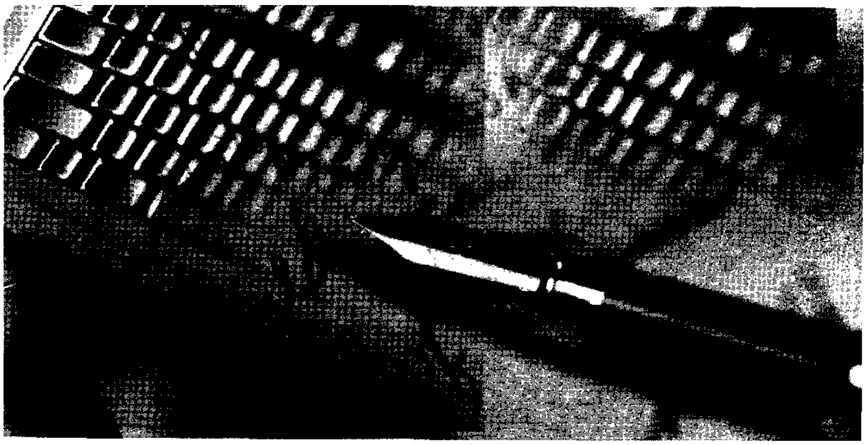
RESEARCH REPORT

MOLDS IN FINISHED BASEMENTS



CMHC SCHL

brought to you by:

LEGALETT

HOME TO CANADIANS

Canada

CMHC—HOME TO CANADIANS

Canada Mortgage and Housing Corporation (CMHC) is the Government of Canada's national housing agency. We help Canadians gain access to a wide choice of quality, affordable homes.

Our mortgage loan insurance program has helped many Canadians realize their dream of owning a home. We provide financial assistance to help Canadians most in need to gain access to safe, affordable housing. Through our research, we encourage innovation in housing design and technology, community planning, housing choice and finance. We also work in partnership with industry and other Team Canada members to sell Canadian products and expertise in foreign markets, thereby creating jobs for Canadians here at home.

We offer a wide variety of information products to consumers and the housing industry to help them make informed purchasing and business decisions. With Canada's most comprehensive selection of information about housing and homes, we are Canada's largest publisher of housing information.

In everything that we do, we are helping to improve the quality of life for Canadians in communities across this country. We are helping Canadians live in safe, secure homes. CMHC is home to Canadians.

Canadians can easily access our information through retail outlets and CMHC's regional offices.

You can also reach us by phone at 1 800 668-2642
(outside Canada call (613) 748-2003)
By fax at 1 800 245-9274
(outside Canada (613) 748-2016)

To reach us online, visit our home page at www.cmhc-schl.gc.ca

Canada Mortgage and Housing Corporation supports the Government of Canada policy on access to information for people with disabilities. If you wish to obtain this publication in alternative formats, call 1 800 668-2642.

Molds in Finished Basements

FINAL REPORT

Prepared for:

Technical Policy and Research Division
Canada Mortgage and Housing Corporation
700 Montreal Road,
Ottawa, Ontario
K1A 0P7

CMHC Project Manager: Don Fugler

Prepared by:

Scanada Consultants Limited
436 MacLaren Street
Ottawa, Ontario
K2P 0M8

Scanada Consultants Limited
Project Manager: Ken Ruest

April 1996

NOTE: **DISPONIBLE AUSSI EN FRANÇAIS SOUS LE TITRE:**

LA MOISISSURE DANS LES SOUS-SOLS AMÉNAGÉS

Disclaimer

ACKNOWLEDGEMENTS

The Molds in Finished Basements project was conducted for the Technical Policy and Research Division of Canada Mortgage and Housing Corporation.

Many people contributed to the success of this project. Contributions varied from providing valuable information, insightful tips and creative ideas, sharing of specialized knowledge to simple support and dedicated hard work. The following deserve to be mentioned:

- From CMHC, Don Fugler and Jim White for sharing their knowledge and guiding the research.

- The mold specialists consulted in developing the mold sampling protocols, Doctors David Miller of Agriculture Canada, David Malloch of the Department of Botany of the University of Toronto and Paul Widden of the Biology Department of Concordia University.

  - Dr. Paul Widden's suggestion of the relatively low cost cellophane tape mold sampling procedure contributed to the success of the final mold sampling protocol.

  - Dr. David Miller's suggestions with his comprehensive knowledge of mycology helped in the development stages of the project, and in interpreting the importance of the mold findings.

  - Dr. David Malloch, not only contributed his expertise in the protocol development but also in doing the identification of the mold samples. He provided extra value to the analysis of the pilot house samples to ensure that the final procedure used would get the most results. His accessibility and cooperation was extremely appreciated.

- All of the homeowners, for the confidence they demonstrated to the investigators in providing access to their houses for this research work.

The project team consisted of:

- Ken Ruest, Terry Robinson, Anil Parekh, Henry Hum and Nicola Rutherford of Scanada Consultants Limited
- Rosemary Spencer of R.J. Spencer and Associates

Table of Contents

ABSTRACT

Finished basements in twenty-seven Ottawa houses were investigated to determine if the basement assemblies could contribute to poor indoor air quality due to molds. The wall cavities were inspected with optical fibrescopes to determine the composition and note the conditions. Visible mold colonies were sampled to identify mold species. The presence of molds correlated with the presence of chronic wetting events rather than any particular basement finishing techniques. Molds were analyzed from 16 (59%) of the houses and toxigenic molds were found in all houses except one.

Executive Summary

Evidence from other research has shown that molds in houses have a negative impact on the occupants' health. Some molds are highly toxic and the interest in better indoor air quality is prompting researchers to determine the causes of mold growth indoors. Basements are often moisture-troubled parts of houses and "finished" basements in particular are of concern because they may be hiding these mold and moisture problems. Canada Mortgage and Housing Corporation contracted Scanada Consultants to undertake this project in which 27 Ottawa houses were investigated for molds in the finished basement walls and floors.

During the winter and early spring of 1995, CMHC conducted a survey of 405 houses in the Ottawa area. The survey consisted of brief basement inspections and homeowner questionnaires to determine the incidence of moisture problems in finished basements. About half of the houses from that survey had signs of moisture in the basement. Twenty-two of the houses for this project were selected from those 405 houses.

The main objective of this field research project was to determine whether typical "finished" basements are contributing to poor indoor air quality as a result of mold growth in the finishing materials. Finished basements were investigated with optical fibrescopes to visually inspect the wall cavities. When visible signs of molds were found, samples were taken and sent for mold species identification. The mold samples were only taken from the surfaces affected and no room air samples were taken. It was assumed that the molds found in the wall cavities could contaminate the room air since the basement wall cavities are not airtight.

The two mold sampling procedures used were swabs and cellophane tape. The first method consists of passing a cotton swab onto the moldy surface and then transferring the material collected to a media to allow the molds to grow and be identified in the laboratory. The second method consists of sticking a piece of adhesive cellophane tape to the moldy surface. The tape is then stuck to a microscope slide to be sent to the lab. The material collected on the tape is subsequently identified with a microscope. This method allows some mold species to be identified if the shape and colour of their spores are distinctive.

Molds were found in 18 houses and sampling was done in 16 of them (molds in the other two basements were not related to the finishing). In all of the 16 houses where sampling was done, molds with properties that are harmful to humans were found.

Details of the basement wall construction in each house were gathered and causes of moisture problems were identified. The majority of basements had wood framing, glass fibre insulation and drywall interior finish. A variety of types and installation conditions were observed with regards to air/vapour barriers and moisture barriers. Moisture sources were mainly from the exterior, such as from: foundation cracks; window well leaks; ineffective dampproofing and perimeter drainage; poor grading; and downspouts at foundation walls. Interior sources were from: clothes dryers and basement bathroom fans which were not vented properly to the outside; high summer relative humidity; and plumbing leaks.

The presence of molds in finished basements correlates with the presence of recurring moisture sources rather than with basement finishing techniques. Some of the harmful molds found warrant remedial measures be taken for health reasons. There were some basements investigated where the durability of the finished basement assembly and thermal performance are being affected by the moisture problems.

1. INTRODUCTION

Over the last few years, studies sponsored by Canada Mortgage and Housing Corporation (CMHC), Health Canada and NRCan, as well as by Harvard University, have established strong links between health problems and moisture in houses. Moisture leads to increases in a number of biological contaminants including mold, dust mites, and bacterial toxins. The most recent studies suggest that, of these, mold is the most important factor.

At the same time as CMHC was conducting comprehensive investigations including mold sampling and occupant health tests in Wallaceburg Houses[1] during the winter of 1995, another CMHC survey of 405 Ottawa houses was in progress. This latter project consisted of brief inspections to determine the incidence of moisture problems in finished basements. Results from this survey showed that:

- Approximately 75% of the homeowners said they had no moisture problems in their basements;
- The field survey indicated that about half of the basements had obvious evidence of previous problems such as spalling concrete, efflorescence, moisture stains and molds, and 35% of basements had either musty, moldy or earthy odours. (see Appendix 4 for statistical information)

Most of the visual observations were made in the unfinished portions of the basements during the Phase I "Survey of Basements for Moisture Problems"[2]. The survey showed that basements are still often being tolerated as a moisture troubled part of houses with all the inherent problems caused by poorly graded, poorly drained, poorly insulated and poorly airtightened basements.

Scanada Consultants Limited with R.J. Spencer, one of the researchers involved in the first phase, was awarded the contract to undertake a detailed study of moisture problems in finished basements and effects health. In this part of CMHC's study, 27 houses were explored in a more intrusive way to verify the presence and type of molds in finished basement walls. Twenty-two houses from Phase I were reinvestigated during this study. The project aimed to survey indoor conditions and construction practices of finished basements, and to identify the mold species to assess the potential health hazards for the occupants.

The pilot house tests were conducted in October and the remainder of the houses were tested from November 8 to December 19, 1995.

[1]Wallaceburg Phase II project

[2] Survey of Basements for Moisture Problems - Anecdotal Report, by Catherine Soroczan and Rosemary Spencer, June 28, 1995

2. Objectives

The main objective of this field research project was to determine whether typical "finished" basements are contributing to poor indoor air quality as a result of mold growth in the finishing materials. Another objective was to see if certain finishing techniques are more likely to create moisture problems. At the onset, it was recognized that the second objective would be difficult to achieve with a small sample of basements.

3. Methodology

One of the challenges was to find a procedure to investigate finished basement wall cavities with the least disruption to the walls and finishes. This was required to minimize costs of repairs, inconvenience to occupants and improve the homeowner's willingness to participate. Finding a reliable sampling procedure for mold species identification, suitable for the limited wall cavity access, was an interesting challenge.

The following assumptions were made during the process of establishing mold sampling and inspection procedures:

- Although the inspections would be done at a time when the basement was not suffering from moisture problems, and mold growth activity was not necessarily at its peak, tell-tale signs of moisture and mold would be visible if such conditions had occurred in the past.
- Basement wall cavities are connected to the indoor air at various construction details and finish penetrations. Therefore, if molds are present in the wall cavities, they are able to contaminate the indoor air.

These assumptions were based on the principal researcher's past experiences and years of moisture investigations, airtightness testing and trouble shooting in houses.

3.1 Mold Sampling Methodology

The project team consulted with three mycology experts from different accredited laboratories in order to refine the mold sampling procedures. Two procedures were selected for gathering mold samples from visible colonies. The methods used were: (1) swab samples, and (2) spores collected on cellophane tape. These two procedures of collecting mold samples complemented one another by permitting the identification of a greater number of mold species.

Most mold sampling procedures for species identification, including the swab sampling procedure, rely on the presence of viable mold spores being present in the collected sample. If some of the spores collected are not viable, they will not grow when cultured in the laboratory. Consequently, if these molds are present in the sampled area but do not grow in the lab, they cannot be identified. For example, mold spores from the *Penicillium* and *Aspergillus* genera tend to remain viable for long periods of time, even after the proper growth conditions no longer exist. These molds would likely grow when transferred from the swabs to the culture media. Some mold species from the two mold genera mentioned above are highly toxic to humans, while other species are not. This is also true for other mold genera and species, so mold analysis is required at the species level. Two examples of species from these two mold genera which are toxigenic[3] are *Penicillium brevicompactum* and *Aspergillus versicolor*[4].

Some mold species' spores do not remain viable a long time after the conditions needed for their growth have changed. As the spores viability declines, there is a point at which they won't grow on laboratory medium but they would still grow in the environment where they were found if the proper conditions recurred.

Spores of *Stachybotrys atra*, a dangerous[5] mold species rarely found in houses, do not remain viable for long periods of time in dry conditions. However, the spores of this species are sufficiently distinctive to be visually identified when viewed with a microscope. The cellophane tape spore sampling method was used to identify some mold species which could not have been detected from the swab samples, if the spores were not viable.

Room air sampling for airborne mold spores, carpet dust samples and ergosterol sampling were also procedures explored in preparing the sampling protocol. Costs and other factors were responsible for choosing not to use these methods for this project.

The swab samples method consists of collecting mold spores with a sterile cotton swab dipped in water, and passing it over the moldy surface. Instead of transferring the collected material to a culture medium in the field, an alternative procedure was developed to minimize possibilities of sample contamination outside the laboratory's controlled conditions. Once the sample had been taken, the swab was secured in an evacuated glass tube and capped with a rubber stopper to prevent it from drying.

---

[3] toxigenic: an organism that produces toxic compounds that have the property to harm humans.

[4] Significance of Fungi in Indoor Air: Report of a Working Group, Health and Welfare Canada, 1987.

[5] The American Industrial Hygiene Association has labelled four molds as "dangerous" — a designation more severe than "toxigenic". This is noted in more detail later in the report.

The sampling method for the collection of mold spores for microscopic observation consists of applying a piece of clear adhesive cellophane tape on to the mold colony. The tape is then fixed to a microscope slide which is sent for identification.

Both types of samples were submitted to the lab within 24 to 48 hours. The swabbed samples were then transferred to the culture media to avoid drying of the spores or mold growth in the cotton swab. After an incubation period, the molds were speciated. The cellophane tape samples on microscope slides did not have to be shipped quickly since they did not need to be cultured. The molds could be identified by microscope at any time.

3.2 Pilot House Testing

The procedures and sampling methods were tried out in three pilot houses. Two of the houses were known to have mold problems while the third had previously had a flooding incident but no visible evidence of problems reported. The results of the mold sampling showed that the procedure was successful in producing excellent samples for analysis in the laboratory.

The pilot houses were labelled P1, P2 and P3 initially to distinguish them from the others which are labelled M1 to M24. There is no other significance to letters P and M since the tests were done the same way in all houses.

3.3 House Selection

During the Phase I survey of 405 houses, homeowners were asked if they would like to participate in a more detailed phase of the research. The entire database of the 405 houses was used to determine the age and types of houses and basements that were surveyed. The selection criteria for this study were based mainly on the proportions of house types, age, basement finishing as were surveyed in Phase I.

To ensure certain types of houses or basements would be included in the sample of houses, the project officer chose additional criteria with a bias towards those reported to be moisture troubled houses. Out of the 27 houses surveyed, there were nine houses with no signs of moisture problems, two houses from the period when full height insulation was required by the Ontario building code, and two with only half height finish and insulation.

The selection process began by searching through the 200 odd files from houses where homeowners had expressed an interest in further research. The homeowners were called and the research and test procedures were explained. A follow-up sheet with the information about the project, along with a disclaimer, which had to be signed to participate, were sent by fax or mail (example sheets in Appendix 1). Further follow-up calls were required to get responses from some homeowners. Others signed and returned disclaimers by fax or called to confirm their willingness to participate within one or two days. Those that declined to participate were mainly concerned about how the interior finish would be affected by the inspection procedure.

3.4 Field Testing

The field inspections were conducted by a two person team.

3.4.1 Sketch and Notes on Surrounding

A plan view of the house and surroundings was made during the exterior walk around. Items such as eavestroughs, downspout locations, large trees, grading, and adjacent buildings proximity were noted to provide some indication of potential basement moisture sources from the outside. Cracks in foundation were noted as well as any detail which might guide the researchers to suspect moisture areas during the interior inspection.

The exterior data such as grading became more difficult to gather as the project progressed due to the snow cover on the ground. House tests performed at night compounded the difficulties of gathering the exterior surroundings information.

3.4.2 Temperature, Relative Humidity and Wood Moisture Readings

Temperature and relative humidity readings were taken inside and outside at each house. The exterior readings were either taken on site with an electronic thermometer/hygrometer or Environment Canada's readings were recorded for the time of the inspection. Indoor readings were taken on the main floor level, and in the finished and unfinished portions of the basement.

Relative humidity readings in the basement were used for two purposes. Besides recording the current conditions during the inspection, these readings were also used to compare with the wood moisture readings, to see if a correlation exists between long term RH and wood moisture contents. The temperatures and RH readings were taken with a sling psychrometer at about half height between the floor and ceiling.

Wood moisture meter readings were taken from exposed lumber such as floor joists and studs. These readings were taken at least two feet away from exterior walls. Areas close to heat distribution ducts were avoided. The furnace room was often the only room where exposed lumber was available. Wood moisture readings in studs were taken at mid-height from the floor to the ceiling. Five readings were recorded in each basement and the location of the readings was also noted to compare with either the finished or unfinished basement temperatures and relative humidity readings.

3.4.3 Wall Cavity Inspection and Sampling

Wall cavities to be sampled were first selected based on the homeowner's recollection of moisture troubled areas. These were either areas that they knew of basement leaks, plumbing leaks (before or after the basement was finished), or visible problems such as carpet wetting, mold growth on wall finishes etc.. If no known problem area existed, the walls were carefully inspected for signs that the homeowners might not have noticed. Exterior observations of poor grading, foundation cracks, and eavestrough downspouts directly at foundation were useful indications to locate areas suspected of being prone to problems.

Where possible, access to the wall cavities was gained at electrical outlets which provided access inside the wall without damaging the interior finish. When there was no easy access to the cavity, holes were drilled for the optical fibrescope inspection. The presence and type of air/vapour barriers, framing, insulation, moisture barrier and other materials were noted. Wood moisture readings were taken from wood components in the wall cavity. Wood temperatures at the wood moisture readings location were also recorded to allow for wood moisture corrections to be made if required later.

Observations on to the conditions of the cavity were noted. If molds were found, mold samples were taken to be sent to the laboratory. When the fibrescoping inspection hole was not sufficient to gather the mold samples properly, an opening of about 75 cm by 50 cm was made. Meticulous care was taken in cutting the openings to avoid affecting the area to be sampled. The interior finish was then repaired to the homeowner's satisfaction.

4. Discussion of Findings

The main question to be answered by this research was whether finished basements contribute to poor indoor air quality. Molds attributable to methods used to finish the basement were the focus. Room air sampling was not conducted since it was determined that molds found in the walls could get into the room air freely if the wall cavities were not airtight. A more diversified series of tests could have quantified the presence mold spores in the basement air, but costs limited the types of tests to be performed. Nonetheless, the mold sampling and investigative procedure were successful in identifying problems and identifying mold species which are undesirable due to their toxicity.

Based on the observations from the 405 house survey, nine houses were selected as having no visible signs of moisture or mold, and 18 with reported signs of moisture or molds. The nine houses without signs were chosen to investigate if hidden mold growth could be found. As the investigations progressed, some basements were reclassified. Four basements reported as moisture trouble free were found to have moisture and mold problems which were not detected in the initial survey. Amongst the basements reported as moisture troubled due to isolated wetting incidents, four were found to be moisture and mold free or the problem not related to the basement finish. Eight houses were reclassified but, the total of moldy and non moldy basements stayed the same.

From the 27 houses investigated, there were visible signs of molds present in the basements of 18 houses. Mold samples were taken and sent for analysis from 16 of those houses. In house M13 the mold sample was taken from a water stained piece of furniture. The basement wall cavities were fine in that house but summer condensation on the basement floor soaked the carpet in the past. It is probable that spores from the molds identified on the furniture are present in the carpet as a result of those past wetting incidents.

Two basement mold cases were not sampled for molds. The presence of molds were from causes unrelated to the basement finishing and insulation. In one of these houses (M3), the basement moisture source was a clothes dryer. The dryer and bathroom exhaust fan were ducted to the outside through the same exhaust hood and the dryer would spill moist air into the bathroom. In the other house which was not sampled (M5), the molds were limited to a small area behind boxes which restricted the flow of air to the area and this was deemed unrelated to the basement finish.

In the other 16 basements with molds, the basement finishing techniques and materials seem to be less of a contributing factor than the presence of moisture sources. There were, nevertheless, some construction practices that seem to contribute to the problem more so than others. These are discussed further in the report.

4.1 Molds

Molds which are considered toxigenic were found in 15 of the houses and although one of the moldy basements had no toxigenic molds, it had one pathogenic[6] mold. The impact of the presence of these molds on health will not be discussed at great lengths here since it is beyond the scope of the project.

The mold species that were detected and should be considered seriously are listed in Table 1. The number of houses in which each of these species was found is indicated and the house I.D. codes where they were detected are also shown. *Aspergillus versicolor*, which is a dangerous mold, was found most often (12 houses). *Stachybotrys atra*, which is also a dangerous mold was detected in five (5) houses. The relatively high incidence of Stachybotrys atra in such a small sample of houses is because the sample was biased towards houses with moisture troubled basements.

[6] pathogenic: organism causing or capable of causing disease

An interesting note to add here is that, in three of the cases where *Stachybotrys atra* was detected, it was with the relatively low cost method of cellophane tape and microscope visual identification. This mold could not have been identified from the swab samples since the spores collected were not viable. As discussed earlier, spores from this species are not viable for long periods of time in dry, unfavourable growing conditions. Even if the spores collected were not viable to grow on the laboratory medium they might still have been viable to grow in the environment from which they were taken. In fact, there would be a 99% chance that the mold colony would still grow if rewetted[7].

Table 1: Toxigenic and Dangerous Mold Species Found in the Houses Tested

Mold Species	No. of Houses where Species Found	House I.D. Codes where Mold Species was Present
*Aspergillus versicolor**	12	P1, P2, M1, M11, M12, M13, M14, M16, M20, M22, M23, M24
Paecilomyces varioti	1	M20
Penicillium aurantiogriseum	1	M21
Penicillium brevicompactum	1	P1
Penicillium crustosum	1	M22
Phoma herbarum	1	M23
*Stachybotrys atra**	5	P1, M11, M15, M20, M23
Trichoderma viride	1	M4

* **Note:** Four molds have been labelled as "dangerous" by the American Industrial Hygiene Association (AIHI) in 1996, a designation more severe than "toxigenic". These are *Aspergillus versicolour, Stachybotrys atra, Aspergillus fumigatus,* and *Fusarium moniliform.*

The full list of mold species identified and the houses in which they were found is shown in Table 2. In this Table, the toxigenic molds are indicated by the shaded band across the columns. It is a two page table and at the bottom of the page, there is a summary of: the number of molds species found per house; the number of toxigenic molds; the number of each type of samples taken; and the number of different sampling locations in the basement. The last column of page 2 shows the number of houses where each mold species were detected.

Note that no mold analysis took place in houses without visible molds or moisture damage. It is possible that these houses would show evidence of molds if thoroughly sampled.

[7] Reference to a conversation with Dr. David Miller of Agriculture Canada

Table 2

Identified Fungal Species from Swab and Cellophane Tape Collection

Species	Toxigenic	P1	P2	P3	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11
Acremonium kiliense		✓													✓
Acremonium psaliotae															✓
Acremonium strictum															
Alternaria alternata															
Arthrobotrys oligospora		✓													
Ascotricha chartarum			✓												
Aspergillus candidus															
Aspergillus cervinus															
Aspergillus herbariorum															
Aspergillus ochraceus			✓												
Aspergillus sydowii		✓	✓												
Aspergillus versicolor	✓	✓	✓		✓										✓
Basidiomycete															
Blastobotrys nivea															✓
Chaetomium cochlioides			✓												
Chaetomium murorum															
Cladosporium cladosporioides															
Cladosporium sphaerospermum					✓										
Cylindrocladium															
Eurotium herbariorum					✓										
Exophiala jeanselmii		✓													
Exophiala sp.			✓												
Geomyces pannorus															
Gliocladium sp.															
Gliomastix luzulae		✓													
Gliomastix murorum															✓
Malbranchia arcuata			✓												✓
Microascus cinereus															✓
Microascus cirrosus															
Microsphaeropsis olivacea															
Mucor hiemalis													✓		
Myxotrichum ochraceum		✓	✓												✓
Oidiodendron cereale		✓													✓
Oidiodendron griseum		✓													
Paecilomyces varioti	✓														
Penicillium aurantiogriseum	✓														
Penicillium brevicompactum	✓	✓													
Penicillium canescens															
Penicillium chrysogenum		✓	✓		✓										✓
Penicillium corylophilum								✓							
Penicillium commune								✓					✓		
Penicillium crustosum	✓														
Penicillium duclauxii															
Penicillium glabrum		✓	✓		✓			✓							
Penicillium hirsutum													✓		
Penicillium rugulosum															
Penicillium simplissimum													✓		
Penicillium variabile			✓												
Penicillium waksmanii															
Petriella setifera															
Phialophora verrucosa		✓													
Phoma herbarum	✓														
Rhizopus nigricans															
Scopulariopsis fusca			✓												
Scopulariopsis brevicaulis															
Sporothrix schenckii															
Stachybotrys atra	✓	✓													✓
Sterigmatobotrys macrocarpa															
Torulomyces lagena															
Trichocladium opacum		✓													
Trichoderma viride	✓							✓							
Ulocladium botrytis															
Verticillium lecanii		✓													
Yeast								✓							
# mold species identified		16	12	-	5	-	-	4	-	-	-	-	4	-	11
# which are toxigenic		3	1	-	1	-	-	1	-	-	-	-	-	-	2
# of tape samples taken		2	3	-	2	-	-	1	-	-	-	-	1	-	1
# of swab samples taken		3	2	-	2	-	-	1	-	-	-	-	2	-	2
# of locations samples taken from		1	3	-	2	-	-	1	-	-	-	-	2	-	2

Table 2

Identified Fungal Species from Swab and Cellophane Tape Collection

Species	M12	M13	M14	M15	M16	M17	M18	M19	M20	M21	M22	M23	M24	# of houses with species
Acremonium kiliense												✓		3
Acremonium psaliotae														1
Acremonium strictum												✓		1
Alternaria alternata												✓		1
Arthrobotrys oligospora														1
Ascotricha chartarum														1
Aspergillus candidus		✓									✓			2
Aspergillus cervinus									✓	✓				2
Aspergillus herbariorum		✓							✓			✓		3
Aspergillus ochraceus														1
Aspergillus sydowii									✓		✓			4
Aspergillus versicolor	✓	✓	✓		✓				✓		✓	✓	✓	12
Basidiomycete									✓					1
Blastobotrys nivea			✓						✓	✓				4
Chaetomium cochlioides				✓										2
Chaetomium murorum												✓		1
Cladosporium cladosporioides	✓									✓		✓	✓	4
Cladosporium sphaerospermum									✓	✓	✓	✓		5
Cylindrocladium									✓					1
Eurotium herbariorum														1
Exophiala jeanselmii														1
Exophiala sp.														1
Geomyces pannorus												✓		1
Gliocladium sp.												✓		1
Gliomastix luzulae														1
Gliomastix murorum									✓					2
Malbranchia arcuata			✓											3
Microascus cinereus														1
Microascus cirrosus		✓	✓											2
Microsphaeropsis olivacea										✓				1
Mucor hiemalis														1
Myxotrichum ochraceum														3
Oidiodendron cereale			✓											3
Oidiodendron griseum														1
Paecilomyces variotii									✓					1
Penicillium aurantiogriseum										✓				1
Penicillium brevicompactum														1
Penicillium canescens					✓									1
Penicillium chrysogenum			✓		✓				✓		✓	✓		9
Penicillium corylophilum									✓					2
Penicillium commune													✓	3
Penicillium crustosum											✓			1
Penicillium duclauxii									✓					1
Penicillium glabrum														4
Penicillium hirsutum														1
Penicillium rugulosum									✓					1
Penicillium simplissimum														1
Penicillium variabile			✓								✓			3
Penicillium waksmanii										✓			✓	2
Petriella setifera		✓												1
Phialophora verrucosa														1
Phoma herbarum												✓		1
Rhizopus nigricans													✓	1
Scopulariopsis fusca												✓		2
Scopulariopsis brevicaulis											✓	✓		2
Sporothrix schenckii											✓			1
Stachybotrys atra				✓					✓			✓		5
Sterigmatobotrys macrocarpa				✓										1
Torulomyces lagena									✓					1
Trichocladium opacum														1
Trichoderma viride														1
Ulocladium botrytis			✓									✓		2
Verticillium lecanii														1
Yeast	✓									✓		✓		4
# mold species identified	2	5	8	3	3	-	-	-	16	7	9	16	5	
# which are toxigenic	1	1	1	1	1	-	-	-	3	1	2	3	1	
# of tape samples taken	0	1	1	1	1	-	-	-	4	2	3	6	2	
# of swab samples taken	1	0	4	1	1	-	-	-	5	2	3	6	2	
# of locations samples taken from	1	1	2	1	1	-	-	-	4	2	1	2	2	

Cladosporium cladosporioides, a phylloplane mold (leaf molds) that can be found in outdoor air was detected in four houses. However, in two of these houses, there were **indoor** sources which could contribute to higher indoor counts. In house M12, there is a partitioned portion of the basement that is used as a green house to grow flowering plants. Dead leaves and plant parts decaying in the excess water catch basins below the plants could actually be an indoor source for such molds. The other case, house M24 has lots of dried branches, leaves and weeds in baskets in the basement which could also be a source of these molds inside.

A full list of the molds detected from each sample collected is included in Appendix 2. The notation with regards to "Quantity" is simply related to the number of spores seen on the microscope slide and tape or the number of mold colonies that grew on the petri dish culture media. These comments with regards to quantity cannot be related to the quantities of mold spores or colony-forming units that would be found in the room air of the houses tested. This is simply an indicator of quantities of material collected by each sample at those locations. The sampling collection methods would have had to be different to extrapolate quantitative data from these results.

4.2 Basement Finishing Techniques and Observations

The 27 houses offered a variety of typical basement finish types. These included basements finished by builders (finished during construction) or contractors (finished later as a renovation) and homeowner finished basements (also as a renovation). The house age range as well as the finishing periods included most basement finishing trends.

The majority of basements had some form of stud framing with glass fibre insulation and a finish of drywall or wood product such as wood panelling, as opposed to rigid insulation glued to the wall. Only five houses had expanded polystyrene insulation. Three of these had stud framing over the polystyrene insulation to support the interior finish and two had glass fibre insulation between the studs.

Due to a variety of different installation practices of vapour barriers, moisture barriers, and full height versus half height insulation, it was challenging to group houses to compare performance of finishing techniques and presence or absence mold and moisture. Twelve houses could be grouped as having drywall finish full height, poly AVB, glass fibre insulation full height, and stud framing full height. If the moisture barrier was considered for those 12 houses there would be five different types or installation conditions. Six of these houses had mold/moisture problems and the moisture barrier type or placement did not correlate with the problematic basements. Table 3 summarizes the wall types included in the 27 houses. The data has been sorted first by year of construction and then by year of basement finishing when more than one condition existed.

The fourth line of the table shows which houses had molds as indicated by the uppercase "M". The lower case "m" indicates houses where molds were found but the causes were not

Table 3. Wall Construction Details

House I.D.Code	P2	M11		M1		M2	M16		P1	M20	M3		M21		M4	M5	M13		M10	M18	
year built	20	21	21	46	46	50	57	57	59	60	62	62	62	62	62	68	69	69	70	70	70
year basement finished	66	89	90	83	92	70	60	95	79	86	62	68	70	93	89	70	85	85	75	80	80
M=molds present m=molds unrelated	M	M	M	M	M		M		M	M	m		M	M	M	m	m				
health risks due to molds	✓	✓	✓	✓	✓		✓		✓	✓			✓	✓	?		?				
basement has durability problems	✓	✓	✓							✓				?							
one time wetting incident											✓				✓				✓	✓	✓
sporadic wetting																					
chronic wetting	✓	✓	✓	✓	✓		srh		✓	✓			wrh	wrh			srh				
corrected moisture problem						✓	✓														
minor localized problem															✓	✓					
no AVB			✓			✓		✓	✓						✓				✓		
poly AVB				✓	✓					✓				✓		✓	✓	✓			
kraft paper AVB		✓									✓	✓								✓	✓
foil AVB	✓						✓														
glass fibre batts full height		✓	✓						✓			✓		✓	✓	✓					
glass fibre batts to 300 mm above floor				✓	✓																
glass fibre batts top 1.2 m only								✓			✓						✓	✓		✓	✓
expanded polystyrene						✓			✓										✓		
glass fibre batts R-19 ful height										✓											
cellulose fibre (BIBS system)																					
2 x 4 or 3 full height		✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
2 x 4 or 3 half height																					
2 x 4 or 3 flat (as a strapping)																			✓		
2 x 2 or 1 x 2 strapping															✓						
building paper full height										✓											
building paper top half only								✓												✓	✓
poly full height											✓	✓					✓	✓			
no moisture barrier	✓	✓	✓	✓	✓	✓	✓		✓				✓	✓	✓	✓				✓	✓
poured concrete foundation	✓	✓	✓	✓	✓		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
concrete block foundation						✓			✓												
dampproofing membrane (Platon)																					

Table 3. Wall Construction Details

House I.D.Code	M14	M24	M22		M19		M12		P3	M9		M17		M15		M23	M7	M6		M8
year built	70	75	82	82	83	83	84	84	86	87	87	87	87	88	88	92	93	94	94	94
year basement finished	95	93	82	86	83	89	84	86	89	87	87	87	90	88	88	92	93	94	94	94
M=molds present m=molds unrelated	M	M	M					M			M				M	M				
health risks due to molds	✓	✓	✓					✓			✓				✓	✓				
basement has durability problems	✓	✓									✓									
one time wetting incident							✓		✓											
sporadic wetting																✓	✓			
chronic wetting	✓	✓	✓		✓			✓			✓				✓					
corrected moisture problem																				
minor localized problem																				
no AVB						✓														
poly AVB	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
kraft paper AVB																				
foil AVB																				
glass fibre batts full height			✓						✓		✓		✓					✓	✓	✓
glass fibre batts to 300 mm above floor														✓		✓				
glass fibre batts top 1.2 m only				✓	✓		✓	✓		✓		✓								
expanded polystyrene		✓				✓														
glass fibre batts R-19 ful height		✓																		
cellulose fibre (BIBS system)																	✓			
2 x 4 or 3 full height	✓	✓	✓					✓	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓
2 x 4 or 3 half height				✓	✓		✓			✓		✓								
2 x 4 or 3 flat (as a strapping)																				
2 x 2 or 1 x 2 strapping						✓														
building paper full height																✓		✓	✓	✓
building paper top half only	✓		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓			✓			
poly full height											✓									
no moisture barrier		✓													n/a					
poured concrete foundation	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
concrete block foundation																		✓	✓	
dampproofing membrane (Platon)																				

directly related to the basement finishing. The shading of some data boxes highlight the correlation between the chronic wetting conditions, the presence of molds and the health risks associated with the molds found and lastly the basements which have durability problems.

Attempts were made to find trends in construction details which could be common to the moisture troubled or moldy basement walls but none could be found. Air/vapour barrier types, full height or half height insulation, moisture barrier type and installation practices were all looked at in attempts to determine contributing factors for the occurrence of molds. None could be found in the limited number of houses tested. The common factor in all moldy basements was the presence of moisture sources or repeated or prolonged wetting incidents. A variety of wetting mechanisms were observed in the troubled basements as well as in the trouble-free basements. The moisture sources will be discussed further in the report.

General Observations About Basement Finishing Practices:

- The basement wall assemblies are not airtight and air movement could be felt at electrical outlets or other openings through the finish. The insulated wall cavities are usually opened to the room air at the top of the finished wall or at the edges of finished and unfinished basement portions;

- Only seven basements had moisture barriers for the full depth below grade (houses M3, M6, M8, M9, M13, M20, M23). The moisture barrier was polyethylene in three cases (M3, M9, M13) and the remaining had building paper. In house M20, the building paper had been fitted between the original studs against the foundation wall. Moisture could easily run into the insulated cavities from exterior leaks. Houses M6 and M8 had the moisture barrier for the full depth insulation as required by the Ontario building code (1993-1994 period). Houses M9 and M23 had some moisture problems that led to mold growth but the problems could not be attributable to the presence of the full depth moisture barrier;

- In two houses, mold growth was observed on the building paper moisture barrier. In house M20, it was the wall's moisture barrier which was moldy while in house M14, it was the sleepered floor's moisture barrier which was affected;

- Nine (9) houses had moisture barriers for the top 1.2 meter of the basement wall only. In some cases the wall had originally only been finished half height by the builder and the homeowners had finished the bottom part. Seven (7) of these basements have had some moisture problems but only two have had mold problems. The nature of the moisture sources (eg. one time water leak rather than chronic leaks or floods) seem to be the reason for the lack of mold problems in all seven houses;

- Baseboards can slow the drying of wet interior finishes. Molds were found between the baseboards and the interior finish in nine (9) out of 18 houses with baseboards in the finished basement. The presence of molds behind the baseboard is a good indicator of mold problems in the insulated cavity. All nine (9) houses with molds on the back of the baseboards had molds in the cavity;

- The two houses with full height insulated basements as required by the Ontario building code were mold free. One of these had an air gap membrane as dampproofing/drainage layer on the exterior of the foundation;

- Spalling of old foundation's concrete was observed to be filling the bottom of the wall cavities in houses P2 and M11. Both of these houses are 1920s vintage and the foundation walls tend to spall. In P2, the basement had been finished in the 1960s with strapping on the concrete, foil AVB, and wood panelling. The cavity was filling with spalled concrete and trapped moisture was soaking the panelling where the cavity was filled (approximately 500 mm along the bottom of the wall). In house M11, the basement finishing had been redone in 1990 as a result of flood damage. No measures had been taken to prevent further water leakage, and no moisture barrier nor air/vapour barriers were installed. Continued water seepage and resulting spalling was filling the bottom of the 2 x 4 frame, glass fibre batt insulated cavity. The moisture retained in the cavity has contributed to mold growth in the wall cavity;

- Drywall in contact with the floor slab can wick moisture from the floor slab. Minor water leakage or spills can result in mold growth which would not have occurred otherwise had the drywall not been in contact with the concrete floor. The heat loss from the drywall to the cooler floor slab can also bring the drywall's surface temperature below the dew point and create a moist surface for molds to grow on. In some basements, along the same wall, molds were present where the drywall was in contact with the floor slab while areas with drywall not in contact were mold free;

- The presence of a polyethylene air/vapour barrier directly behind the drywall can prevent moisture trouble in the cavity from showing-up on the room side through the drywall. The polyethylene prevents the cavity moisture from wetting the drywall;

- Six houses had sleepered floors (M3, M9, M11, M14, M21 & M22). House M9 had parquet hard wood flooring which had lifted due to basement wall leakage.

4.3 Moisture Sources and Wetting Mechanisms

As pointed out previously, mold problems in finished basements correlated with the presence of moisture sources rather than with specific methods of basement finishing and insulating. Furthermore, it is the presence of recurring or chronic moisture problems that are common in houses with mold problems. However, isolated wetting events can cause mold problems if the moisture is trapped and materials remain soaked for a long time.

Except for plumbing leaks and high interior relative humidity, all moisture sources were from exterior sources. Table 4 shows the various interior and exterior moisture sources and wetting mechanisms that were found.

Table 4: Moisture Sources and Wetting Mechanisms

Exterior water/moisture entry into basements due to:	• lack of effective dampproofing on foundation wall • lack of effective perimeter drains • poor soil grading around the house • lack of eavestroughing • lack of proper water diversion from eavestrough downspout away from foundation • foundation cracks • window well flooding • sump pump failure in high water table areas
Interior water/moisture sources:	• burst water pipes • water leak from plumbing pipes • high basement RH in winter due to: - green house in basement - clothes dryer not vented to the exterior - humidifier use - basement temperature fluctuations (thermostat set back when rooms not used) - improperly vented basement bathroom with shower • high basement RH in summer due to: - high summer RH and cool surfaces in basements (worse in deep basements, but also compounded by poor exterior moisture source management as outlined above) - clothes dryer not vented to the exterior - improperly vented basement bathroom with shower

There are some interesting observations that should be pointed out. They are as follows:

- In a few cases, recurring leaks from foundation cracks or window wells did not cause prolonged wetting or mold growth. These leaks did occur in portions of basements which were only finished and insulated for the top half. The water was allowed to drain out of the finished area and was not trapped for long periods in the finished portion of the wall;

- Summer condensation in basements can be the cause of complaints of musty odours. Items and furnishings in basements may become moldy while the finished walls and insulated cavities are not affected. In house M13, the carpet gets soaked in the summer if they do not operate a dehumidifier. Many others also reported complaints of musty odours in the basement if they did not operate dehumidifiers in the summer. Although molds were found in the wall cavities of house M22, the bulk of molds seen were on the interior surface of the baseboard and bottom of the drywall. This condition had occurred last summer when they had neglected to operate the dehumidifier as they had done in previous years;

- The two cases where there had been problems with burst water pipes did not have mold problems as a result of those incidents. This water was domestic "treated" water as opposed to water which had seeped in from outside through the soil. Water leaks through the soil may be bringing mold spores into the house.

Table 5 indicates the moisture sources identified in each house.

4.4 Wood Moisture Readings and Long Term Relative Humidity

Five wood moisture meter readings were taken in each basement to see if a correlation could be made with the measured relative humidity in the room. As shown in Figure 1, the correlation between the average wood moisture meter readings and the relative humidities is demonstrated.

Additional data should be gathered in a variety of conditions and seasons to see if the trend is maintained. Most of these readings were taken in the heating season and in houses with forced air heating with active flues. Although some basements had moisture problems, the wettest period was not necessarily at the time they were tested. Data should be gathered from houses with electric heat (no flues) and houses with moisture problems other than in the basement. If these type of conditions still show a good correlation between wood moisture readings and RH, tables to predict long term RH from wood moisture readings could be developed.

The summaries of data collected with regards to wood moisture readings, indoor temperature and RH in each house are in the Appendix 3.

Table 5. Moisture sources

House codes	Molds Found		Bad Perim Drain	Sump Pump Failur	Poor Grade Slope	No Rain Gutter	Down Spout @fdn	Foundation Leak		Plumbing Leak		Window Well Leak			High Interior RH		Comments
	Yes	No	chronic	twice	chronic	chronic	chronic	sporadic	chronic	once	chronic	once	sporadic	chronic	summer	winter	Comments
P1	✔				✔		✔		✔								
P2	✔		✔		✔	✔											
P3		✔								✔							
M1	✔		✔		✔		✔		*								*leak now repaired
M2		✔							*								*leak now repaired
M3	*									✔					✔	✔	*mold unrelated to finish
M4	✔											✔					minor area affected only
M7		✔											✔				leak drains below half height finish
M9	✔				✔		✔	✔									
M10		✔										✔					
M11	✔		✔		✔			✔									
M12	✔															✔	greenhouse in basement
M13	*														✔		*from floor condensation
M14	✔								✔					✔			
M15	✔										✔						
M16	✔								*						✔		*leak now repaired
M18		✔					*					✔					*downspout leader fell off twice
M19		✔							*								*leaks below half height finish
M20	✔		✔		✔				✔					✔			
M21	✔															✔	molds on fdn wall before finishing
M22	✔				✔										✔		
M23	✔			✔													pump disconnected, (300mm flood)
M24	✔				✔				✔						✔	✔	unvented dryer, basement shower

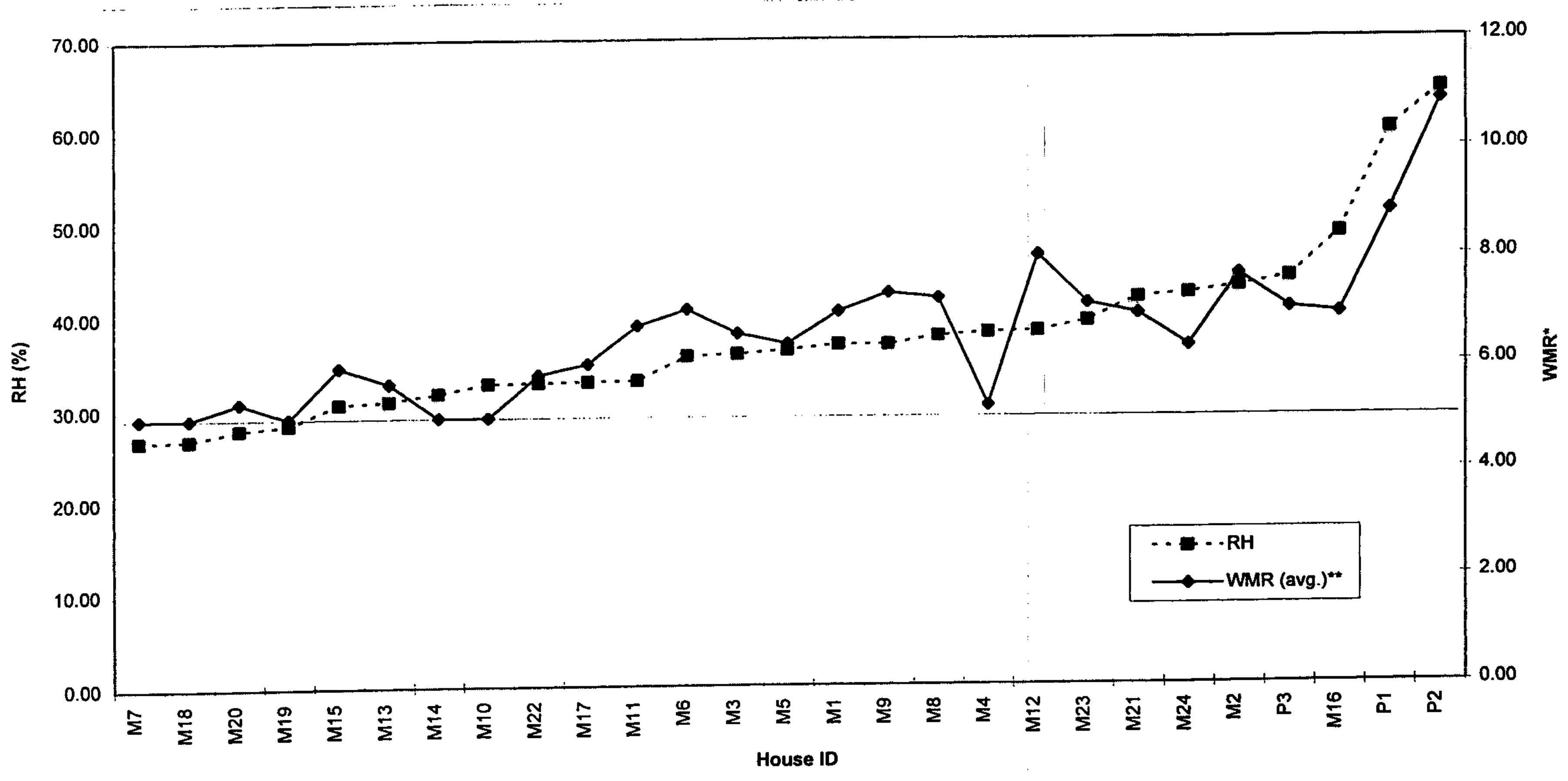


Figure 1. Wood Moisture Readings versus Long Term Relative Humidity

* Data was collected from October to December 1995.

** The Wood Moisture Readings (WMR) which were less than 6 have been replaced by a value of 5 in order to plot the data. The horizontal line on the graph indicates level of less than 6.

5. CONCLUSIONS

The following conclusions can be drawn from this research project:

1. Some finished basements do present health hazards to the occupants due to the presence of toxigenic and dangerous molds in the wall cavities;

2. The causes of mold growth in finished basements are directly related to chronic wetting incidents rather than the wall finishing and insulating techniques;

3. The main chronic moisture sources associated with mold growth in finished basements are exterior moisture sources and wetting mechanisms;

4. Poor grading, lack of eavestroughs or downspouts directly at foundation can lead to excessive foundation moisture. These moisture problems can be exacerbated by the lack of durable foundation dampproofing and perimeter drainage tile systems.

5. Besides the mold concerns, some basements have moisture problems that affect the durability of the finished basement assembly and general performance;

6. The two mold sampling procedures (swabs and cellophane tape) were complementary and allowed for the identification of mold species when visible molds were found;

7. The cellophane tape sampling method with microscope identification is a very good, relatively inexpensive mold sampling method.

8. If the investigative procedure had been more disruptive to the interior finish, most homeowners would have refused to participate. The optical fibrescope was an invaluable inspection tool for this type of investigative project.