

**USE OF BIOCIDES BY
RESIDENTIAL DUCT CLEANERS**

for

Canada Mortgage and Housing Corporation
Ottawa, ON

by

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Utilisation des biocides par les nettoyeurs de conduits d'installations résidentielles

RÉSUMÉ

Ce rapport présente les résultats d'une étude sur le terrain menée sur l'utilisation de biocides par les entreprises de nettoyage de conduits d'installations résidentielles. L'étude a pour but de déterminer la fréquence et la méthode d'application des biocides un peu partout au Canada et d'évaluer les concentrations intérieures de ces produits à la suite d'applications normales dans des habitations. L'étude vise particulièrement à examiner l'effet de l'utilisation des biocides sur les occupants. L'efficacité des biocides pour l'élimination des contaminants microbiologiques n'a toutefois pas été étudiée.

Un sondage téléphonique effectué d'un bout à l'autre du Canada révèle que l'utilisation des biocides varie considérablement d'une entreprise de nettoyage de conduits à une autre. Certains des entrepreneurs sondés ont accepté de parler de leurs services et de leurs méthodes de travail, alors que d'autres ont été réticents à fournir quelque information pertinente que ce soit sur leurs activités.

Plusieurs grandes entreprises franchisées incluent les biocides dans l'ensemble des services qu'ils offrent dans tous leurs points de vente canadiens. Pour ce qui est des entrepreneurs indépendants, le recours aux biocides est courant dans le centre et l'est du Canada, mais rare dans les Prairies et l'Ouest canadien.

De nombreux entrepreneurs indépendants utilisent quelques produits qui s'ajoutent aux produits de marque déposée auxquels font appel les franchisés. Certains entrepreneurs ont changé de produit après que des clients se soient plaints d'odeurs ou d'irritation ou parce qu'ils estimaient que les nouveaux produits étaient plus efficaces. Aucun des entrepreneurs sondés ne connaît de règlements ou d'exigences régissant l'utilisation des biocides dans les réseaux de conduits des habitations.

Les fiches signalétiques (FS) et l'information des fournisseurs concernant les biocides signalent que ces produits peuvent irriter la peau, les yeux et l'appareil respiratoire, causer des maux de tête et, dans certains cas, entraîner la mort. La grande diversité des troubles de santé signalés provient de la nature des composés chimiques en cause et de la méthode selon laquelle les effets sur la santé sont signalés. L'information contenue dans les FS porte sur les troubles de santé que peuvent éprouver les travailleurs qui manipulent et emploient le produit et ne concerne que des ingrédients actifs bien précis plutôt que le mélange en entier. Il en résulte une évaluation incomplète des répercussions globales de ces produits sur la santé.

Les données relatives aux effets sur la santé qui ont été présentées comportent de l'information sur le produit concentré fourni par le fabricant ou sur le mélange recommandé en vue de l'utilisation finale.

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En général, les produits concentrés sont mélangés à de l'eau dans une proportion approximative de 0,5 p. 100 avant leur application et, par conséquent, le mélange destiné à l'utilisation finale a tendance à entraîner peu de conséquences graves pour la santé.

Certains des produits mentionnés sont des désinfectants d'usage général servant à nettoyer la vaisselle, les appareils ménagers ou d'autres surfaces, tandis que d'autres sont spécialement conçus et commercialisés pour le nettoyage des conduits. Dans tous les cas, les produits avaient été mélangés à de l'eau conformément aux directives du fabricant et vaporisés à l'intérieur des réseaux de conduits au moyen d'un nébulisateur électrique ou d'un vaporisateur à pompe manuelle.

Les renseignements donnés par les fournisseurs montrent que certains produits ont été enregistrés pour être utilisés au Canada ou aux États-Unis. Pour obtenir un numéro d'enregistrement de produit antiparasitaire aux termes de la Loi sur les produits antiparasitaires, les produits doivent subir une évaluation de leur innocuité pour la santé, de leur sécurité pour l'environnement et de leur efficacité par rapport aux allégations du fabricant. Aucun des biocides relevés à l'occasion de l'étude ne possédait de numéro d'enregistrement de produit antiparasitaire pouvant être utilisé dans les réseaux de conduits. Certains produits possédaient un numéro d'enregistrement de produit antiparasitaire, mais la documentation concernant le produit ne faisait pas mention du nettoyage de conduits comme usage indiqué. D'autres produits n'étaient enregistrés que par l'agence américaine de protection de l'environnement.

Les résultats des essais sur le terrain ont montré que les concentrations aériennes initiales de biocides étaient très faibles et qu'elles atteignaient, après sept jours, un niveau inférieur au seuil de détectabilité. Des frottis obtenus aux diffuseurs d'air ont révélé que les ingrédients actifs s'y trouvaient en faibles concentrations. L'absence de directives claires concernant les concentrations précises des biocides en utilisation résidentielle rend impossible l'évaluation de l'acceptabilité de ces substances dans l'optique de la qualité de l'air intérieur.



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OVERVIEW

This report summarizes the results of a field investigation on the use of biocide compounds by residential duct cleaning contractors. The study objectives were to examine the frequency and method of biocide application across Canada and to evaluate the indoor concentrations of biocide compounds resulting from typical field applications. The focus of the study was to examine the impact of biocide use on the building residents. The effectiveness of the biocides for controlling microbiological contaminants was not investigated.

The results of a cross-Canada telephone survey indicated that there is a wide variety in the use of biocides by residential duct cleaning contractors. Some of the contractors contacted were willing to supply information about their company services and work practices, however a number of the contractors were reluctant to release any significant information about their activities.

Several large franchise companies use biocide compounds as a standard package of service in all locations across Canada. With independent operators, the use of biocides was common in Central and Eastern Canada but uncommon in the prairies and Western Canada.

There is a small number of products which are used by many of the independent contractors, in addition to proprietary products used by franchise operators. Some of the contractors had used a number of products in the past and had changed to other products because of customer complaints about odours or irritation or because they felt the newer products had superior performance. None of the contractors contacted were aware of any specific regulations or requirements concerning the use of biocides in residential ductwork systems.

The MSDS and vendor information for the products list health effects including irritation of the skin, eyes and respiratory system, headaches and, in some cases, death. The wide range in reported health effects is related to the nature of the chemical compounds present and to the method by which the health effects are reported. The MSDS information focuses on health effects on workers during handling and use of the product and only deals with specific active ingredients rather than the complete mixtures. This provides an incomplete assessment of the total health impact of the products.

The health effects data that were submitted included information on the concentrated product as supplied by the manufacturer and/or the recommended final use mixture. Typically, the concentrated products were mixed with water to a concentration of approximately 0.5% prior to application and therefore, the final use mixtures tended to produce less severe health effects.

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Some of the products were general disinfectants which were intended for use on dishes, appliances and other surfaces, while some were specifically developed and marketed for duct cleaning. In all cases, the products were mixed with water according to manufacturers' instructions and sprayed into the duct system using an electric "fogger" or hand pump sprayer.

Information supplied by the vendors indicated that some of the products had been registered for use in Canada and/or the United States. To obtain a Canadian PCP registration number under the Pest Control Products Act, products must undergo an assessment of health safety, environmental safety and effectiveness for the purposes claimed. None of the biocides identified in the study had PCP registration for use in duct systems. Some products had PCP registration numbers but the product literature did not identify duct cleaning as an intended use while others were listed by the United States Environmental Protection Agency.

The results of the field testing showed that the initial airborne concentrations of the biocides were very low and decreased to below the detection limit after seven days. Surface wipes from the supply air outlets showed low concentrations of the active ingredients. The lack of formal residential guidelines for specific biocide compound concentrations prevents the assessment of the acceptability of the biocides from this indoor air quality perspective.

INTRODUCTION

This report summarizes the results of a study on the use of biocides by Canadian residential duct cleaners. The study included a telephone survey to investigate the prevalence of biocide use by residential duct cleaners and a field investigation to monitor the airborne and residual surface concentrations of various biocide products used in five test residences. The efficiency of the biocides for controlling microbiological contaminants in ducts was not investigated. The work was conducted on behalf of Canada Mortgage and Housing Corporation.

INVESTIGATION PROTOCOL

The telephone survey was conducted by obtaining the Yellow Pages of the telephone directory for a major city in each province and calling one or more contractors listed. In some cities, a large number of listings were available and phone contacts were arbitrarily selected. If an in-person contact was not made (no answer, answering machine or answering service), another contractor would be called. This process was continued until at least one contractor provided the required information. The information requested included the name of the product used (if any) and; MSDS and product literature, cost, percentage of duct cleaning jobs where biocide is used, amount used and method of application and comments from the contractor.

On-site testing was conducted in five residences using five different biocide compounds. The residences selected each had the ductwork cleaned and the biocide installed using the usual work practice of the contractor. The contractors were aware of the investigation and were fully co-operative in conducting the study. The airborne and duct surface concentration of biocide products was measured in each house approximately 24 hours after the biocide application. Two houses were selected for follow-up testing approximately one week after the initial testing.

Although not specifically requested by the duct cleaning contractors, the duct cleaning was scheduled so that the home occupants were away from the house during the work and for a minimum of three hours following the biocide application.

At the completion of the biocide application, all of the houses were left with the furnace fans running continuously, the windows open and the bathroom fans on for a minimum of three hours. This protocol was consistent with the duct cleaning contractors' recommendation to "let the house air out for a few hours". The contractor who worked in house 1 did not provide any specific instructions regarding occupant exposure during the biocide application or upon re-entry to the house. The house 2-5 contractor required all occupants and pets to vacate the

house during the biocide application and for 10-15 minutes following the application but did not provide any other specific information.

In order to stabilize the outdoor air exchange rate and indoor biocide concentration, all windows were closed and the bathroom fans were shut off for a minimum of six hours prior to testing. A tracer gas decay measurement was conducted on each house to ensure that the ventilation rate was quantified and was within the range expected for typical residences. The furnace fans were left operating continuously. Following the initial testing, all of the houses were returned to normal operation.

For the two houses that were re-tested after approximately seven days, the houses were operated in a normal mode by the homeowners.

The on-site investigation at each house involved a number of activities, tests and measurements:

1) *Walkthrough and Discussions With Duct Cleaning Contractor*

The walkthrough was used to identify more detailed information on the work practice for the duct cleaning and biocide application.

2) *Tracer Gas Decay*

Carbon dioxide was used as a tracer gas to determine the effective air exchange rate for each house (1) at the time of the initial testing.

3) *Airborne Biocide Concentration Measurements*

The airborne biocide concentration in the living room of each house was measured 18-24 hours after the biocide application was completed. In two houses, follow-up measurements were made approximately seven days after the initial measurements.

Air samples were collected at 1 meter above the floor in the centre of the living room area. 150 mL/min air samples were drawn through midget impingers filled with 25 mL of distilled water, 0.1 N HCl or 0.1 N NaOH (depending upon biocide) for a period of approximately two hours. A sampling time of 3-4 hours was used for the follow-up measurements since the indoor air concentrations were expected to be lower.

4) *Surface Biocide Concentration Measurements*

The concentration of biocide residue on the ducts was measured by swabbing the inside surface of three supply air duct boots distributed throughout the house (House 5 was an older home with central wall registers). Surfaces were swabbed using KIMWIPES tissues moistened with the same solution used in the air sampling. The surface sampling was conducted while the airborne biocide concentration measurements were being taken.

The organic amine compound concentrations (active ingredients) were determined by a colorimetric procedure using methyl orange complexing agent and chloroform extraction. Pure product samples were used as a instrument calibration standard for the biocides used in houses 4-5. For houses 2-3, a pure product sample was not available and therefore a fatty acid amine was used as an instrument standard. The amine product was then analyzed to obtain a relative response factor with respect to the fatty acid standard.

The tin concentrations were determined using inductively coupled plasma mass spectrometry.

HVAC SYSTEM DESCRIPTION

Houses 1-4 had conventional forced air furnaces with ducted supply outlets to every room and central return air grilles at several locations. House 5 had a conventional forced air furnace with ducted supply outlets in a central location in the hallways. None of the furnace humidifiers were operational during the testing.

Following the ductwork cleaning and biocide application, the furnace fan was operated continuously. The bathroom fans were operated continuously for a minimum of three hours following the biocide application and then returned to normal operation. Windows were opened for several hours immediately after biocide application and then closed.

The house was returned to normal operation (windows closed, bathroom fans off except when the bathroom was being used and furnace fan on continuous) for at least six hours prior to the initial testing.

During the air sampling, the continuously operating furnace fans were briefly stopped and immediately restarted eight times (10-15 minute intervals over the approximately two hour sampling time) to simulate ductwork vibration and air flow disturbances that would normally occur.

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RESULTS

The results of the investigative protocols are shown in the accompanying Tables and Figures.

1) Telephone Survey

The results of the telephone survey are given in Tables 1 and 2. Table 1 contains general information and Table 2 contains a description of the biocide installation methodology described by the contractors.

Table 1. General Telephone Survey Information

Company	Prov.	Biocide	Cost	Use (% of jobs)	Contractors' Comments
BC1	BC	Micro Ban		< 5	- feels it is being asked for more frequently
BC2	BC	not used			- do not use because of concerns about safety - would like to find "approved" product for use - wash boots, grilles and registers with soap
AB1	AB	BioClean		<5	
AB2	AB	unspecified "Texas" product			- would not discuss due to concerns about competitors
SK1	SK	Micro Ban	\$ 40	<5	
SK2	SK	UltraFresh DM 50	- inc. in pkg.	100	- provide complete package
SK3	SK	BioWash-Q or Bio-Terq	\$ 35	10	- becoming more popular
MB1	MB	none			- never used or been asked to use

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MB2	MB	BioClean		<5	<ul style="list-style-type: none"> - good "kill" results - uses as a deodorizer for fire clean-up - only uses if visible microbial growth present
ON1	ON	P-250 Pine or Lemon Tree		5	<ul style="list-style-type: none"> - does not like to use - concerned about health effects and law suits
ON2	ON	Fultrol Plus		>50	<ul style="list-style-type: none"> - std. practice unless clients say no
PQ1	PQ	Quavon			<ul style="list-style-type: none"> - std. practice unless clients say no
PQ2	PQ	none			<ul style="list-style-type: none"> - feels it is unnecessary if ducts thoroughly vacuumed
NB1	NB	BioClean	\$ 25	25	<ul style="list-style-type: none"> - feels public demand is increasing - uses BC because literature says it can be used in ducts - corporate franchise concerned about air quality complaints
NS1	NS	BioWash-Q		<5	<ul style="list-style-type: none"> - regular practice in non-residential but not houses

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PE1	PEI	BioClean	\$ 40-60	<5	<ul style="list-style-type: none"> - concerned about safety - stated that many local contractors use a duct "sealer" which leaves a matted mess in the ducts - uses only if client requests
NF1	NFLD	UltraFresh DM 50	- inc. in pkg.	100	- duct cleaning not very common in NFLD.
NF2	NFLD	SD-2 Sani-Duct	- inc. in pkg.	100	- always done unless client requests not to

Blank Cells - data not available or contractor would not disclose

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Table 2. Contractor Biocide Application Descriptions

Company	Biocide	Amount Used	Method Of Installation
BC1	Micro Ban	- concentrate mixed with 4 L water as per mfg. specs.. - 4 L mixture used	- mixture "fogged" into duct outlets using fan powered atomizer - approx. 10 seconds per outlet
AB1	BioClean	- 25 mL concentrate per 4 L water - 4 L mixture used	- mixture "fogged" into duct outlets using fan powered atomizer - approx. 10 seconds per outlet - duct cleaning system (large truck mounted exhaust fan with duct connected to furnace plenum) left operating to depressurize ducts and exhaust biocide fumes directly outdoors
AB2	"Texas" product	- mix with water	- spray into outlets while vacuum fan is on
SK2	UltraFresh DM 50	- 10 mL concentrate per 2 L water - 2 L mixture used	- mixture sprayed into main supply ducts and return grilles (with furnace fan on) using a hand held pump tank sprayer
SK3	BioWash-Q or Bio-Terq	as per AB1	as per AB1
MB2	as per AB1	as per AB1	as per AB1
ON1	P-250 Pine or Lemon Tree	- 16 mL concentrate per litre water - 2 L mixture used	- fan powered "mister" used to spray short (5-10 sec) bursts into duct outlets

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ON2	Fultrol Plus	- mix with water as per manufacturers instructions - some clients request "extra"	- fan powered "fogger" blown down each duct outlet for 5-10 sec. while compressed air is discharged down duct outlet
NB1	BioClean	- 25 mL concentrate per 4 L water - 2-4 L of mixture used depending upon house size	- fan powered "fogger" blown down each duct outlet for 15 - 30 sec. while truck mounted exhaust fan is connected to ductwork to exhaust fumes directly outdoors
NS1	BioWash-Q	as per AB1	as per AB1
PE1	BioClean	as per AB1	as per AB1
NF1	UltraFresh DM 50	as per SK2	as per SK2
NF2	SD-2	- 750 mL concentrate per 2.25 L water - 3 L of mixture used for typical house	- fan powered "fogger" blown down each duct outlet for 10 sec.

The duct cleaning contractors were asked to supply Material Safety Data Sheets (MSDS) and/or other vendor data on the biocide products. In cases where the contractors did not have information, the product supplier or manufacturer was contacted. The health effects data provided are summarized in Table 3.

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Table 3. Summary of Vendors' Data on Health Effects of Biocides

Product Name *Information Source* ** Product Registration and intended use **	Active Ingredient (% WT/WT)	LD ₅₀	LC ₅₀	Data provided from information sources
Microban * MSDS * ** EPA #6768-9 Hospital **	Isopropyl alcohol (<10%) Paradiisobutylphenoxyethoxyethyl (0.852%) Dimethylbenzyl ammonium ortho Phenyl phenate bromine complex	N/A	N/A	- no inhalation hazard at ambient temperatures - direct contact may cause skin irritation - may cause eye, throat and respiratory irritation - acute exposure may cause throat and lung irritation and headache - special precautions advised for infants, elderly, pregnant women and individuals with respiratory problems
Bioclean * Vendor data sheet and MSDS * ** EPA #51267-1 Ductwork **	n-Alkyl dimethyl benzyl ammonium chloride (5%) n-Alkyl dimethyl ethylbenzyl ammonium chloride (5%) Bis (tributyltin) oxide (1%)	> 2g/kg (skin)	> 6.5 mg/L air (inhalation)	- diluted product considered not toxic - meets CFR 16:1500.3 (5)(6)(7) oral toxicity - meets CFR 40:158-135, Part 81-82 dermal toxicity - meets CFR 40:163.81-83 inhalation toxicity - meets CFR 40:158-135, Part 81-84 eye irritation
UltraFresh DM 50 * MSDS * ** PCP 14498 Carpet Deodorizer **	Tri-n-butyltin maleate (15-40%)	925 mg/kg (rabbit)	2.7 mg/L air (inhalation)	- skin contact will cause mild dermatitis - may cause severe eye irritation and corneal damage - may cause headache
Biowash-Q * Vendor data sheet and * ** PCP 23172 Ductwork **	Didecyl dimethyl ammonium chloride (7.5%)	N/A	N/A	- corrosive to eyes - avoid skin contact - harmful if swallowed - may cause mucosal damage - may cause circulatory shock, respiratory depression and convulsions

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Bio-Terq Barquate MB-80 * MSDS *	Benzalkonium chloride (10%)	2.3 mL/kg	N/A	- may cause skin irritation and dermatitis - can cause eye damage - may irritate mucous membranes - ingestion may be fatal
P-250 Pine * MSDS * ** PCP 14297 Disinfectant Cleaner **	Ortho-Benzy-para-Chloropheno1 (3.75%) Pine Oil (2.5%) Isopropyl Alcohol (10%) Methanol (10%)	1700 mg/kg (oral rat) 3.2 g/kg (oral rat) 5.05 g/kg (oral rat) 13 g/kg (oral rat)	2.5 mg/kg (inhalation-rat)	- no effects from inhalation - may cause mucosal damage, nausea, vomiting and diarrhea - will cause eye irritation - may cause skin irritation
Lemon Tree * MSDS * ** PCP 18427 Disinfectant Cleaner, Deodoriser **	Didecylidimethyl ammonium chloride Ethylene diamine tetra acetate Na ₄	N/A 330 mg/kg (mouse)	N/A N/A	- no effects from inhalation - ingestion may cause mucosal damage, nausea, vomiting and diarrhea - will cause eye irritation - may cause skin irritation
SD-2 * Vendor data sheet and MSDS * ** EPA 10182.30 Ductwork **	Vinylacetate/ ethylene copolymer 30% 1,2 Benzisothiazolin-3,1	N/A N/A	N/A N/A	- no special handling or clean-up procedures required - can cause skin, eye and respiratory irritation

2) Walkthrough

In general, the contractors followed an established protocol for the ductwork cleaning and biocide installation. Given the wide variation in furnace/ductwork arrangements in houses, a great deal of "feel" was used by the contractors to estimate the length of time spent to apply the biocide into the individual duct outlets.

House 1 was cleaned by a large national franchise contractor which used compressed air driven brushes and a vacuum hose inserted down each supply air and return air outlet as well as the main ducts and plenums. The biocide was installed by spraying a mist into the supply air plenum at the furnace and into the return air grilles. The furnace fan was used to distribute the biocide throughout the ductwork.

The contractor did not advise the homeowner to take any special precautions to avoid exposure to the biocide and did not use any personal protective equipment during biocide application.

Houses 2-5 were all cleaned by a large national franchise contractor which used a large truck mounted exhaust fan installed in the supply air and return air plenums of the furnace. While the ductwork was under a negative suction, a fan powered blower was directed down each supply and return outlet to blow the debris into the main ducts where it was exhausted by the exhaust fan. After cleaning, a fan powered "fogger" was used to direct a biocide mist into each of the outlets for 10-20 seconds.

The contractor removed all persons and pets from the house prior to and for 10-15 minutes following the biocide application. The two personnel applying the biocide used personal protective respirators equipped with pesticide vapour cartridges.

3) *Tracer Gas Decay*

The results of the tracer gas decay tests to determine the total air exchange rates are given in Table 4.

Table 4. Ventilation Rates Measured by Tracer Gas Decay

House	Ventilation Rate (ach ⁻¹)
1	0.25
2	0.28
3	0.46
4	0.33
5	N/A

4) *Airborne and Surface Biocide Concentration Measurements*

The total biocide installed in the house and the results of the airborne and surface concentration measurements (based on measured amine concentration) are given in Table 5.

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Table 5. Biocide Concentration Measurements

House	Biocide	Total Concentrated Biocide Applied		Airborne Biocide Concentration (mg/m ³)		Initial Surface Biocide Concentration (mg/m ²)
		mL	g	Initial	7 day	
1	UltraFresh DM 50	9.9	10.3	0.54		36.4
2	Bio-Terq	59	55.5	5.2		207
3	BioWash-Q	20	20.0	10.6		123
4	BioClean	22.2	22.3	3.3	< 0.2	5.2
5	P-250 Pine	16	15.2	34.3	< 2.4	7.1

The chemical analysis for the various biocide products was focused on identifying and quantifying a specific active ingredient of the product (amine and/or tin). The analyst then calculated the equivalent concentration of the biocide product based on the chemical composition. The biocide product concentration values given in Table 5 were calculated based on the amine concentration for house 2-5 and on the tin concentration for house 1.

Since the galvanized ductwork may contain tin, chemical determinations using tin as the reference compound can be in error. For the case of house 1, the calculated surface biocide concentration of 36.4 mg/m² may be higher than the true value due to the collection of tin from the galvanized surface.

DISCUSSION

The practice of installing biocides in ductwork is highly variable across Canada. In general, the industry contains a small number of very large franchise operations and a large number of independent operators.

The large franchises provide the individual operators with a "fixed" protocol for cleaning ductwork, including equipment and supplies. The telephone survey and review of the yellow pages for the various cities indicated that most large cities had representation from the franchise companies. The franchise operators felt that the parent company had developed the best methodology and had undertaken to ensure that the

methods used were acceptable. One parent franchise always installed a biocide, whereas others made it available to the individual operators who may or may not install it based on individual site assessments or client preferences.

The independent operators had a much more diverse range of methodologies and services, characterised by local market and operator preferences. In some cases operators were; unaware of biocide use, concerned about possible legal implications, responding to local market pressure to supply the service and suspicious about the "government" and other groups' interest in how they conducted their business.

Although the range of biocide products was quite large, many of the biocides used some type of ammonium chloride as the active ingredient, with others using tin-, phenol- or alcohol- based compounds. Since the chloride and tin compounds are not volatile, but exist as a solid precipitate when the water carrier evaporates, the emission profiles are not expected to resemble the typical, time dependent VOC emissions from building materials. The forced ON/OFF furnace fan cycling during testing was intended to induce ductwork vibrations which could displace the precipitated compounds. In the follow-up testing of the two houses, the airborne biocide product levels had dropped to below the detection limit.

Since this was a small field study, the range of experimental parameters had to be reduced in order to achieve some comparability in the field test results. The testing protocol was developed to avoid the highly dynamic period immediately following the duct cleaning and biocide application. During the first 24 hours following the contractor's work, the house air exchange and biocide emission rates would be erratic, resulting in a wide range of indoor biocide concentrations. The 24 hour and longer testing was done to evaluate the longer term chronic concentrations rather than peak concentrations that could occur.

For typical short duration indoor pollutant sources, a mass balance indoor air quality model would predict that the highest biocide concentrations would occur soon after application and the concentration would decrease with time. Detailed information on the dynamic properties of the source and its interaction with other building components would be required to produce accurate indoor air and surface concentration profile estimates. It is recognized that a complete health assessment would require more detailed data on the airborne and indoor surface concentration of the biocide compounds, including the time period immediately following the biocide application. Obtaining this data will require a more comprehensive field and laboratory study.

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Although not specifically required by the duct cleaning contractors, the project manager requested that the houses remain unoccupied for a minimum of three hours following the biocide application to provide an "airing out" period. Immediately following the biocide application, an odour could be noticed in most of the houses. None of the homeowners or occupants indicated that they were concerned about the duct cleaning process or that they noticed any unpleasant odours or irritation when re-entering the house.

Most of the active ingredients used in the biocides are not listed by the ACGIH (2) or the HWC Residential Guidelines (3). Their suitability for use in residential environments and the maximum allowable concentrations can not be determined using these criteria.

The products had a very wide range of health effect data reported in the MSDS and vendor data sheets. Since the MSDS data is primarily concerned with the storage and use of the product from a worker perspective, the data focuses on exposure to the concentrate and worker exposure during application. The MSDS data also refers to the listed active ingredients and may not give a complete assessment of all of the cumulative effects of the final product mixture.

Reported health effects (in order of frequency of reporting in the MSDS) include; 1) irritation of the eyes, skin, throat and respiratory system, 2) nausea and gastrointestinal irritation, 3) headaches, and 4) shock, respiratory depression, convulsions and death.

In some cases, the MSDS and product literature gave general guidance on occupant exposure through the use of cautionary statements about providing adequate ventilation and advising elderly, pregnant women, infants and other "at risk" groups to take special but undefined precautions. Although including these statements may be necessary from a regulatory perspective, the statements are not particularly useful for the duct cleaning contractors or home occupants. The information is too general to be used by contractors to formulate work practice or to advise home occupants on how and when they can safely re-occupy their home.

In Canada, the use of pest control products is regulated and products used for disinfection of microbial pests require registration under the Pest Control Products Act (4). Only one of the biocide products with a PCP registration number (BioWash-Q) had printed product literature which specifically indicated that the product could be used as a duct sterilizer. Upon checking the PCP registration, it was found that duct sterilization was not included. Several other products were PCP registered for other purposes including deodorizing and general disinfection. Two products had been registered by the United States Environmental Protection Agency (EPA) for use in ductwork but were not registered in Canada.

Data collected in this study that may be used for general consideration in conjunction with the published health effects data are the LC_{50} data (the airborne concentration which is lethal to 50% of the exposed specific animal subjects). Field data that could be considered in conjunction with the LD_{50} data (the ingested, injected or skin applied dose which is lethal to 50% of the exposed specific animal subjects) were not obtained. *The use of toxicological data obtained from animal studies to assess the safety of a product for human exposure requires a thorough risk assessment which is beyond the scope of this document.*

For BioClean, the LC_{50} is given as > 6.5 mg/L. The initial measured airborne concentration (24 hours after application) of BioClean in house 4 was 3.3 mg/m³ which was approximately 1/2000 of the LC_{50} . None of the other biocide products tested had vendor's data which was comparable with the field test results.

CONCLUSIONS

1. The practice of applying biocides in residential ductwork is highly variable across Canada, but is increasing in frequency due to client demand and industry promotion.
2. Large franchises have established procedures for ductwork cleaning and biocide application, whereas independent operators have a much more diverse methodology.
3. There is a low level of awareness amongst duct cleaning contractors regarding the regulatory aspect of biocide use in residences.
4. Contractors can not provide home occupants with appropriate information on the health implications of biocide use in duct cleaning since none of the ductwork biocide products identified are registered for this use under the Pest Control Product Act.
5. Depending upon contractor work practice, many home occupants occupy residences soon after (or during) ductwork biocide application and can be exposed to biocide compounds.
6. The concentration of biocide products measured in the air in houses that had recent duct cleaning were relatively low, although there are no specific chemical concentration standards to compare with.

REFERENCES

1. "ASTM E741-83, Standard Test Method For Determining Air Leakage Rate By Tracer Dilution", American Society for Testing and Materials, Philadelphia, PA., July, 1984.
2. "1992-93 Threshold Limit Values for Chemical Substances and Physical Agents", American Conference of Governmental Industrial Hygienists, Cincinnati, OH, 1993.
3. "Exposure Guidelines for Residential Indoor Air Quality", Health and Welfare Canada, Ottawa, ON, 1989.
4. "Pest Control Products Act", Revised Statutes of Canada, 1985.