AN INVESTIGATION OF THE BIOMETHYLATION OF ARSENIC IN PRESERVED WOOD FOUNDATIONS

Prepared for

the Research Division
Policy Development and Research Sector
Canada Mortgage and Housing Corporation

by

FORINTEK CANADA CORP.
Eastern Laboratory
800 Montreal Road
K1G 3Z5

Principal Consultant: Edward E. Doyle, B.Sc.

CMHC Project Manager: Norman Low
Peter Russell

DISCLAIMER

This study was conducted by Forintek Canada Corp. for Canada Mortgage and Housing Corporation under Part V of the National Housing Act. The analysis, interpretations, and recommendations are those of the consultants and do not necessarily reflect the views of Canada Mortgage and Housing Corporation or those divisions of the Corporation that assisted in the study and its publication.

ABSTRACT

The transformation of inorganic forms of arsenic to volatile, organic forms by various microorganisms occurs naturally in the environment. The literature on this phenomenon, which is termed biomethylation, is reviewed, with particular emphasis on its occurrence as related to arsenic-containing preserved wood. Documentation of isolated occurrences of the problem in houses built with preserved wood foundations is also reported.

While biomethylation can yield various forms of methylated arsenic compounds, trimethylarsine is the most commonly reported form in studies dealing with preserved wood. Preliminary toxicological investigations reported in the literature indicate that this compound, which has a distinct garlic-like odour, is relatively non-toxic, and would present no immediate health hazard to occupants of homes built with preserved wood foundations.

FOREWORD

There have been isolated incidents of persistent pungent odours occuring in houses built with preserved wood foundations. It has been established that the odour is of trimethylarsine and comes from a fungus which thrives on the wood and in damp conditions.

In view of the continuing practice of building preserved wood foundations, and the trend towards reduced ventilation rates, which may result in increased concentrations of air contaminents, the Research Division of CMHC was requested to find an answer to the question, "Is this a serious pollutant?"

Forintek were contracted to carry out this study in view of both their expertise in wood pathology and because of their prior involvement in carrying out field evaluations of the problem.

SUMMARY

Based on several incidents recently encountered by Forintek Canada Corp. in which mould growth and pungent, garlic-like odours were found in the basements of homes built with preserved wood foundations, a study into the nature and extent of the problem of biomethylation of arsenic in residential buildings was undertaken. This study involved carrying out a literature search on the historical background to this problem, the mechanisms and occurrences of the biomethylation of arsenic in the environment as well as in preserved wood, and the toxicity of trimethylarsine, the major product of biomethylation. Documentation of all reported field cases of this problem in residential buildings has also been included.

It has been found that apparent occurrences of the biomethylation of arsenic problem dated back to the early nineteenth century in which numerous poisonings of people living in damp houses containing arsenic-pigmented wallpapers were reported. It is now known that the biomethylation of arsenic is a common occurrence in the environment, being part of a natural cycle for the redistribution, or detoxification of arsenic. It involves the biological conversion of various arsenic compounds into volatile methylarsine gases by the action of fungi and bacteria. Trace levels of these gases have been found in soil, air and water. As reported in the literature and observed in isolated field cases, the process also is thought to affect the arsenic oxides used in preserved wood foundations under conditions of excessive moisture. The trimethylarsine gas which would be formed under these conditions was found to have a low acute inhalation toxicity rating compared to known poison gases such as carbon monoxide and hydrogen cyanide. In the cases examined, it was found that the reduction of high moisture contents and surface treatment of

the wood with a fungicide solution were apparently effective in eliminating fungal growth and biomethylation problems.

Based on the findings of this report, it was concluded that the biomethylation of arsenic in preserved wood foundations should present no immediate or potential health problem to occupants of homes built with preserved wood foundations, and that their use still remains a sound alternative to conventional foundation systems. However, because there is still a nuisance problem associated with the unpleasant odour of this gas, and since there is still uncertainty associated with the effects of long-term exposure to low levels of trimethylarsine, further occurrences of this problem in residential buildings are undesireable. Recommendations are therefore made for further basic research, including a laboratory study to establish the specific conditions under which biomethylation can occur in preserved wood, and a study to monitor the growth of fungi and production of trimethylarsine gas on a simulated preserved wood foundation currently in use at Forintek Canada Corp. The findings from these studies would provide valuable information in developing effective means to control, or to eliminate, the odour and related problems associated with the biomethylation of arsenic that can occur in some houses built with preserved wood foundations.

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INTRODUCTION

Preserved wood foundations (PWF) are being used in increasing numbers by the Canadian house construction industry. It is estimated that there are currently over thirty thousand preserved wood foundations in use in Canada, and this number is expected to continue to grow (Brudermann, 1982). The PWF, which is made of lumber and plywood treated with ammoniacal copper arsenate (ACA) or chromated copper arsenate (CCA) according to CSA standard 080-15-1974, offers distinct economic and energy-saving advantages over conventional poured concrete or block foundations. As reported by the British Wood Preserving Association (1968), the toxic arsenic salts used in these formulations are "fixed" in the wood (i.e., they are non-water soluble) and, as such, present no danger to health.

However, there is some evidence, based on several field incidents recently encountered by personnel from Forintek Canada Corp. (see page 14) that certain arsenic-resistant strains of fungi can grow on the treated wood used in housing under conditions of excessive moisture. In such cases, there is the possibility that these fungi could biologically convert the inorganic arsenic salts contained in the preservative to volatile methylarsine gases. If this process, which is generally termed biomethylation, does occur, the arsenic salts are thereby released into the air in a chemically modified form, and could accumulate in sufficient concentration in poorly vented basements to pose odour and possible health problems to occupants.

In view of these observations, it was considered necessary to carry out a preliminary investigation into the biomethylation of arsenic, particularly with respect to preserved wood foundations, and to determine if there were any serious odour or health problems that could result from the use of PWF's in housing. This is a report of that investigation.

OBJECTIVES AND SCOPE

The main purpose of this study is to assess the nature and extent of the occurrence of biomethylation of arsenic in preserved wood foundations and to estimate the level of toxicity of methylarsine gases which may occur in housing. The investigation has been carried out as follows:

1) A literature search on the biomethylation of arsenic has been made.

2) The possibilities of occurrence of biomethylation in preserved wood foundations have been examined.

3) A literature search on the toxicity level of trimethylarsine gas, the most probable product of biomethylation, has been made.

4) All available reported cases concerning complaints of disagreeable odours that have arisen from the use of preserved wood foundations have been documented and the solution to these complaints have been noted.

METHODS EMPLOYED

Literature searches were carried out using the facilities available at the Canada Institute for Scientific and Technical Information (CISTI) located at the National Research Council in Ottawa. The following data bases were searched for references concerning the biomethylation of arsenic: Biological Abstracts, Chemical Abstracts, IRL Life Sciences Abstracts, and Pollution Abstracts. For information on the toxicity of trimethylarsine, the Toxline, Toxback 74 and Toxback 65 data bases were searched, along with the 1980 Registry of Toxic Effects of Chemical Substances. Officials at Health and Welfare Canada were contacted regarding interpretation of toxicological data.

Various agencies and individuals in the federal and some provincial governments, the National Research Council (Technical Information Service), Canada Mortgage and Housing Corporation, wood industry consultants, wood-treating industries, Forintek Canada Corp., and the Environmental Protection Agency and Department of Agriculture of the United States Government were contacted in an attempt to locate information on any reported cases of odour problems in houses built with preserved wood foundations.

FINDINGS

A) Historical Background

As early as 1815, references began to appear in scientific journals which cited arsenic poisoning as the cause of death for occupants living in damp houses in Europe. Gmelin (1839) proposed a theory relating these deaths to the poisonous action of certain gaseous organic arsenic compounds which were liberated by moulds growing on damp, arsenic-pigmented wallpaper. The paste used at the time contained such compounds as Scheele's green (cupric arsenite) and Schweinfurt green (copper acetoarsenite). He was also the first to report that the rooms where these deaths occurred had a garlic-like odour. It has also recently been speculated by Jones (1982) that Napoleon Bonaparte, while in exile on St. Helena, may have been a victim of such poisoning.

Studies by Gosio (1893) demonstrated in laboratory experiments that certain moulds identified as strains of *Penicillium* (*P. brevicaule*), *Aspergillus* (*A. glaucus*) and *Mucor* (*M. mucedo*) were capable of growing on potato pulp containing arsenic trioxide. This growth was accompanied by the formation of an unidentified arsenic-containing gas that had a distinct garlic-like odour. This gas was referred to as "Gosio gas" in a number of subsequent publications. Bignelli (1901) incorrectly identified "Gosio gas" as triethylarsine.

Thom and Raper (1932) screened a large number of fungal isolates for their ability to produce gases from inorganic arsenic contained in the growth medium. Approximately five strains of *Aspergillus*, fourteen strains of *Aspergillus sydowi* and ten strains of *Scopulariopsis* (*P. brevicaule* series) proved to be active gas producers. The two latter groups are common to soils and other substances. Based on their findings that the disintegration of arsenic compounds may be caused by a wide variety of fungi, they cautioned that the use of arsenical preservatives for materials to be utilized in enclosed areas should be avoided.

The Analyst (1932) reports on the death of two children in the Forest of Dean, England. The room in which the children were found was reported to have been very damp, with moulds growing on the wallpaper. The presence of arsenic in the wallpaper paste and in the organs of one of the victims led the investigators to the conclusion that the children may have died from arsenic poisoning, which was released from the arsenic-containing paste into the room air in the form of a gaseous arsenic compound by the action of the moulds. These findings were later questioned by Hay (1939) after examining the literature on arsenical poisoning associated with mould growth. He concluded that these historical cases of arsenic poisoning from wallpaper were due, at least partially, to aspergillosis, penicillosis, or other causes associated with the damp, unhealthy environments common to most cases.

These historical references have been included to show that the problem now being investigated has been a scientific curiosity since early in the last century. The true nature of this phenomenon did not begin to be understood until quite recently.

B) Biomethylation of Arsenic

Challenger and his associates (1933; 1935; 1945; 1951) were responsible for the first extensive laboratory investigations concerned with the biomethylation of arsenic and other compounds, beginning with their work on the identification of "Gosio gas" in 1933. Using bread crumbs containing arsenic trioxide, they cultured Scopulariopsis brevicaulis and collected the resulting gas by precipitation as derivatives from various aqueous solutions. Examination of the derivatives enabled them to correctly identify "Gosio gas" as trimethylarsine. From their studies, Challenger et al. proposed a metabolic pathway in S. brevicaulis for the formation of trimethylarsine from inorganic arsenite (As^{+3}) in which the hydroxy-groups (-OH) of arsenic are replaced by methyl groups ($-CH_3$) through the action of the moulds. This pathway is shown in Figure 1.

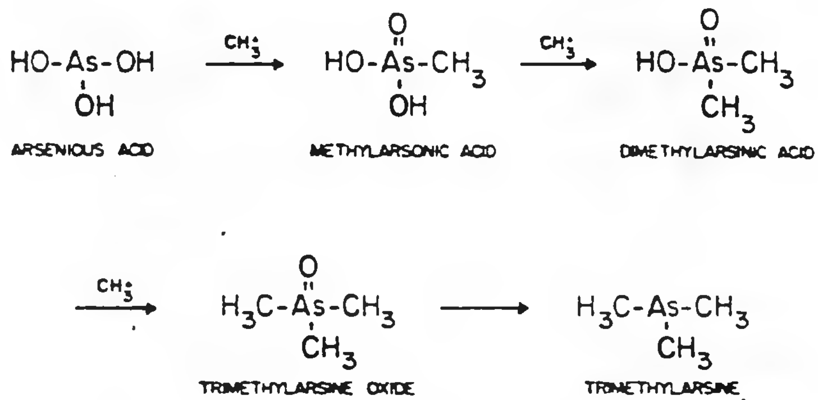

Figure 1. Proposed metabolic pathway for the formation of trimethylarsine from inorganic arsenite (Challenger).

Bird et al. (1948) studied the capacity of a number of other moulds to methylate both inorganic and organic compounds of arsenic, selenium and tellurium. Thus, A. niger, P. notatum and P. chrysogenum in bread cultures produced trimethylarsine only when exposed to organic forms of arsenic (i.e., alkyl-arsenic acids) but not in the presence of arsenite. A. versicolor and A. glaucus produced trimethylarsine with both arsenite and sodium methylarsonate. Bird attempted to explain his results as due to a process of selective methylation, but no definite conclusions were made. Zussman et al. (1961) found that Trichophyton rubrum produced a gas with a strong, garlic odour from cultures with arsenate (As^{+5}) but not with arsenite (As^{+3}). It was not established if the gas was arsine or a methylated arsine.

Merrill and French (1964) screened a large number of wood-rotting fungi for their ability to produce trimethylarsine when grown on a medium containing arsenic trioxide. Of sixty-five species studied, only Lenzites trabea Pers. ex Fr. and Lenzites saepiaria (Wolfe ex Fr.) produced a gas with a garlic odour. Although probably trimethylarsine, the gas could not be identified. McBride and Wolfe (1971) reported the methylation of inorganic arsenic by a species of Methanobacterium under anaerobic conditions. This was the first reported evidence that bacteria were also capable of carrying out biomethylation. In their studies they showed that arsenate is reduced to arsenite which is methylated to form methylarsonic acid. Further methylation and reduction of methylarsonic acid results in the formation of dimethylarsine.

Following the work of McBride and Wolfe, an increasing number of references began to appear presenting evidence for the biomethylation of arsenic in the environment. The rapid development of highly sensitive analytical instrumentation during this period also enabled researchers to identify methylation products at the trace levels occurring in nature. Johnson and Braman (1975) used a d.c. discharge-emission spectroscopy technique to quantify trace levels of various forms of arsenic found in air samples. Most samples contained inorganic arsenic, dimethylarsine as well as trimethylarsine. Indoor air samples from greenhouses showed much higher levels of trimethylarsine, and this led the investigators to speculate that plants may have the ability to methylate arsenic and that the production of volatile alkylarsine compounds could be a natural arsenic elimination mechanism.

Cox and Alexander (1973) and Cox (1975) reported the capability of three sewage fungi, *Candida humicola*, *Gliocladium roseum* and a *Penicillium* species, to produce trimethylarsine gas from various arsenic compounds. Only *C. humicola* produced the gas from arsenates and arsenites, while the other two species could only convert arsenates. Identification of trimethylarsine was made by a gas chromatographic-mass spectrometry (GC-MS) technique. Cullen *et al*. (1977; 1979) also studied the methylation of arsenic compounds by *C. humicola* and concluded that their findings supported Challenger's proposed pathway, although it was an over-simplification of the many processes involved. Chau and Wong (1978) used an analytical technique based on gas chromatography-atomic absorption to detect traces of di- and trimethylarsines produced by organisms growing in river sediment. In addition, they found that several pure bacterial cultures, *Aeromonas* and *Flavobacterium* sp., isolated from lake water, and *Escherichia coli*, commonly found in the intestines of an organism and in polluted water, could methylate arsenic compounds under aerobic, or oxygen-rich, conditions with both arsine and trimethylarsine being detected.

Woolson (1977) studied the generation of alkylarsines from soils containing various arsenic compounds and found that they are formed readily, especially under aerobic conditions. Both di- and trimethylarsines were detected, but there was no evidence of monomethylarsine. Braman (1975) also studied the evolution of alkyl arsines from soil. In his work, he found that both di- and trimethylarsine were produced from soil treated with dimethylarsinic acid, sodium arsenite and phenylarsonic acids, while only trimethylarsine evolved from methylarsonic acid treatment. He concluded that all commercially used arsenical pesticides are biomethylated to volatile forms. Cheng and Focht (1979), in their study on the fate of arsenicals in soil, found that arsine was produced from all arsenical substrates evaluated, while mono- and dimethylarsine were produced only from methylarsonate and dimethylarsinate. No evidence of trimethylarsine was found. These results, which contradicted those of Braman (1975) and Woolson (1977), led them to conclude that reduction of arsenicals to arsine, not biomethylation to trimethylarsine, was the primary mechanism for gaseous loss of arsenicals from soil. This discrepancy in results has yet to be resolved.

Wood (1974) was probably the first to propose the existence of a biological cycle for toxic elements, including arsenic, in the environment. This cycle, in which biomethylation plays an important role, is shown in Figure 2. Brinckman et al. (1977) and Braman (1977), recognizing that the biomethylation of metals, including arsenic, was part of a global redistribution process, stressed the need for sophisticated analytical instrumentation to monitor the various species of arsenic in the environment in order to better understand the processes involved. Sandberg and Allen

(1975) proposed a model for an arsenic cycle in an agronomic ecosystem.* This model, involving plant, soil, air and water, accounted for the redistribution of arsenic from pesticides applied to soil. The cycle relied heavily on the biomethylation of arsenicals to volatile alkylarsines at the soil-air interface, accounting for the loss of 17 to 35 percent of the total input of arsenic to the soil. Finally, McBride _et al_. (1978), based on the results of their studies with methanogenic bacteria, also concluded that there was an arsenic cycle in nature that relied on both biological and abiotic, or non-biological, reactions. Their cycle was similar to that proposed earlier by Wood (1974).

Thus, there is little doubt that the biomethylation of arsenic is a common occurrence in the environment, with evidence for methylarsines having been found in air, soil and water. The presence of these volatile methylarsine gases has been shown to have come from the biological conversion of organic and inorganic arsenic compounds by the action of various fungi and bacteria.

C) Occurrence of Biomethylation in Preserved Wood

As reported previously, Merrill and French (1964) found that, of sixty-five species of common wood-rotting fungi, only _Lenzites trabea_ and _Lenzites saepiaria_ produced a garlic odour when grown on a medium containing arsenic oxide. Arsenault (1975) argued that since copper and chromium, the other ingredients in CCA, were not present, the tests of Merrill and French

*Agronomic Ecosystem: an agricultural system, specifically that dealing with field crop production and soil management, that includes living and non-living parts interacting to produce a stable system in which the exchange of materials between the living and non-living parts follows circular paths.

were not indicative of any hazard that might occur from fungi growing on CCA-treated wood. Butcher (1971) reported that, although numerous fungi have been isolated from CCA-treated test stakes, Lenzites sp. had never been found because of its sensitivity to copper, one of the ingredients of CCA; thus, Lenzites trabea was shown to have a total inhibition point of 2640 ppm with arsenic but only 240 ppm with copper, and 371 ppm arsenic and 204 ppm copper in a mixed copper-arsenic system.

Doyle and Unligil (1981) studied the possibility of the production of trimethylarsine from fungi growing on ACA- and CCA-treated wood blocks. In the study, Douglas-fir plywood and red pine test blocks, treated with preservative solutions to the retention levels specified in CSA standard 080-15-1974 for preserved wood foundations, were exposed to Lenzites trabea and a Penicillium species in test jars. After a suitable growth period, the headspace of the jars was analyzed for the presence of alkylarsines using a gas chromatographic-atomic absorption technique. No evidence of trimethylarsine, or other alkylarsines, were found under the test conditions employed. Marshall (1981) reported, in a similar study, the effects of fungal growth on Douglas-fir plywood test blocks treated to both the retention level and to half the retention level specified in CSA 080-15-1974 (i.e., 0.6 and 0.3 pounds per cubic foot). Half the test blocks were subjected to leaching prior to exposure to simulate the effect of excessive moisture in PWF's. Four types of fungi were evaluated to determine their ability to produce trimethylarsine gas: these included Lenzites trabea, Aspergillus sp., Penicillium sp., and an unidentified species isolated from the walls of a preserved wood foundation in St. Thomas, Ontario. Similar analytical procedures reported by Doyle and Unligil (1981) were used to measure the alkylarsines formed in the headspace of the exposure jars after suitable growth periods. *Lenzites trabea* was found to produce trimethylarsine when growing on both leached and unleached CCA-treated blocks at both 0.6 and 0.3 pcf retention levels, on leached ACA-treated blocks at both retention levels and on leached blocks treated with CZAA, an experimental preservative containing copper, zinc and arsenic, at the 0.3 pcf retention level. This experimental result was found to be the only reported study which indicated that trimethylarsine is produced by fungi growing on wood treated to simulate actual preserved wood foundations in service. The fact that trimethylarsine was formed by *Lenzites trabea* growing on unleached CCA-treated blocks at the 0.6 pcf retention level would appear to contradict the work of Doyle and Unligil (1981).

Aside from these references, no other studies have been reported concerning the biomethylation of arsenic in preserved wood. Thus, the research to date indicates that biomethylation by the wood-rotting fungi *L. trabea* can occur in preserved wood under conditions of excessive moisture.

D) Toxicity of Trimethylarsine

Numerous references in the literature have implicated the possible toxicity or non-toxicity of trimethylarsine. The most recent references, such as Lakso and Peoples (1975), Bramam and Foreback (1973), Peoples (1975), and Sandberg and Allen (1975), seemed to favour the opinion that the methylation of arsenic is a natural detoxification mechanism in the environment, so that the products of biomethylation (i.e., alkylarsines) are much less toxic than their inorganic or organic arsenic precursors. However, none of these speculations has been based on actual toxicological evaluations.

In connection with its use in the semi-conductor industry, Breckenridge *et al*. (1982) recently investigated the acute inhalation toxicity of trimethylarsine as compared with the toxicity of arsine gas, a potent hemolytic agent having a TLV* of 50 ppb. Using mice and exposing them to the gas for four-hour periods, they found that there was a dose-dependent increase in mortality, with the LC_{50}** being 20,500 and 22,100 ppm for males and females, respectively. Surviving mice recovered rapidly and were reported to be clinically normal within two days. They concluded that trimethylarsine does not cause hemolysis like arsine gas and would not present a hazard to life at a concentrations below that which would be intolerable because of its pungent odour.

For the sake of comparison, the LC_{50} values for carbon monoxide and hydrogen cyanide, two common poison gases, are 5718 ppm (4.0 hours, mice) and 544 ppm (5.0 minutes, rats), respectively. Thus, in terms of acute inhalation toxicity, trimethylarsine can be considered to have a low toxicity rating.

Laham (personal communication) however, indicated that these results are a preliminary assessment only. In order to obtain a complete toxicity evaluation of this compound, more detailed studies involving long-term exposures would have to be carried out. Furthermore, he cautioned that acute toxicity data using 4.0 hour exposures cannot be used for assessing the toxicity of an indoor air contaminant which may be present in the home for a period exceeding 8.0 hours.

*TLV (Threshold Limiting Value): an estimate of the average safe concentration of a compound that can be tolerated on a repetitive basis.

**LC_{50} (Lethal Concentration, 50% Kill): the concentration of a toxicant which, when administered to test animals for a definite time period, kills 50% of them. LC_{50} is given in parts per million (ppm) for that time period.

E) Actual Cases of Odour Problems in Preserved Wood Foundations

Several cases of garlic-like odours characteristic of trimethylarsine in the basements of houses built with preserved wood foundations have been reported in the past few years.. These are discussed in detail below. No other reported instances of such odour problems could be found by the investigators.

Case 1: Condominium Townhouses, Victoria, British Columbia

In the mid-seventies, personnel from the Western Forest Products Laboratory (now Forintek Canada Corp.) examined several units of a recently built condominium townhouse development in Victoria, B.C. which utilized preserved wood foundations in their construction. All units examined had high moisture contents in the preserved wood, with moisture readings exceeding 19 percent. It was reported that the wood, which had been treated with ACA preservative, had been exposed to the weather for a considerable period of time before installation, and was wet when finally utilized.

All units examined showed some evidence of fungal growth, along with a garlic odour in the basements. The fungi were tentatively identified as Asperigillus sp. and Penicillium sp. Several attempts were also made to detect the presence of trimethylarsine using analytical facilities available at the University of British Columbia. However, no positive identification was made, probably because of the extremely low concentration of gases collected.

The odour in the basements of these houses later dissipated over a period of two to three years as the moisture content of the wood dropped. No written reports were prepared for this incident.

Case 2: Single Family Homes, St. Thomas, Ontario

In January 1980, personnel from Forintek Canada Corp.(Eastern Laboratory) investigated two homes in the St. Thomas, Ontario, area after a homeowner complained to the National Research Council in London, Ontario, about odours in the basement of his home which had been built on a preserved wood foundation. Both houses, an occupied split-level on MacKenzie Place and an unoccupied two-storey on Idsardi Street, were located in the suburbs of St. Thomas in an area that has a heavy clay soil. The houses were built by a local contractor, using a mixture of CCA- and ACA-treated wood.

Initial investigations found that both basements were very damp, with moisture contents of the preserved wood exceeding 50 percent in some areas. Both basements had been insulated with fibreglass batting. The MacKenzie Place house was also finished with a drywall. Upon removal of the wall coverings, large areas of fungal growth on the preserved wood itself were observed. A faint, but distinct garlic-like odour was very noticeable in both basements. Samples of the room air, fungal growths and treated wood were collected for analysis.

Subsequent laboratory investigations revealed the fungi to be Penicillium sp. and Aspergillus sp. both common moulds, and an unidentified species. The preserved wood used in both houses appeared to be a mixture of ACA- and CCA-treated Douglas-fir plywood and hemlock, fir and pine lumber. Analysis indicated that all samples were well-treated with preservatives. However, attempts to identify trimethylarsine in the air samples using gas chromatography/mass spectrometry techniques were unsuccessful.

According to Hayhoe of Tek Builders (1982), there were several other homes in the same area that had experienced high moisture and some odour problems, but none was as severe as the two investigated.

Forintek's involvement with the investigation ended at this point. Recent personal communication with the homeowner and contractor revealed that the problem in both houses had been corrected by the contractor according to directions from the wood treaters. The work performed is described below.

1. Home located at Isardi Street

The foundation was excavated and found to contain ruptured plywood sheathing. The backfill material originally used was a heavy clay which did not conform to building specifications. The combination of these problems was probably responsible for the severe water-penetration problems. The structural damage was subsequently repaired, the outer polyethylene seal was replaced and proper gravel backfill was used. The insulation was also removed from the interior of the basement walls to allow the wood to dry out. The fungal growth was scraped off and a proprietary fungicide solution was brushed on the wood before the walls were reinsulated. These modifications have been observed to be effective in reducing the moisture and odour problems at this location.

2. Home located at MacKenzie Place

The moisture-penetration problem at this location was observed to be less severe. As a result, it did not require excavation. As carried out at the Idsardi Street house, the drywall and insulation were removed to allow the treated wood to dry. A fungicide solution was applied on the wood before reinsulating. The homeowner reported that this treatment has been effective and indicated that there were no further problems.

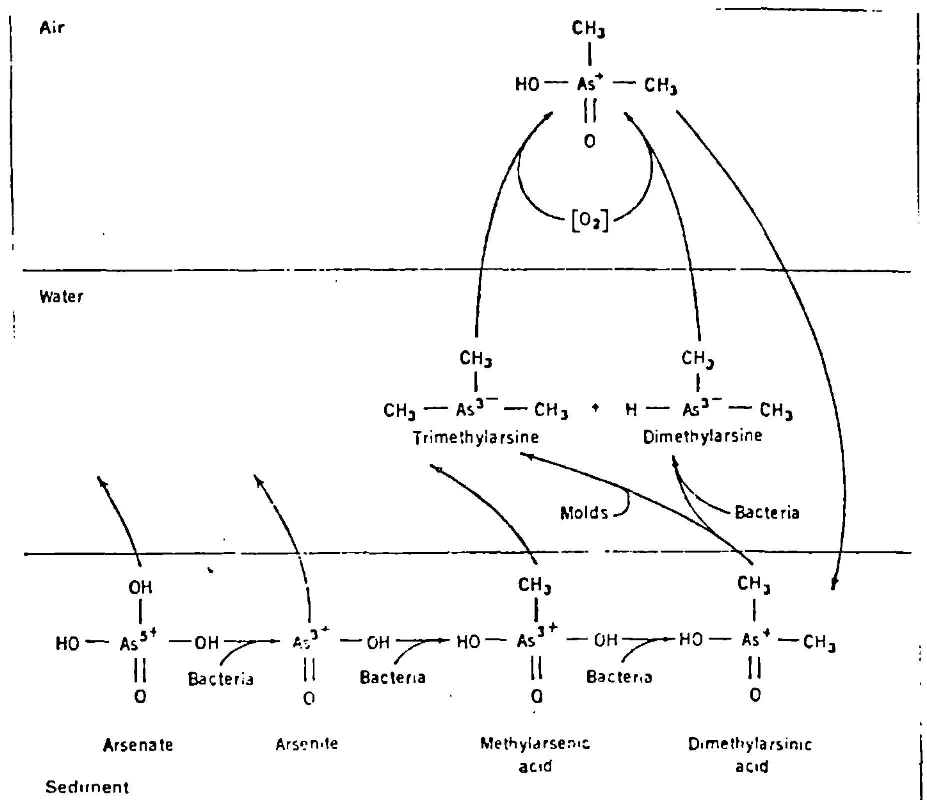

Figure 2: The biological cycle for arsenic proposed by Wood (1974).

CONCLUSIONS

The biomethylation of arsenic is a common occurrence in the environment, being part of a natural cycle for the redistribution, or detoxification of arsenic. The process involves the biological conversion of various types of organic and inorganic arsenic compounds into volatile methylarsine gases by fungi and bacteria.

There is evidence in the literature to suggest that biomethylation can also affect the arsenic oxide salts used in preserved wood, giving rise to trimethylarsine gas. This is most likely to occur under conditions of excessive moisture. Actual cases of biomethylation of arsenic are believed to have occurred in houses built with preserved wood foundations, although these cases appear to be very isolated events. The faint, garlic-like odour noticeable in the basements at these sites was probably due to the presence of trimethylarsine, but no positive identification of the gas could be made. In the cases reported, the excessive moisture content of the wood was the major cause leading to fungal growth on treated wood and ultimately to the garlic-like odour associated with the biomethylation of arsenic. Reduction of the high moisture contents and application of a fungicide solution to the surface of the wood in these basements led to the elimination, or reduction, of the odour problem.

Trimethylarsine gas is reported to have a low toxicity rating and its possible occurrence at the low levels expected in basements of homes built with preserved wood foundations would not be a health hazard to the occupants. The pungent, garlic-like odour of the gas would also serve as a convenient warning to occupants long before dangerous concentrations of this gas could possibly be generated.

Based on the findings of this report, the isolated occurrences of the biomethylation of arsenic in preserved wood foundations would be mainly a nuisance problem. Thus the PWF remains a sound alternative to conventional foundation systems in residential buildings when proper construction and treatment practices are adhered to.

RECOMMENDATIONS

The fact that a garlic-like odour associated with the biomethylation of arsenic has been found to occur, although infrequently, in residential housing gives rise to the possibility of further occurrences of this problem. Although these occurrences will not present an immediate health hazard, there is still a problem associated with the unpleasant odour of the gas, and this could lead to some concern on the part of homeowners exposed to it. Also, the health effects of long-term exposure to low levels of trimethylarsine have not been evaluated. Thus, further occurrences of this problem in residential buildings are undesirable, and additional basic studies, funded by an appropriate government agency or Crown corporation, such as Canada Mortgage and Housing Corporation, are recommended. These studies would be a required preliminary step in developing methods to effectively control and eliminate the problem.

First, a continuation of laboratory studies similar to those reported by Doyle and Unligil (1981) and Marshall (1981) should be carried out in order to better define the microbial growth conditions which can lead to biomethylation of arsenic in preserved wood, and to clear up existing contradictions in the literature. These studies, which would involve monitoring trimethylarsine production from treated test blocks inoculated with suitable fungi, would be required before effective control measures could be developed.

Secondly, a study involving the monitoring of fungal growth and trimethylarsine production on a simulated PWF in service should be carried out. Results from this study would be valuable in determining relationships between moisture content, fungal growth and gas production in an actual PWF, and would also be a convenient site for the evaluation of control measures developed in the laboratory phase of the studies. Forintek Canada Corp. is presently using a test structure for work being carried out for the Canadian Forestry Service to evaluate the performance of a PWF under simulated natural soil, drainage and service conditions (including high moisture content). Since the results of this report have indicated that the presence of excessive moisture is the main cause of fungal growth and subsequent odour problems, the availability of this test structure presents a unique opportunity to carry out this phase of the recommended studies.

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