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Business-Led Initiative on Air Pollution in Hong Kong and the Pearl River Delta

Volatile Organic Compounds

Living Under Blue Skies Paper No.5

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“Living under Blue Skies” is a business-led initiative to reduce air pollution in Hong Kong and the Pearl River Delta.

Report prepared by the Business Environment Council (May 2006)

Table of Contents

1. Introduction

This paper has been prepared by the Business Environment Council (BEC) to brief members on the nature of volatile organic compounds (VOCs) and the significance of these substances in air pollution.

This paper forms part of the series of reports produced by the BEC on a business-led initiative to improve air quality in Hong Kong and the region[1]. The following topics are covered within this paper:

- Background
- Regional context
- Hong Kong context
- Government and cross-boundary measures
- Examples of best practices
- Next steps

2. Background

2.1 What are VOCs?

VOCs are a family of chemical compounds that possess a high vapour pressure and low water solubility. Many VOCs are human-made and are used in, as well as produced from, the manufacture of paints, inks, adhesives, pharmaceuticals and refrigerants. In industry, VOCs are commonly used for processes such as degreasing, thinning and dissolving. Typical examples are trichloroethylene (industrial solvents), methyl tertiary-butyl ether also known as MTBE (fuel oxygenates), and chloroform (a by-product of chlorination in water treatment).

Figure 1. Typical VOC-containing products (Source: Environmental Protection Department)

[1] The "Living under Blue Skies" series looks at the causes of air pollution in the PRD region and proposes measures that can be adopted to improve air quality. The reader is referred to previous papers prepared by BEC as follows: Paper 1. *A Review of Air Pollution in Hong Kong and the PRD*; Paper 2. *Market Mechanisms for Tackling Air Pollution*; Paper 3. *Case Studies in Air Pollution Abatement*; and Part 4. Clean Energy Review of the PRD.

2.2 Harmful Properties of VOCs

Some VOCs have harmful properties. These types include benzene, its derivatives, especially polycyclic aromatic hydrocarbons, and butadiene compounds. Benzene in particular increases susceptibility to leukaemia in humans exposed for prolonged periods. There are several hundred benzene derivatives, also known as aromatic hydrocarbons, which arise from natural and man-made sources and are cancer causing. Some are called polycyclic after their complex molecular structure.

Butadiene compounds have similar harmful properties to benzene-containing chemicals, as there is a correlation between butadiene exposure and risk of cancer. These compounds are formed in the manufacturing of synthetic rubbers, are in the emissions from petrol-driven vehicles, and in cigarette smoke.

VOCs contribute to the formation of atmospheric ozone (O_3), usually under sunlight conditions. Ground-level ozone is a highly reactive gas that in high concentrations can irritate the eyes and cause upper- and lower-respiratory problems, even in healthy people. Further, atmospheric ozone may provoke asthmatic attacks in people given to such complaints. Some evidence suggests exposure to high concentrations of O_3 may permanently damage lung tissue and interfere with the immune system.

2.3 The Problem of Smog

VOCs are one of the principal causes of photochemical smog, or smog, which is produced when they react in the sunlight with nitrogen oxides (NO_x) and particulates.

Smog was originally named for the mixture of smoke and fog. But fog is mistaken for pollution when it is merely the result of evaporated surface moisture rising, cooling and condensing.

Smog, on the other hand, is a form of pollution and it is worse during periods of warmer, sunnier weather when the upper air is warm enough to inhibit vertical circulation. It is especially prevalent in geologic basins encircled by hills or mountains e.g. Hong Kong.

Figure 2. Hong Kong's Smog Problem (Source: AFP Press)

Smog is highly visible and pervasive and often lingers over densely populated cities, earning them a direct association with poor air quality. Direct scientific measurements of smog are difficult. Being the mixture of different individual pollutants, smog concentrations are impossible to quantify. Instead, visibility impairment is used as the measure of smog intensity.

The photochemical formation of smog from VOCs is shown below:

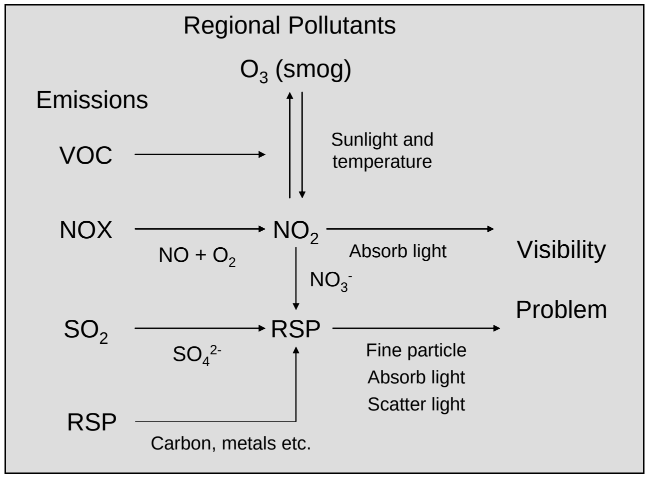

Figure3. Formation of Smog (Source: Environmental Protection Department)

Most VOCs have the potential to form smog, but the potential of various compounds to do so varies greatly: those most likely are butane, ethanol, and toluene.

Ozone creating VOCs	**Sources**
Butane	Evaporative, refining and distribution losses from petrol, solvents and petrol-handling
Ethanol	Solvent use and production processes, particularly in the food industry
Toluene	Petrol exhausts and from solvents used for industrial purposes

Table 1. Ozone-creating VOCs and their Sources

The most common human activities that give rise to non-methane VOCs are shown in Appendix A.

3. Regional Context

3.1 VOC Emissions in the PRD

More VOCs are being produced in the Pearl River Delta (PRD) each year. In 2005, the region produced at least 60,000 tonnes – 44 per cent more than in 2002, when a Hong Kong Government study[2] took air inventory measurements. Just over a tenth of this came from Hong Kong. VOC production is predicted to grow further, as the table below shows.

Classification		Pollutant	1997	2000	2005	2010	2015
Emission (kilo tonnes per year)	HK	VOC	54	57	67	79	95
	PRD	VOC	412	574	603	504	537
Regional Emission Growth from 1997		VOC	-	36%	44%	25%	36%

Table 2. VOC Emissions in the PRD and Hong Kong

The main activities and places that use and emit VOCs in a regional context are driving, (during which the VOCs are emitted in motor vehicle emissions) and petrol-filling stations. Otherwise, paints and printing inks, dry cleaning operations and specific consumer products also contribute to emissions of VOCs. The 2002 study estimated that by 2005 some 60 per cent of VOC emissions would be from vehicles, and that consumer products would account for the next highest contribution – 28 per cent. Be that as it may, other influences since then, including rapid economic growth, may have affected the predictions made in the report: Hong Kong's own data show that its VOC levels in 2005 are lower than the 67 kilo tonnes per year forecast in the 2002 report.

3.2 Cross-Boundary Cuts

In 2002, the Hong Kong and the Guangdong Governments set up a joint initiative to reduce smog-related pollution in the region as part of a joint agreement. Each set itself a 2010 target to cut VOC emissions by 45 per cent from 1997 levels. The initiative included sulphur dioxide, nitrogen oxides, particulates and other air pollutants[3].

[2] Environmental Protection Department, "Study of Air Quality in the PRD" (2002)

[3] Agreed reduction targets (based on 1887 levels) are sulphur dioxide – 40%; nitrogen oxides – 20%; respirable suspended particulates – 55%; and VOCs – 55%.

Figure 5. Typical Coating Unit in PRD Factory (Source: BEC)

The Guangdong statistical handbook shows that in 2001 the PRD accounted for more than half of Mainland China's total production of telephones, printers, fax machines, digital switches, electrical fans, hi-fi equipment, electric rice cookers, microwave ovens, cameras and gas water heaters. Given the scale involved, any reduction in the use of solvents for painting, coating or cleaning in these operations would contribute significantly to lowering VOC emissions. The Guangdong Government has also legislated to reduce the amount of solvents in paints, a key step in a raft of other measures.

4. Hong Kong Context

4.1 Better Technology Eases VOC Emissions

Since 1997, the overall level of VOC emissions in Hong Kong has fallen by almost a third, due partly to improved technology, particularly in transport sources, but also with the introduction of alternative products with either fewer or no VOCs. In 2004, figures released by the Environmental Protection Department show that almost 42,000 tonnes of VOCs were emitted in Hong Kong.

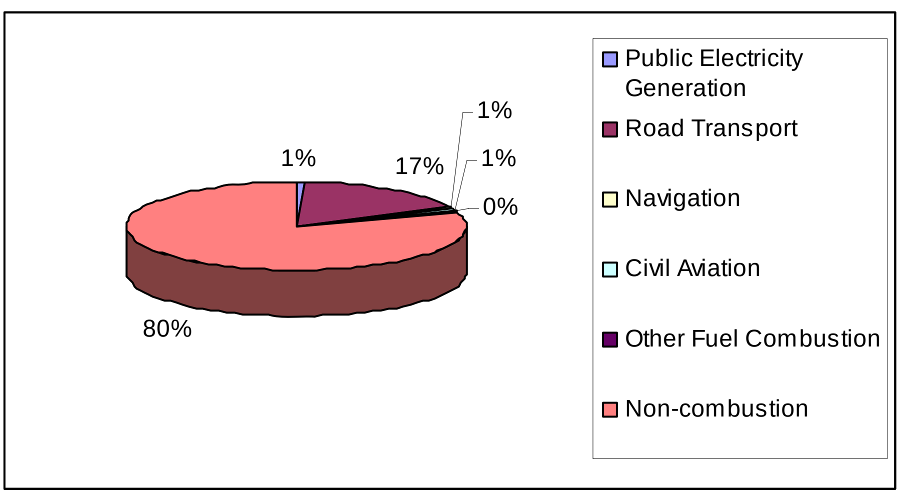

Figure 6. Breakdown of VOCs emitted in Hong Kong (Source: EPD)

As Figure 6 shows, by far the most VOCs come from the category of non-combustion, which comprises consumer products, paints and printing. Each of these segments is roughly 20-30 per cent of all of VOC emissions in Hong Kong.

4.2 Government Measures

The focus of the Hong Kong Government has been to introduce limits on VOCs:

- For consumer products, limits are to be introduced by January 2009 in stages for hairsprays, insecticides, insect repellents, air fresheners, floor-wax strippers, and multi-purpose lubricants. Suppliers of some products will need to reformulate or source alternative products.
- In the paint industry, VOC limits set by January 2010 are to be based on the Californian standards used by the South Coast and Bay Area Air Management Districts. To comply with them, suppliers of paints will need to change their products, or replace some of the high-VOC, solvent-based paints with water-based alternatives.
- VOC limits on printing inks are to be introduced by January 2009. Special processes are exempted, such as screen printing (used on compact discs, handbags, decals, and signboards) and heat-set printing.

Figure 7.
Examples of VOC sources (clockwise from top left) paints, a printing press, and consumer products

5. Best Practices

In this section we look at examples of how alternative technology and process design can reduce or avoid VOC emissions.

5.1 Alternative Inks for the Printing Industry

VOCs are used throughout the printing industry. Applications of VOC materials are common in screen and plate adhesives, on-press solvents, inks, and screen-reclamation systems. Within the printing industry, about 82 per cent of emissions come from VOC-containing materials with the remaining 18 per cent from ink.

In Canada, a partnership between Environment Canada and the Specialty Graphic Imaging Association established a programme[4] for the industry to shift to using UV curable ink systems rather than relying on a fast-evaporating solvent component. UV inks contain less than 1 per cent of VOCs by content. This reduced by at least 40 per cent total VOC emissions from the participating graphic screen-printing facilities.

Elsewhere, the textiles and the graphic display industries are also turning to alternatives: textiles makers are using water-based plastisol inks, and paper printers for indoor graphic displays are choosing low-VOC or water-based inks.

5.2 Changing the Paint Industry

Paints have a wide variety of applications, not least of which are as architectural and product coating. Solvents make up 60 per cent of most conventional paints by volume. Typically only 25 per cent is solids, with the balance consisting of a mixture of substances such as primer. VOCs are added to paints to disperse paint constituents, such as binders, pigments, and additives, and to thin the solution so that it can be applied manually, or as a high-pressure air spray.

In architectural paints, waterborne coatings can reduce VOC emissions. The reduction of VOCs in these kinds of paints has financial benefits too: less paint volume is needed, and with fewer toxic residues the disposal costs of paint waste is decreased.

Many product manufacturers are also trying to switch to waterborne paints. In a 1997 report, the carmaker Chrysler[5] detailed how by substituting waterborne coatings for solvent-based coatings it was able to reduce its emissions significantly in the US whilst saving between US$20,000 and US$30,000 per year by eliminating the costs of disposing of hazardous waste. Additional savings came from lower fire insurance premiums.

Another option is to eliminate unnecessary paints and coatings that are used only for appearances[6]. Not only does this reduce capital, operating and maintenance costs, but it also reduces potential liability from toxic chemical use. The use of injection-molded plastic sheets in place of painted metal cabinets in the electronics industry is one example of this trend. If a coating is needed to provide an engineering function, such as improved

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[4] Environmental Performance Agreement between Environment Canada and Specialty Graphic Imaging Association (2003)

[5] Waste Minimization at Chrysler Corporation (1997)

[6] Northeast Waste Management Officials' Association (USA), Metal Painting and Coating Operations Handbook (1989)

corrosion resistance, some companies have changed to a base material that does not require a coating, like plastic, aluminum, or titanium.

5.3 Solvent Recovery in Manufacturing

US company DuPont manufactures synthetic fibres, and uses the VOC dimethyl-formamide as a solvent in the process. Typically each year until 1995 the company released 1,700 tonnes of VOCs to the atmosphere. But under legislative pressures, DuPont undertook to recycle the solvent[7].

In general, solvent can be recovered by distilling collected solvent waste either in batch or continuous stills. Continuous stills are more commonly used for chemical manufacturing, paint stripping and paint degreasing and can recover large amounts of solvent faster than batch stills. However, to be cost effective they require sufficient quantities of solvent waste to be fed continually.

DuPont decided to recycle the solvent vapour using a water scrubber and distillation set-up. By establishing a continuous still system comprising two scrubbing columns, a packed column and bubble cap collection trays, the company was able to recover 1,400 tonnes of solvent per year. Overall air emissions from the manufacturing plant fell 70 per cent, and the need to purchase virgin solvent decreased, bringing savings.

5.4 Cleaner Production Method

Pharmaceutical giant GlaxoSmithKline's R&D site in Triangle Park, North Carolina, in the US, developed a new drug-manufacturing process that reduced waste and solvent use and eliminated the use of other harmful substances[8]. Time-consuming and inefficient, the processes this replaced involved up to eight steps. The new process involves only three steps and with many advantages.

- As solvents are needed to aid synthesis at each step, fewer steps mean less solvent is required – 70 per cent less – as well as lower VOC emissions.
- Some 70 per cent less waste is produced.

In summary, there are methods and technologies available to reduce the emission of VOCs from industries. These can be applied to Hong Kong and PRD industries with the right incentives and motivation. Economic activity will not cease per se but it is possible to adopt alternatives to reduce the impact caused by VOC emissions.

[7] Virginia Department of Waste Management, "Fact Sheet: Solvent Recovery in a Fiber Production Plant"
[8] Glaxo Corporate Environmental Report (2005)

6. Conclusions

In conclusion, as can be seen, VOCs not only contribute to Hong Kong's air quality problems but also have the potential and been shown to harm human health.

There is a broad base of major sources – substances and activities – of VOC emissions in the region, among which are vehicles, consumer products, paints and printing inks.

Legislation to limit the use of VOCs in the PRD region is coming into place driven largely by the 2010 emission reduction targets set under the joint government agreement.

In Hong Kong, as legislation controlling VOCs becomes more stringent and emission standards are tightened, industry will have to find new methods of operation where these pollutants must be involved.

Otherwise, companies may review their operations for how solvents can be replaced, such as through the use of water-based paints. Or, they may remove the need for VOC-containing materials through re-engineering a manufacturing process, changing a product's design, or recovering VOCs through solvent recovery systems, provided there is sufficient scale.

By 2010, it is likely that certain consumer products, paints and printing inks that are high in VOC content will be banned in favour of low-VOC or water-based alternatives. The sourcing of such alternatives on the market may present businesses with challenges, as may price differences since these alternatives at present are twice the price: such costs may have to be passed on to the customers.

Pricing notwithstanding, this shift should be encouraged, and government and business must work closely to enable new products to be introduced in the market and new materials and technologies made available.

As Hong Kong's industry sectors, namely printing, paints and consumer products, are working towards achieving reduction in VOC-based emissions, successful methods developed in Hong Kong could possibly be extended to the region.

Appendix A

*Top VOC-Emitting Human Activities**

Non-methane volatile organic compounds activity emissions

Road transport – passenger cars: urban driving

Road transport – gasoline evaporation from vehicles

Road transport – passenger cars: rural driving

Commercial, institutional and residential –combustion plants

Solvent use – paint application: other industrial application

Solvent use – paint application

Solvent use – domestic solvent use (other than paint application)

Solvent use – other use of solvents and related activities

Waste treatment and disposal – open burning of agricultural wastes

Solvent use – metal degreasing

Gasoline distribution – service stations (including refuelling)

Solvent use – paint application: construction and buildings

Road transport – passenger cars: highway driving

Extraction, 1st treatment and loading of liquid fossil fuels – off-shore

Road transport – mopeds and motorcycles < 50 CM3

Agriculture – animal breeding (excretions): fattening pigs

Solvent use – printing industry

Road transport – heavy duty vehicles and buses: urban driving

Road transport – heavy duty vehicles and buses: rural driving

Road transport – light duty vehicles < 3.5 t: urban driving

Other mobile sources – off road vehicles and machines: agriculture

Solvent use – paint application: domestic use

Solvent use – application of glues and adhesives

Road transport – heavy duty vehicles and buses: highway driving

Road transport – motorcycles < 50 CM3: urban driving

Road transport – motorcycles < 50 CM3: road driving

* Adapted from Corinair 1990 Top30 activities for Europe (Sept. 1995), http://reports.eea.europa.eu/EMEPCORINAIR3/en/BTOP.pdf, viewed 9 June 2006

Appendix B

Plan for control on VOCs in consumer products

Type of Products	Max. VOC Limits	Implementation Date
Hairsprays – US Federal Standard	80	1 January 2007
Multi-purpose lubricants	50	1 January 2008
Floor wax strippers		1 January 2008
Light and medium polish build-up	3	
Heavy polish build-up	12	
Double phase aerosol air fresheners	25	1 January 2008
Single phase aerosol air fresheners	30	1 January 2008
Dual purpose air freshener and disinfectant aerosol air fresheners	60	1 January 2008
Flea and tick insecticides	25	1 January 2008
Insecticide foggers	45	1 January 2008
Aerosol lawn and garden insecticides	20	1 January 2008
Hairsprays – CARB standard	55	1 January 2009
Aerosol flying bug insecticides	25	1 January 2009
Air fresheners (solid or gel)	3	1 January 2009

Plan for control on VOCs in consumer products, continued

Type of Products	Max. VOC Limits	Implementation Date
Air fresheners (liquid or pump spray)	18	1 January 2009
Aerosol insect repellents	65	1 January 2009
Aerosol crawling bug insecticides	15	1 January 2009

Plan for control on VOCs in architectural paints *Appendix C*

Type of Products	Max. VOC Limits	Implementation Date
(a) Bond Breakers	350	1 January 2008
Clear Wood Finishes		
(b) Varnishes	150	1 January 2010
(c) Sanding Sealers	150	1 January 2008
(d) Lacquers	550	1 January 2010
(e) Clear Brushing Lacquers	650	1 January 2008
(f) Concrete-Curing Compounds	350	1 January 2008
(g) Dry-Fog Coatings	400	1 January 2008
(h) Fire-Proofing Exterior Coatings	350	1 January 2008
Fire Retardant Coatings		
(i) Clear	650	1 January 2009
(j) Pigmented	350	1 January 2010
(k) Flat Coatings	50	1 January 2009
(l) Floor Coatings	250	1 January 2010
(m) Graphic Arts (Sign) Coatings	500	1 January 2008
(n) Industrial Maintenance Coatings	250	1 January 2010
(0) High-Temperature Industrial	420	1 January 2010
Maintenance Coatings	250	1 January 2010
(p) Zinc-Rich Industrial		

Plan for control on VOCs in architectural paints continued *Appendix C*

Type of Products	Max. VOC Limits	Implementation Date
Maintenance Primers		
(q) Japans/Faux Finishing Coatings	350	1 January 2009
(r) Magnesite Cement Coatings	450	1 January 2008
(s) Mastic Coatings	300	1 January 2008
(t) Metallic Pigmented Coatings	500	1 January 2010
(u) Multi-Color Coatings	250	1 January 2009
(v) Non-Flat Coatings	150	1 January 2009
(w) Pigmented Lacquers	275	1 January 2008
(x) Pre-Treatment Wash Primers	420	1 January 2010
(y) Primers, Sealers and Undercoaters	200	1 January 2010
(z) Quick-Dry Enamels	250	1 January 2010
(aa) Quick-dry Primers, Sealers and Undercoaters	200	1 January 2010
(ab) Recycled Coatings	250	1 January 2008
(ac) Roof Coatings	50	1 January 2008
(ad) Roofs Coatings, Aluminium	250	1 January 2008
(ae) Roof Primers, Bituminous	350	1 January 2009
(af) Rust Preventative Coatings	400	1 January 2010
Shellacs		
(ag) Clear	730	1 January 2008
(ah) Pigmented	550	1 January 2008
(ai) Specialty Primers	350	1 January 2008
(aj) Stains	100	1 January 2008
(ak) Interior Stains	250	1 January 2008

Swimming Pool Coatings		
(al) Repair	340	1 January 2008
(am) Other	340	1 January 2008
(an) Traffic Coatings	150	1 January 2010
(ao) Waterproofing Sealers	250	1 January 2010
(ap) Waterproofing Concrete/Masonry Sealers	400	1 January 2008
Wood Preservatives		
(aq) Below- Ground	350	1 January 2008
(ar) Other	350	1 January 2008
(as) Low-Solids Coatings	120@	1 January 2010
(at) Superior Durability	420	1 January 2010
Solvent-borne Coatings for Metal		
(au) Pre-Treatment Coatings for Metal	420	1 January 2010
(av) Extreme High-Gloss Coatings for Metal	420	1 January 2010
(aw) Granite Look-a-like Coating/ Textured Undercoaters	100	1 January 2009
(ax) All Other Architectural Coatings Not Listed Above	250	1 January 2008

Plans for controls on VOCs in printing ink **Appendix D**

Type of Products	Max. VOC Limits	Implementation Date
Lithographic ink	300	1 January 2007
Letterpress ink	300	1 January 2007
Gravure ink	300	1 January 2009
Flexographic ink - non-porous substrate	300	1 January 2007
Flexographic ink - porous substrate	225	1 January 2007
Flexographic fluorescent ink	300	1 January 2007
Screen printing ink	400	1 January 2009