on being able to remove any pollutant from a gas stream.

Alkaline Gases

Similar to Acid Gases (page 2), Alkaline gases are, by definition, water soluble. In a water solution they create an alkaline pH of above neutral (7.0). The degree of solubility directly affects the type and size of equipment used to remove them.

Ammonia (NH_3)

Ammonia is a very common industrial chemical, being a precursor to fertilizers and a building-block for the synthesis of many pharmaceuticals. It is also produced in the decay of nitrogenous animal and vegetable matter and can be a component of the odours emanating from abattoirs and animal production. Ammonia readily absorbs into water, hence it is well suited for water based absorption scrubbing systems.

Based on this ammonia has generally been removed by **TAPC c-SORB™** packed tower scrubbers using an acidic reagent (typically sulphuric acid). In recent years, biotrickling filters (**TAPC b-SORB™**) have emerged as another alternative. These units utilise biological agents to bio-degrade ammonia.

TAPC **c-SORB™** Packed Tower Scrubber plant removing Ammonia (QLD)

TAPC **Venturi** Scrubber with **c-SORB™** removing Ammonia

Amines ($R\text{-}NH_2$, $R2\text{-}NH$, $R3\text{-}N$, $Ar\text{-}NH_2$)

Amines are organic compounds that are derivatives of ammonia, where one or more hydrogen atoms have been replaced by a substituent such as an alkyl or aryl group. Common industrial amines include dimethylamine, biogenic amines, trimethylamine, and aniline. Simple amines are water soluble, but as they become more complex with increasing numbers of carbon groups, their solubility drops. Hence, scrubbing solutions vary with the chemistry of each type of amine.

A typical application is foundry ventilation where triethylamine (TEA) is evolved from the core box sand. Due to its solubility, a **TAPC c-SORB™** chemical scrubber is generally used to remove this compound.

TEA Packed Tower Scrubber plant, USA

Mercury

In gas streams mercury typically exists in two forms; mercuric oxide (HgO) and elemental mercury (Hg). Mercuric oxide forms when the metal is exposed to air for long periods at elevated temperatures. At around 400°C mercuric oxide converts to elemental mercury. Mercuric oxide and elemental mercury are toxic substances which can be absorbed into the body by inhalation , through the skin and by ingestion. They are irritating to the eyes, the skin and the respiratory tract and may have effects on the kidneys, resulting in kidney impairment. In the food chain, bioaccumulation takes place, specifically in aquatic organisms causing higher food chain members to concentrate mercury. Atmospheric mercury is produced from a number of industrial processes including coal fired power (65%), gold production (11%), cement production (6%), and non-ferrous metal smelters (like lead)(7%).

As mercury typically exists in two forms, it is important to design a removal system based on the quantities of each. Mercuric oxide exists as a fine particulate in industrial gas streams. It is largely insoluble in water, hence particulate collectors such as **TAPC PowerJets™** are used.

Elemental mercury is a gas, which is soluble in water, hence a gas scrubbing solution is needed. This can be removed either through a chemical scrubber (**c-SORB™**) or by activated carbon (**a-SORB™**). Mercury removal plants typically have two stages either:

1. A particulate removal device (fabric filter or venturi scrubber) followed by a packed bed scrubber.
2. An activated carbon injection/mixing system followed by a fabric filter.

Please contact us so that we can determine what is right for your plant.

Volatile Organic Compounds (VOCs)

Volatile organic compounds (VOCs) are organic chemicals that have a high vapour pressure at ordinary, room-temperature conditions. Their high vapour pressure results from a low boiling point, which causes large numbers of molecules to evaporate or sublimate from the liquid or solid form of the compound and enter the surrounding air. An example is formaldehyde, which has a boiling point of –19°C and over many years, slowly exits wall paint and is detectable in most indoor environments.

VOCs are extremely numerous. They include both human-made and naturally occurring chemical compounds. Some VOCs are dangerous to human health or cause harm to the environment, such as dioxins and furans. Harmful VOCs are typically not acutely toxic, but instead have compounding long-term health effects. Because the concentrations are usually low and the symptoms slow to develop, research into VOCs and their effects is difficult.

The following is a general guide to the categories of VOCs and the air pollution control equipment suitable for each:

- Hydrocarbons (alkanes, alkenes, alkynes) and aromatic hydrocarbons (benzene, toluene, xylene etc.)
- Dioxins and Furans
- Solvents (aliphatic hydrocarbons, ethyl acetate, glycol ethers, and acetone) and Halogenated Hydrocarbons (Chlorohydrocarbons, Fluorohydrocarbons, Chlorofluorocarbons (CFCs) etc.)

Hydrocarbons and Aromatic Hydrocarbons

Hydrocarbons and aromatic hydrocarbons are generally insoluble in water which makes water based systems like biotrickling filters and chemical scrubbers incapable of capturing the pollutant. Activated carbon readily adsorbs these compounds and is the main method of capture. In simple, low concentration systems, the activated carbon may take the form of replaceable **a-SORB™ Canisters**. In larger systems such as large petroleum storage plants, where the gas being captured is valuable, the activated carbon can be desorbed to return the liquid hydrocarbon using either vacuum or steam. These systems are known as **a-SORB™ VRU**.

Typical pollutants removed in this style of system include compounds such as alkanes (C_nH_{2n+2}), alkenes (C_nH_{2n}), alkynes (C_nH_{2n-2}) and aromatic hydrocarbons such as Benzene, Xylene and Toluene.

TAPC **a-SORB™ Canister** (Victoria)

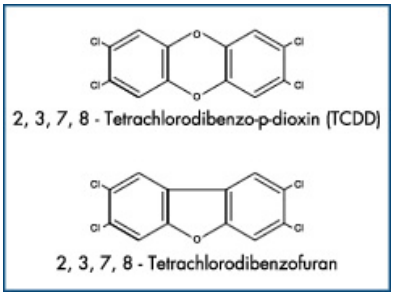
TAPC **a-SORB™ VRU** recovering Xylene and Toluene (Malaysia)

Dioxins and Furans

Dioxins and Furans (or more technically PCDDs and PCDFs) are organic compounds typically formed in burning processes that operate in the range of 400-700°C. They are a special class of VOCs called HAPs—Hazardous Air Pollutants. PCDDs and PCDFs are persistent in the environment and are considered highly toxic and able to cause reproductive and developmental problems, damage the immune system, interfere with hormones and also cause cancer.

We can take a number of approaches to remove these compounds from a gas stream depending on the gas composition and temperature:

- Low temperature (<50°C), Low concentration: **a-SORB™** Activated carbon systems can be used to adsorb these compounds.
- Medium temperatures (50°C to 400°C), any concentration: Thermal Oxidisers (**TO**s) or Regenerative Thermal Oxidisers (**RTO**s), followed by an acid gas **c-SORB™** scrubber.
- High temperatures (230°C to 700°C), any concentration: CRI Catalytic Destruction



CRI Catalyst Destruction System removing Dioxin (USA)

Thermal Oxidiser removing Dioxin (USA)

Solvents and Halogenated Hydrocarbons

Solvents and Halogenated Hydrocarbons are generally insoluble in water which makes water based systems like biotrickling filters and chemical scrubbers incapable of capturing the pollutant. Activated carbon readily adsorbs most of these compounds and is the main method of capture. In simple, low concentration systems, the activated carbon may take the form of replaceable **a-SORB™ Canisters**. In larger systems such as large chemical storage tanks, where the gas being captured is valuable, the activated carbon can be desorbed to return the liquid hydrocarbon using either vacuum or steam. These systems are known as **a-SORB™ VRU**.

Where the pollutant is an unwanted or dangerous compound, Thermal Oxidisers (TO), Regenerative Thermal Oxidisers (RTOs) and Catalytic Oxidisers are the preferred abatement choice. Typically a **TAPC c-SORB™** system will follow one of these devices to remove the resulting acid gases.

TAPC **a-SORB™ VRU** recovering acetone (Victoria)

Thermal Oxidiser and TAPC **c-SORB™** Acid Gas Scrubber on PCB soil remediation plant (NSW)

Odours and Smells

An odour (commonly referred to as a smell) is caused by one or more volatilized chemical compounds, generally at a very low concentration, that humans or other animals perceive by the sense of olfaction. Bad smells and odours are, by far, the largest complaints received by environmental protection agencies world wide. So whilst they may only be very low concentrations, and may not be harmful, they can cause the most offence to the public. The following is a general guide to the categories of odours and the air pollution control equipment suitable for each.

Hydrogen Sulfide (rotten egg gas)

Hydrogen Sulfide (H_2S) often results from the bacterial breakdown of organic matter in the absence of oxygen, such as in swamps and sewers; this process is commonly known as anaerobic digestion. Typical sources of H_2S are sewage treatment plants and land fill sites. Rotten egg gas is one of the most common and most complained about odours.

We have three tried and proven approaches to removing H_2S from gas streams. These include:

- **a-SORB™** Activated Carbon
- **b-SORB™** Biotrickling Filters
- **c-SORB™** Chemical Scrubbers

We have multiple installations of each of these technologies.

TAPC **a-SORB™ Activated Carbon** system on a sewer ventilation system (NSW)

TAPC **b-SORB™ Biotrickling Filter** on a Waste Water Treatment Plant (NSW)

TAPC **c-SORB™ Chemical Scrubber** on a Waste Water Treatment Plant (WA)

Rendering Plants, Abattoirs, Livestock facilities

Characterizing malodorous chemicals in these processes is difficult because they vary in nature and occur in trace amounts. The amount and type of odorant also varies significantly from installation to installation.

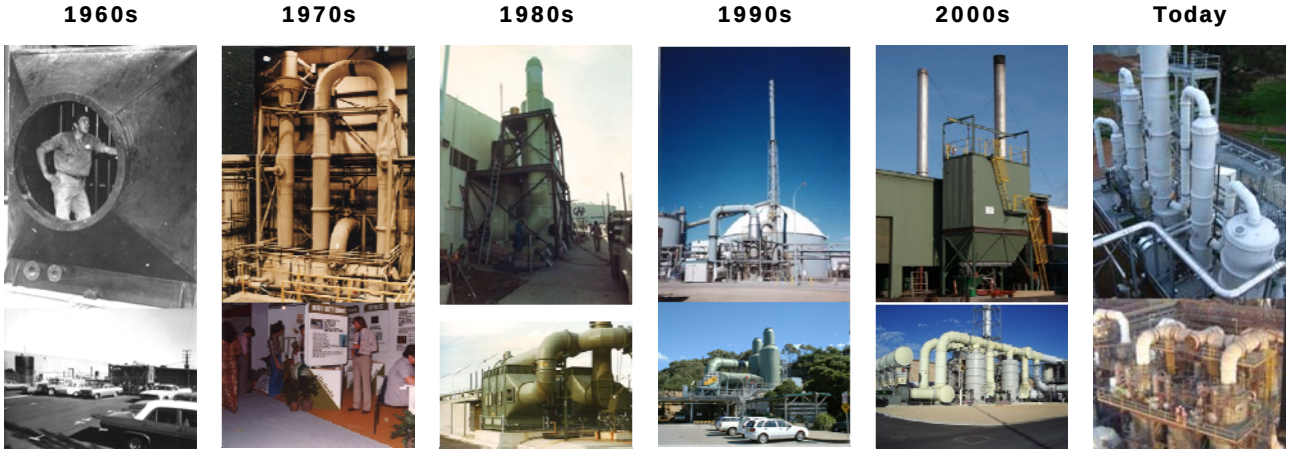
We have three tried and proven approaches to removing odours from these type of process gas streams. These include:

- **a-SORB™** Activated Carbon
- **b-SORB™** Biotrickling Filters
- **c-SORB™** Chemical Scrubbers

TAPC **c-SORB™ Chemical Scrubber** on a Pet Food Facility (NSW)

TAPC **c-SORB™ Chemical Scrubber** on a Rendering Plant (Victoria)

Air Pollution Control Experts since 1968



History

In 1968 Ceilcote Tasmania was formed as a specialist producer of fibreglass packed bed scrubbers based on Tellerette packing. Ceilcote became Transfield RPC in the 1980s and Horizon APC in the 1990s. In 1998 the Environmental Group (EGL) acquired Horizon APC to augment its existing air pollution control business that included activated carbon systems and flares. From 1998 until 2012, the business grew to become the largest in Australia at removing gaseous pollutants from industrial processes.

In 2001 TAPC was formed as the Australasian representative for BHA Group Inc (now GE Energy). TAPC quickly established itself as one of the region's leading industrial air pollution control companies in the field of particulate capture using electrostatic precipitators and fabric filters.

In 2007 the Environmental Group (EGL) acquired TAPC to add particulate capture technologies to its already substantial gaseous pollutant technologies. In 2012 it was decided to merge the two business units into one entity; Total Air Pollution Control (TAPC). In so doing, forming Australia's largest and most comprehensive air pollution control company. No matter what the pollutant, TAPC has the technology, experience and capability to capture it.

EGL is listed on the Australian stock exchange under the code "EGL". TAPC is a wholly owned subsidiary of EGL. EGL The Environmental Group Limited

Australia's Leading Air Pollution Control Company.

Gas Scrubbing

Fabric Filters

Electrostatic Precipitators

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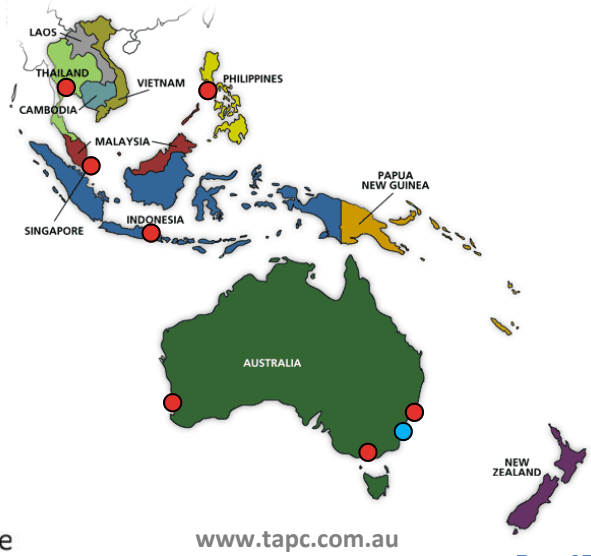

Quality ISO 9001 SAI GLOBAL | Environment ISO 14001 SAI GLOBAL | Health & Safety AS 4801 SAI GLOBAL

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