RESEARCH REPORT

Build Green and Conventional Materials Off-Gassing Tests

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BUILD GREEN AND CONVENTIONAL MATERIALS OFF-GASSING TESTS

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R E P O R T

Build Green and Conventional Materials Off-Gassing Tests

A Final Report to:	Canada Mortgage & Housing Corp. 700 Montreal Road Ottawa, Ontario K1A 0P7
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Summary

Indoor contaminant control strategies are based on reduction, removal and dilution. Building codes now address the control of indoor pollutants through mechanical ventilation. Building codes, however, do not make reference to choosing material with low pollutant content, other than asbestos.

A number of environmental initiatives are being undertaken that will have an effect on indoor air quality. Researchers have identified building materials and furnishings as one source of indoor pollutants and many emission investigations are being undertaken.

Another initiative is the reduction of waste from the construction industry. This has stimulated the development of products which have a recycled material content. The Build Green Program is a certification program that will identify and label products with a known recycled content.

The introduction of these recycled materials has raised the concern that these products may emit more indoor chemicals than conventional materials. To address this concern, the objective of this study is to analyze Build Green and conventional materials to assess their potential for off-gassing.

This study involved emission tests of thirty-seven materials, both Build Green and conventional materials. Materials tested included carpet, carpet undercushion, structural lumber, foundation material, insulation, drywall/fiberboard, counter tops and cabinetry.

The tests determined that,

1. The Build Green products evaluated emitted equivalent quantities of Volatile Organic Compounds (VOCs) and formaldehyde as compared to conventional products.

2. Emissions from building materials can originate from the building material, from the material finish, from chemicals applied during construction and from chemicals adsorbed from other sources, e.g. during storage.

3. Chlorinated hydrocarbons were not emitted from these building materials.

RÉSUMÉ

Il existe des stratégies afin d'éliminer les agents contaminants présents dans un bâtiment. Les codes du bâtiment font appel à la ventilation mécanique. Toutefois, ils ne font pas référence aux matériaux contenant peu de polluants, autres que l'amiante.

Un certain nombre d'initiatives environnementales permettront d'améliorer la qualité de l'air intérieur. Les chercheurs ont établi que les matériaux de construction de même que les articles d'ameublement et de décoration peuvent être des agents contaminants. De plus, diverses études relatives à l'émanation de polluants sont en cours.

Une autre initiative est la diminution de la quantité de déchets produits par l'industrie de la construction. Cela a favorisé la création de matériaux recyclés. Le programme «Bâtissons un avenir écologique» est un programme d'accréditation de produits composés de matières recyclables.

Depuis l'introduction de ces matériaux recyclés on se demande s'ils n'émettent pas plus d'agents contaminants que les matériaux classiques. Pour répondre à cette question, le but de l'étude est d'analyser les matériaux approuvés en vertu du programme ainsi que les matériaux classiques afin de déterminer s'ils émettent des agents contaminants.

Des tests relatifs à l'émanation de polluants ont été effectués sur 37 matériaux (matériaux approuvés en vertu du programme et matériaux classiques). Ces matériaux comprennent la moquette, la thibaude, le bois de charpente, les matériaux de fondation, les isolants, les plaques de plâtre, les panneaux de fibres, les plans de travail et les armoires.

Résultats des tests :

1. Les produits approuvés en vertu du programme «Bâtissons un avenir écologique» ont un taux d'émanation de composés organiques volatiles (COV) et de formaldéhyde équivalent à celui des produits classiques.

2. Les émanations des matériaux de construction peuvent provenir du matériau lui-même, de la finition, de produits chimiques appliqués durant la construction et de produits chimiques absorbés, lors de l'entreposage par exemple.

3. Ces matériaux de construction n'émettent pas de chlorocarbures.

1. Introduction

The issue of air quality in residences has become of increasing concern, as the population has become more aware of personal health and the environment. Canadians, due to the climate, also spend a large portion of their time indoors.

Indoor contaminant control strategies are based on reduction, removal and dilution. These strategies have been incorporated into building codes which now address the control of indoor pollutants through mechanical ventilation. Indoor air quality researchers are now investigating building materials and furnishings as sources of indoor contaminants.

Traditionally, construction products have been designed and developed based on product formulations which take into account performance issues such as durability, structural integrity, fire resistance, etc. Existing material performance standards do not require that materials are evaluated for off-gassing. Also, the Canadian building codes do not make reference to choosing materials with low pollutant content, other than asbestos. In this area, questions are raised about new products in terms of their off-gassing potential.

Initiatives to reduce waste from the construction industry have resulted in innovative products which have a recycled material content. An initiative to encourage the use of recycled materials is the Build Green Program. The Build Green Program is a partnership program between the Greater Toronto Home Builders' Association (GTHBA) and ORTECH. The program aims at promoting the use of recycled content building materials in the construction and renovation of buildings, increasing awareness abut Build Green products and facilitating and initiating the development new products made from waste materials. This effort is aimed at diverting construction, demolition and municipal wastes from landfill.

This project involves off-gas testing of thirty-seven products, both Build Green and conventional building materials.

2. Objective

The objective of this study of Build Green and comparable conventional products, was to identify specific products which may release compounds which have the potential for adverse indoor air quality. As an initial study, one intent is to get a sense of how a number of construction products that are used on a routine basis perform in terms of off-gassing.

3. Test Protocol

3.1 Materials Tested

The Build Green and conventional building materials to be tested are listed in Table 1. A total of thirty-seven typical materials have been identified which include categories of carpet, carpet undercushion, drywall/fiberboard, insulation, counter tops, foundation material, structural lumber and cabinetry. As requested by the manufacturers, product manufacturers and product names for the materials tested have not been identified. Materials are identified by a code under the eight material categories.

3.2 Testing and Analytical Methodology

The material off-gassing tests were tested using the ASTM document "Standard Guide for Small Scale Environmental Chamber Determinations of Organics from Indoor Materials/Products, D5116-90"(1) as a guide. The intent of small chamber tests is to simulate conditions similar to indoor environments in a chamber under controlled conditions and measure the pollutants of interest that are emitted. It is not intended that this report provide data to determine time decay characteristics or rigorous emission factor data for detailed indoor pollutant concentration modelling.

3.3 Sample Selection and Handling

Staff at ORTECH contacted the product manufacturers to obtain representative samples. Product manufacturers were also requested to forward information on the chemical content of the products. Samples were forwarded in their product packaging, as if they were delivered to a construction site. Upon receipt at ORTECH, samples were logged and given sample numbers.

In most instances, product chemical information was not provided. Also, various manufacturers were reluctant to participate in the program and would not agree to forward samples in the time period requested. The inability to obtain product samples and chemical information, caused delays in initiating the testing program. In these instances, when the manufacturer would not send a sample, sample materials were purchased through commercial outlets or distributors and tests were performed without product chemical information. Also, in some instances, samples were forwarded to ORTECH not properly wrapped or the samples were showroom display samples and not suitable for testing. These samples were returned and suitable samples requested.

3.4 Test Preparation

Small chamber off-gas test procedures require the determination of a material loading ratio (m^2/m^3), which is the ratio of the test specimen area to the chamber volume The intent of this ratio is to provide physical material dimensions of the material test sample in the test chamber to correspond to normal use patterns for the same product in "full scale" environments. The loading ratios for this study varied according to material category and are presented in Table 2.

3.5 Chamber Tests

The dynamic chamber test system consisted of a small chamber of 55 litre volume that received ultra pure air from a compressed air cylinder (see Figure 1). The dimensions of the chamber are length 46 cm, width 34 cm and height 35 cm. Humidity and temperature was controlled. Temperatures and humidities were maintained at 23°C and 50% RH, respectively. The chamber was operated under a slightly positive pressure, +0.05 inches water pressure, to ensure there was no leakage into the chamber.

The air exiting the chamber was split into two lines, one for formaldehyde and the other for volatile organic compound collection (VOC). To collect formaldehyde, the sample line passed through a midget impinger containing an absorbing solution, 1% sodium bisulphite. The other sample line passed through a multi-adsorbent tube for the collection of organic compounds. A sampling pump was used to draw the samples through these collection devices. Actual sample collection flowrates were measured and were used in the calculation of the results. Sampling times varied, depending on the source strength of the materials. The air exchange rate through the chamber was 0.5 air changes per hour.

3.6 Water Extract Tests

As previously mentioned, most product manufacturers did not provide product chemical information. As a result, prior to testing it was not known whether the material was a strong, moderate or weak source of volatile organics and formaldehyde. Odour and general knowledge of the material assist the test operator, but this is not quantitative. To overcome this uncertainty, one-hour distilled water leach tests were performed on small samples of the products for formaldehyde. The leachate or water extract was analyzed for formaldehyde to provide information on the potential for formaldehyde release.

3.7 Analytical Procedures

The formaldehyde solutions were analyzed by the chromatropic acid method[2,3]. In this method the solutions were reacted with chromatropic and sulphuric acid. Quantification was by colorimetry.

The multi-adsorbent tubes were analyzed for volatile organic compounds by thermal desorption at 300,C and using an HP gas chromatograph/mass spectroscopy connected with an Envirochem purge and trap system. Prior to sample analysis, the sample tubes were injected with an aliquot (1 µl) of an internal standard solution by a helium sweep technique.

4. Results and Discussion

The results of the off-gas tests conducted for Build Green and conventional products are presented in Table 2. The data from the chamber tests has been used to calculate emissions rates for total volatile organic compounds (TVOCs) and formaldehyde of the materials tested. The units of the emission rates are presented as quantity of TVOCs and formaldehyde emitted per surface area per hour for the materials ($\mu g/m^2 \cdot h$).

The water extract test results are expressed in units of µg of formaldehyde detected per gram of material, (µg/g).

In addition to the emission rate results presented in tabular form in Table 2, the emission rates are also presented in graphical format in Figures 2 to 6. Graphical data are presented for the material categories of carpets and carpet undercushions, structural lumber, insulation, counter tops, fiberboard, cabinetry and gypsum wallboard.

The carpets and carpet undercushions tested met the Canada Carpet Institute Indoor Air Quality Testing Program[4] criteria for volatile organic compounds and formaldehyde (see Figure 2). Three of the carpets exhibited emissions of TVOCs greater than 50% of the criteria. One undercushion exhibited TVOC emissions of greater than 50% of the criteria. Two of the carpets exceeded 50% of the formaldehyde emission criteria. On a mass basis, emissions of VOCs exceeded emissions of formaldehyde.

A total of five structural lumber materials were tested, three Build Green and two conventional materials (Figure 3). On a mass basis, more VOCs were emitted than formaldehyde. The laminated lumber (BG-L2) and the spruce (C-L1) exhibited higher VOC emissions than the other materials. For formaldehyde, the spruce exhibited higher emissions than the other lumber materials. There presently are no emission guidelines for structural lumber.

A total of eight insulation materials were tested, and the data are presented in Figure 4. On a mass basis, the formaldehyde emissions exceeded the VOC emissions. Formaldehyde is used in the manufacture of glass fibre insulation and was also detected in the water extract analysis. The exterior sheathing exhibited higher formaldehyde emissions than the fibre batts and the foam insulation. There are presently no emission guidelines for insulation materials.

Emission data for counter tops, fiberboard and cabinetry are grouped together and presented in Figure 5. With the exception of a solid wood cabinet door (C-C1) emissions of formaldehyde and VOCs were similar for the materials.

Formaldehyde was detected in the water extract analysis of the particle board, fiberboard and solid wood materials. It is believed that the solid wood cabinet door's (C-C1) high emissions are the result of the stain and lacquer finish applied to the wood. There are also no emission guidelines for the categories of counter tops and cabinetry. The Canadian Particle Board Association has a standard for formaldehyde[5] that could be applied to the fiberboard. The particle board standard is expressed in units of a resultant formaldehyde air concentration in a chamber, not an emission rate measurement as determined by these tests.

Gypsum wallboard emissions from the three samples are presented in Figure 6. The two conventional drywall materials were obtained from commercial outlets and not from the manufacturer. The higher VOC and formaldehyde emissions are probably the result of these samples having acted as sinks at the commercial outlet. The gypsum wallboard could potentially absorb VOCs and formaldehyde emitted from other building materials such as plywood, particle board, etc. During testing, these compounds obtained in the building material storage area, are then released and measured during testing. There are also no materials emissions guidelines for gypsum wallboard.

The results data for the category of foundation materials are presented graphically in Figure 7. There were no measurable formaldehyde emission from the foundation materials. The cast-in-place concrete had one of the highest VOC emissions of all materials. This was not from the concrete, but from an oil product that is used with concrete forms. The oil is applied to the forms so that the concrete does not adhere to forms. Some of this oil lubricant remains with the surface of the concrete when the forms are removed and then releases oil based hydrocarbons. There are no materials emission guidelines for foundation materials.

The water extract formaldehyde analysis results were compared to the formaldehyde emission rate results to determine if a relationship exists. An evaluation of the data indicated that there is no relationship for this set of test results.

The analysis of the multi-adsorbent tubes for volatile organic compounds identified the main chemicals released. The majority of the compounds were branched hydrocarbons from C-6 to C-12. Toluene and xylene were the most frequently occurring compounds from this analysis. No chlorinated hydrocarbons were detected. Formaldehyde emissions were detected in 22 out of 37 materials. Toluene, xylene and formaldehyde are common industrial solvents.

This test program evaluated emission from a total of 37 materials. However, with this total distributed among eight material categories, there were only a few samples per category group. Also, only one test per sample was conducted. With this small sample size, these results can only be considered to be indicative for the materials tested.

5. Conclusions

The following conclusions have been derived from this test program:

1. The Build Green products emitted equivalent quantities of VOCs and formaldehyde as compared to conventional products, with two exceptions.

2. Emissions from building materials can originate from the building material, from the material finish, from chemicals applied during construction and from chemicals adsorbed from other sources.

3. Chlorinated hydrocarbons were not emitted from these building products.

4. The results presented indicate that the emissions quantities cove a wide range. This variability is not surprising due to the lack of attention of the manufacturers to emissions and the lack of standard emission test methods for these materials.

6. Recommendations

The off-gassing results presented in this report represent a "first look" at a wide array of traditional building products. The data clearly reveals that off-gassing is an issue that should be an integral product performance issue for all construction materials.

To integrate off-gassing information in construction activity, the following actions should be implemented.

1. Off-gassing criteria needs to be an integral part of product formulation and the results should be widely available to the construction professionals.

2. An industry standard or procedure should be developed for sampling and transporting test materials.

3. Test Methodology Standardization

   - Several issues need to be resolved
     - sample size - small
       - large
     - component or system testing
     - statistical number of replicates for valid data

4. Detailed analysis of emission rate-of-decay and the relationship between lab test data and actual building air quality need to be defined. The net additive effect of various products also needs to be understood.

5. Define the significance of absorption of various construction materials when stored in a warehouse, installed with adhesives or cleaned with aggressive agents.

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PP:DWB/imm

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1. American Society for Testing and Materials, Designation: D5116-90, "Standard Guide for Small-Scale Environmental Chamber Determinations of Organic Emissions from Indoor Materials/Products", published November, 1990.

2. Ontario Ministry of Labour, Occupational Health & Safety Division, "Proposed Regulation Respecting Formaldehyde - Made Under the Occupational Health and Safety Act", Published in the Ontario Gazette, July 30, 1983.

3. Eller, Pewter M., Editor, National Institute of Occupational Health and Safety, "NIOSH Manual of Analytical Methods, Third Edition" with revisions, Cincinnati, Ohio, 1984.

4. Canadian Carpet Institute, Indoor Air Quality Testing Program, Ottawa, 1993.

5. Canadian Particle Board Association, Large Scale Test Method for Determining Formaldehyde Emissions from Wood Products Large Chamber Method FTM2 - 1985, Ottawa, 1985.

6. American Society of Testing and Materials, Designation E1333-90, "Standard Test Method for Determining Formaldehyde Levels from Wood Products Under Defined Test Conditions Using a Large Chamber, Published April, 1990.

TABLE 1

Materials Identified for Off-Gas Testing

Product Type	Candidate Build Green Materials	Conventional Material
Carpet	• 2 Products	• 4 Products
Carpet Undercushion	• 3 Products	• 1 Product
Structural Lumber	• 3 Products	• 2 Products
Foundation	• 2 Products	• 2 Products
Insulation	• 2 Products	• 6 Products
Counter Top	• 1 Product	• 2 Products
Drywall/Fiberboard	• 3 Products	• 2 Products
Cabinetry	• 1 Product	• 1 Product

TABLE 2

Building Material Off-Gas Test Results

Material Type	Description	Emission Rates TVOCs	Emission Rates Formaldehyde	Units	Water Extract Formaldehyde Content (µg/g)	Material Loading Ratio (m^2/m^3)
Carpet	Build Green Products					
	BG-C1 Polyethylene Terephthalate	<1	<1	$\mu g/m^2 \cdot h$	<2	0.41
	BG-C2 Wool	<1	<1	$\mu g/m^2 \cdot h$	18	0.41
	Conventional Materials					
	C-C1 Nylon Carpet Tile	10	<1	$\mu g/m^2 \cdot h$	3	0.41
	C-C2 Stain Treated Nylon	500	<1	$\mu g/m^2 \cdot h$	<2	0.41
	C-C3 Nylon Hard Twist	38	48	$\mu g/m^2 \cdot h$	9	0.41
	C-C4 Nylon Plush	330	40	$\mu g/m^2 \cdot h$	3	0.41
Carpet Undercushion	Build Green Products					
	BG-U1 Rubber	470	<1	$\mu g/m^2 \cdot h$	11	0.41
	BG-U2 Synthetic Fiber	31	<1	$\mu g/m^2 \cdot h$	16	0.41
	BG-U3 Felt	<1	<1	$\mu g/m^2 \cdot h$	47	0.41
	Conventional Materials					
	C-U1 Foam	<1	12	$\mu g/m^2 \cdot h$	8	0.41
Structural Lumber	Build Green Products					
	BG-L1 I-Shaped Wood Beams	67	4.1	$\mu g/m^2 \cdot h$	41	11
	BG-L2 Laminated Lumber	290	8.4	$\mu g/m^2 \cdot h$	75	11
	BG-L3 Parallel Strand Lumber	100	7.6	$\mu g/m^2 \cdot h$	64	11
	Conventional Materials					
	C-L1 Spruce Lumber	360	23	$\mu g/m^2 \cdot h$	16	11
	C-L2 Cedar Lumber	46	4.4	$\mu g/m^2 \cdot h$	42	11

TABLE 2 cont'd.

Building Material Off-Gas Test Results

Material Type	Description	TVOCs	Emission Rates Formaldehyde	Units	Water Extract Formaldehyde Content (µg/g)	Material Loading Ratio (m^2/m^3)
Foundation	Build Green Products					
	BG-F1 Wood/Cement Composite Structural Wood System	<10	<4	$\mu g/m^2 \cdot h$	4	0.4
	BG-F2 Polystyrene Foundation System	280	<5	$\mu g/m^2 \cdot h$	<2	0.9
	Conventional Material					
	C-F1 Standard Concrete Block	26	<3	$\mu g/m^2 \cdot h$	<1	5.5
	C-F2 Cast-in-Place Concrete	2,300	<1	$\mu g/m^2 \cdot h$	<1	0.8
Insulation	Build Green Product					
	BG-11 Glass Fibre Batt Insulation	5.9	35	$\mu g/m^2 \cdot h$	140	0.7
	BG-12 Cellulose Insulation	8	5	$\mu g/m^2 \cdot h$	23	0.4
	Conventional Materials					
	C-11 Glass Fibre Batt Insulation	3.6	105	$\mu g/m^2 \cdot h$	200	0.7
	C-12 Glass Fibre Blowing Wool	<1	<1	$\mu g/m^2 \cdot h$	200	0.7
	C-13 Glass Fibre Insulating Exterior Sheathing	150	135	$\mu g/m^2 \cdot h$	46	0.8
	C-14 Glass Fibre Insulating Exterior Sheathing	<1	300	$\mu g/m^2 \cdot h$	26	0.8
	C-15 Isocyanurate Foam Sheathing	<1	<1	$\mu g/m^2 \cdot h$	<2	0.8
	C-16 Glass Fibre Batt Insulation	1.6	<1	$\mu g/m^2 \cdot h$	200	0.7

TABLE 2 cont'd.

Building Material Off-Gas Test Results

Material Type	Description	Emission Rates TVOCs	Emission Rates Formaldehyde	Units	Water Extract Formaldehyde Content (µg/g)	Material Loading Ratio (m^2/m^3)
Counter Top	Build Green Product					
	BG-T1 Solid Cement based Counter Top Material	7.2	<1	$\mu g/m^2 \cdot h$	<2	0.10
	Conventional Material					
	C-T1 Laminate/Particle Board	590	175	$\mu g/m^2 \cdot h$	420	0.10
	C-T2 Solid Plastic	8.7	<1	$\mu g/m^2 \cdot h$	<2	0.10
Drywall/Fiberboard	Build Green Product					
	BG-D1 Gypsum Wallboard	<1	23	$\mu g/m^2 \cdot h$	45	1.2
	BG-D2 Structural Fiberboard	220	120	$\mu g/m^2 \cdot h$	20	1.2
	BG-D3 Medium Density Fiberboard	37	1,000	$\mu g/m^2 \cdot h$	490	1.2
	Conventional Materials					
	C-D1 Gypsum Wallboard	25	250	$\mu g/m^2 \cdot h$	47	1.2
	C-D2 Gypsum Wallboard	20	60	$\mu g/m^2 \cdot h$	8	1.2
Cabinetry	Build Green Product					
	BG-C1 Laminate/Particle Board	130	177	$\mu g/m^2 \cdot h$	730	0.10
	Conventional Material					
	C-C1 Solid Wood	1,500	9,100	$\mu g/m^2 \cdot h$	21	0.10

FIGURE 1

Schematic for Dynamic Chamber Tests

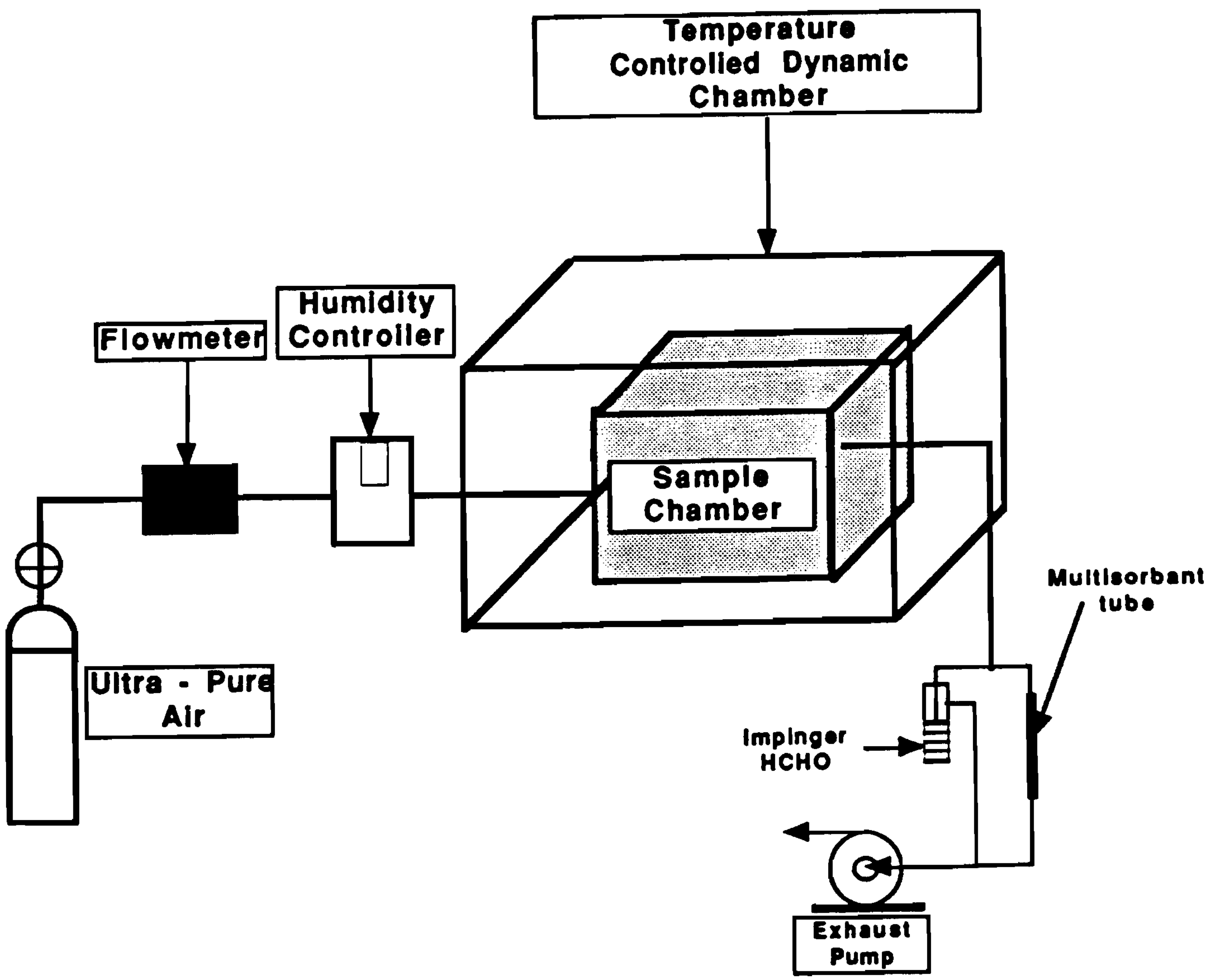


FIGURE 2 - CARPET AND CARPET UNDERCUSHION

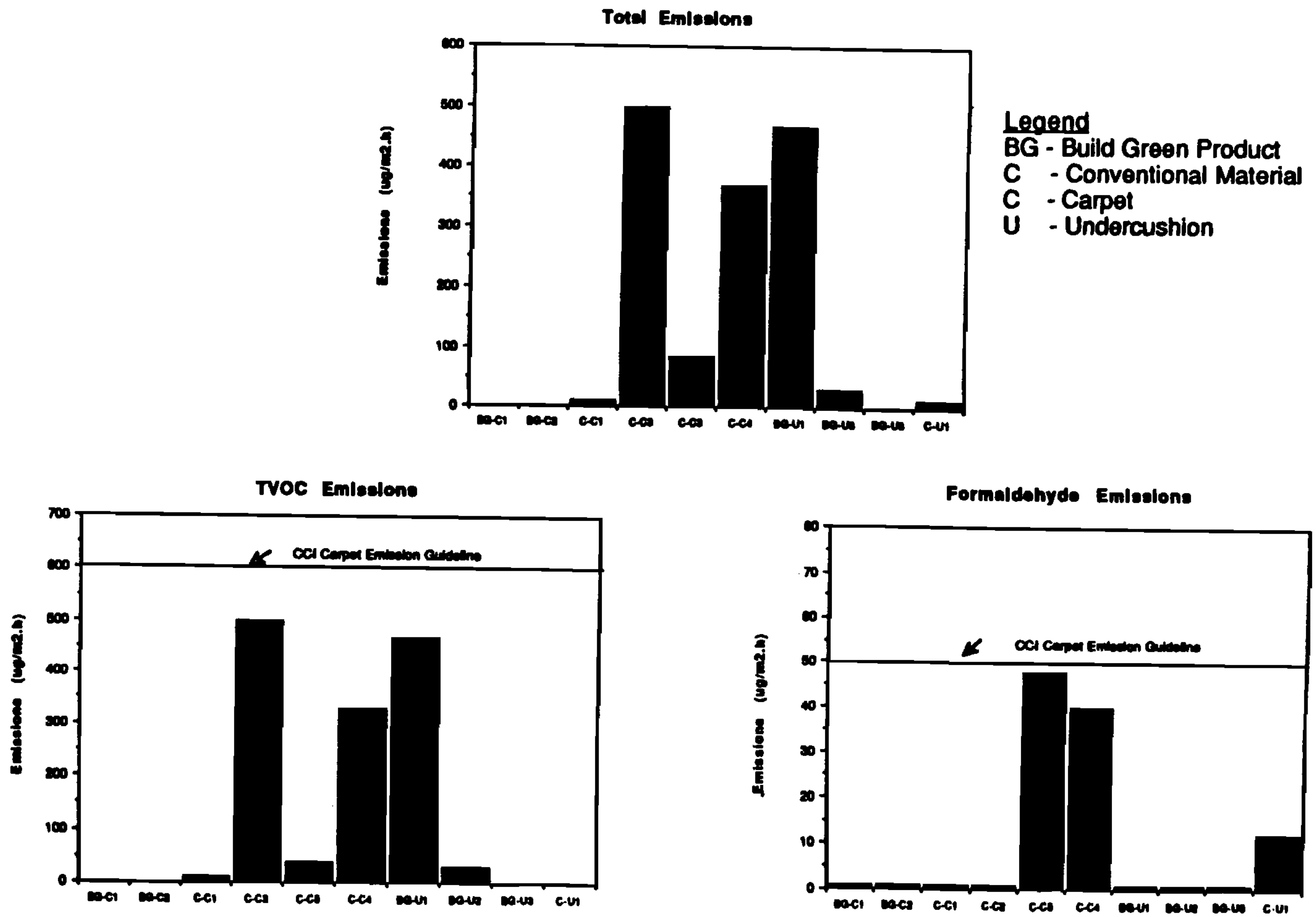
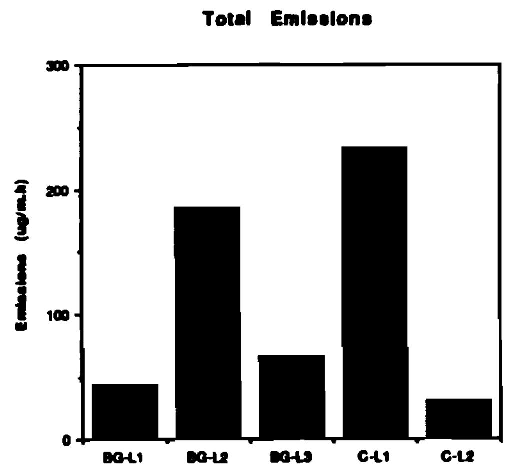
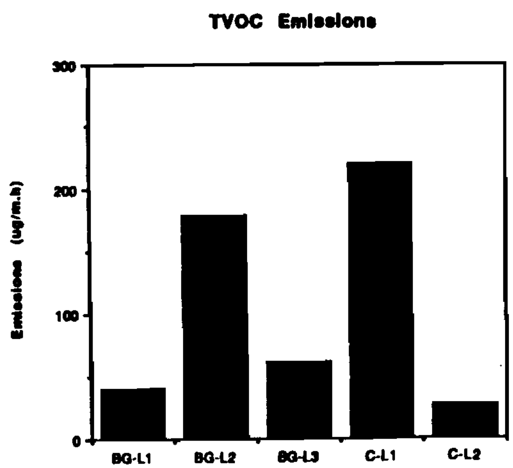


FIGURE 3 - STRUCTURAL LUMBER



<u>Legend</u>
BG - Build Green Product
C - Conventional Material
L - Structural Lumber



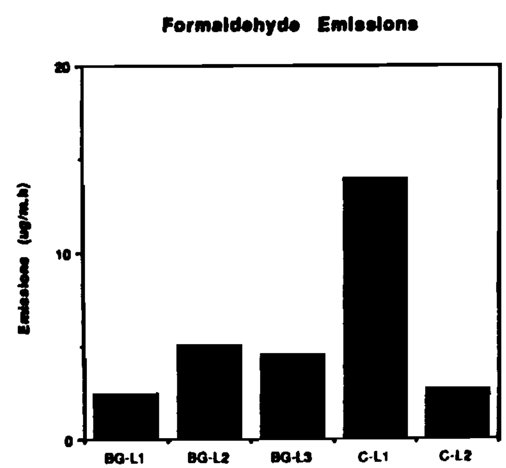


FIGURE 4 - INSULATION

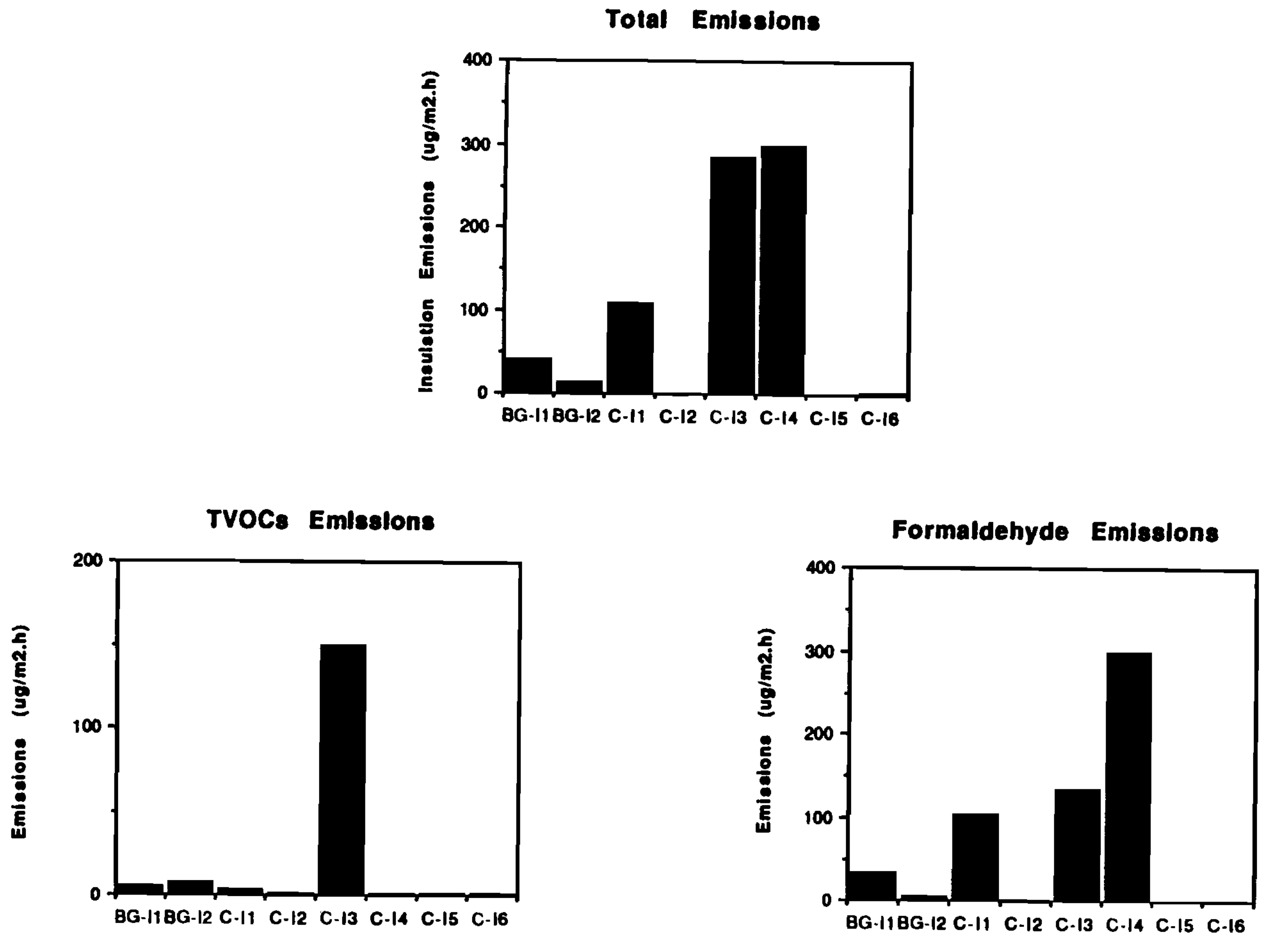


FIGURE 5 - COUNTER TOPS, CABINETRY & FIBERBOARD

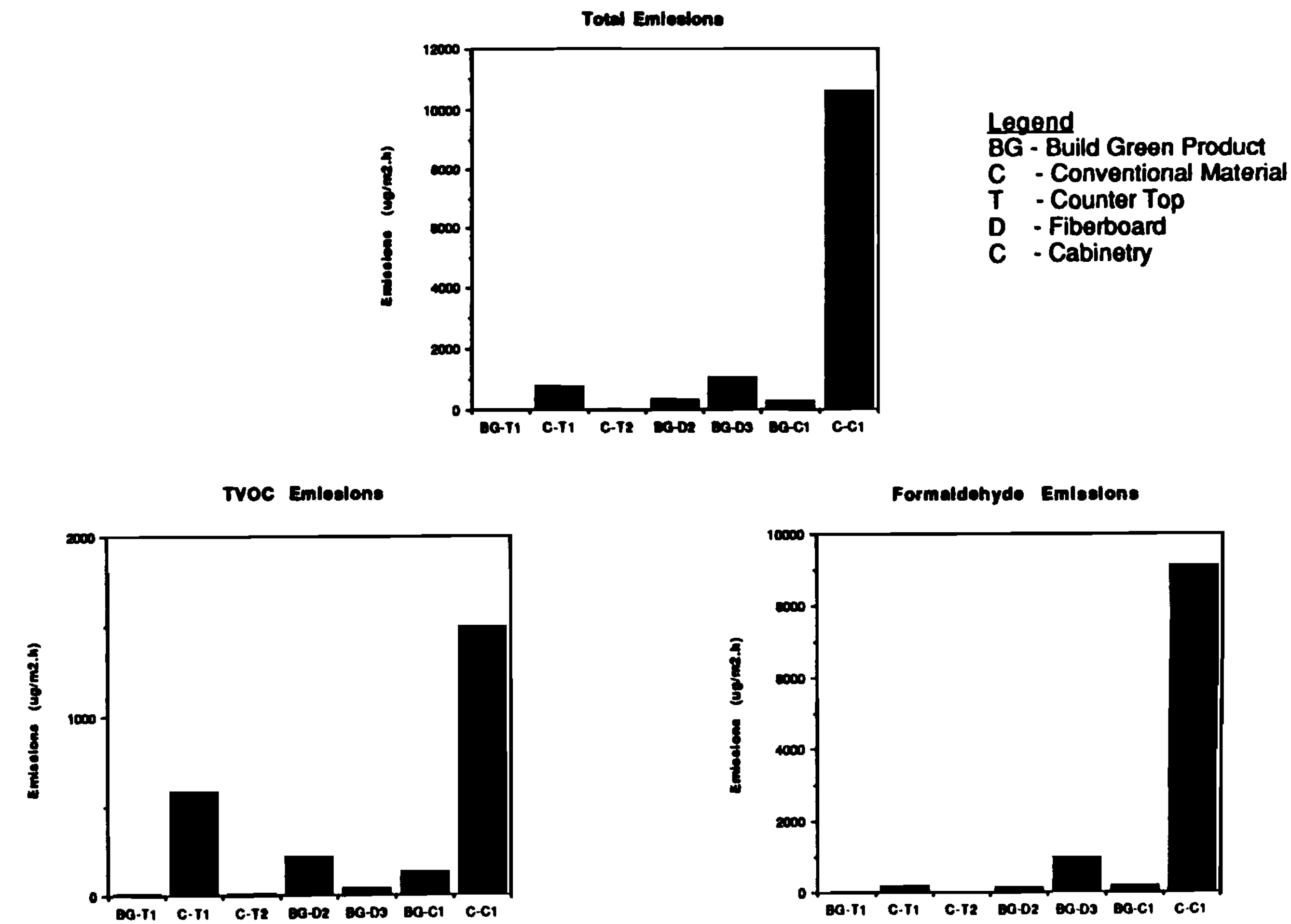
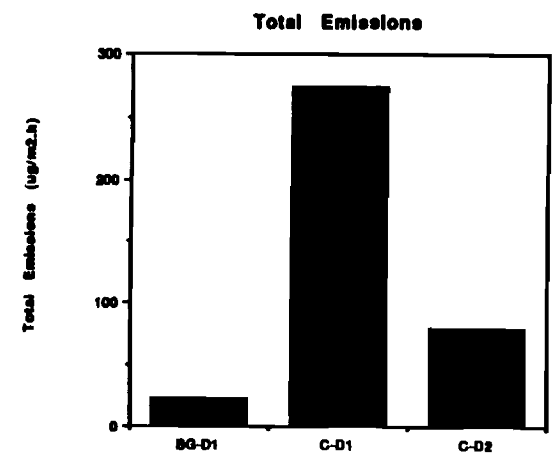
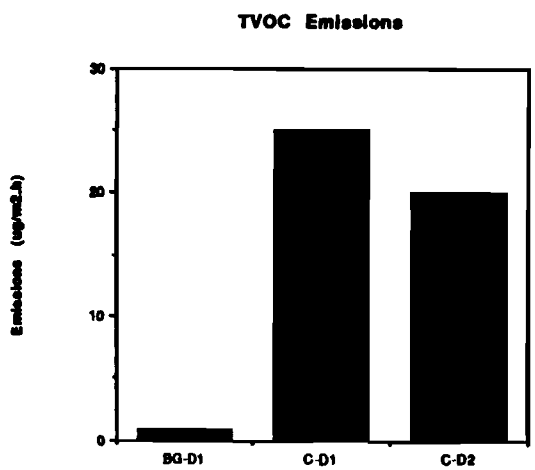


FIGURE 6 - GYPSUM WALLBOARD



Legend
BG - Build Green Product
C - Conventional Material
D - Gypsum Wallboard



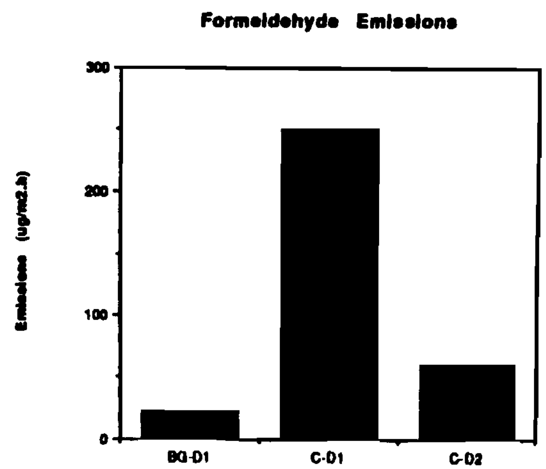


FIGURE 7 - FOUNDATION MATERIAL