Analysis of Threat from Formaldehyde Exposure in Interior Environment of Urban Built Stock.

Dr. Anjali Agnihori*& Dr. Vasudha A. Gokhale & Dr. Deepa Joshi*****
*Professor, Institute for Excellence in Higher Education, Bhopal,
**Professor, B.N. College of Architecture, Pune
*** Faculty, Institute for Excellence in Higher Education, Bhopal

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ABSTRACT: *The term "environmental hazard" is generally referred to severe weather events like air or water pollution, nuclear reactor accidents, and other phenomenon while indoorenvironmental hazards such as exposure to radon, asbestos, smoke, hazardous chemicals are not considered as an event posing the same kind of risk. Research established that environmental pollution levels in indoor spaces often exceed those found outdoors i.e. formaldehyde concentrations indoors can be 20-times higher than that exists outdoors. This research is aimed to analyse impact of formaldehyde exposure in indoor environment. It is aimed to discuss relatively ubiquitous ignorance of indoor environmental risk in context of exposure to formaldehyde which is a suspected human carcinogen. It examines knowledge and awareness of architects and interior designers who shape indoor spatial environment to be used by masses focused to improving awareness and understanding of indoor environmental risk for creating healthy indoor environment in future.*

Key Words*: Formaldehyde, carcinogen, radon, asbestos.*

1. Introduction

Building industry is observing advancement in various manufacturing and processing technologies with improved design for providing durability, safety ease of, execution, and economic feasibility. In constructional and manufacturing processes substantial amount of chemical agents are used which causes environmental pollution.Such pollutants that are present in indoor environments include particulate matter (PM), gases such as ozone (O3), carbon monoxide (CO), nitrogen dioxide (NO2), sulphur dioxide (SO2); volatile organic compounds (VOCs) and formaldehyde (CH2O).In urban environment larger numbers of people are exposed to formaldehyde at much lower levels in day to day life. Impact of these pollutants on human health at low exposure is not very obvious while their high exposure result in sick building syndrome (SBS), multiple chemical sensitivity and toxic-mold syndrome. (Viegas, 2010).Building materials are significant emission sources of Volatile Organic Compounds (VOCs), in indoor environments which include benzene, formaldehyde, acetaldehyde, toluene and xylenes having adverse impact on human health.

2. Hazardous Building Materials

In modern kitchens wood and wood-veneered cabinets are provided with special finishes to render them resistant to water and detergents and foods that may be spilled onto the cabinets during their use. The protective coating is made of three coatings first is a stain followed by a sealer, and finally finished with a topcoat which is a conversion varnish. They are largely used in kitchen cabinets in order to provide a decorative and protective finish. conversion varnishes form strong, water resistant, attractive coatings that cure by chemical reaction after their application. These varnishes are oftenreferred as acid-catalyzed varnishes, and they consist amino cross-linking agents, like melamine formaldehyde or urea formaldehyde, that are "catalyzed" with a strong acid which may emit hazardous air pollutants (HAPs), including formaldehyde. Press wood products like MDFs, and panelling and products made by urea- formaldehyde resins release Formaldehyde in indoor environment. .(McCrillis et al., 1999). Various building materials and Expected Emitted chemicals are shown in table 1.

Table 1 : Chemicals in Interior environment

S.N.	Materials present in buildings	Expected Emitted Priority Compounds
1	Laminate	Formaldehyde, benzene, Xylenes, Tobuens, acetaldehyde
2	Linoleum	Formaldehyde, Xylenes, Tobuens, acetaldehyde
3	Varmish finished furniture	Formaldehyde, acetaldehyde
4	Cork	Formaldehyde, acetaldehyde

5	Plastic water based paints	Formaldehyde, benzene, Xylenes, Tobuens, acetaldehyde
6	Acrylic	Benzene, Xylenes, Tobuens
7	matt	Formaldehyde, benzene, Xylenes, Tobuens,acetaldehyde
8	Wall Plaster	Formaldehyde, Xylenes, Tobuens
9	Gypsum Board	Formaldehyde
10	Ceiling Plaster	Formaldehyde, Xylenes, Tobuens
11	Particle Board	Formaldehyde, acetaldehyde ,Xylenes
12	Plywood	Formaldehyde, acetaldehyde, Tobuens
13	Chipboard	Formaldehyde, acetaldehyde, , Tobuens
14	Pine wood	Formaldehyde, acetaldehyde
15	Carpet	Formaldehyde, acetaldehyde, , Tobuens

Modern residential buildings, offices, schools, as well as other non-industrial work places widely use building materials like plywood, solid wood, wall coverings, coating products and flooring panels which often result in high formaldehyde emissions formaldehyde emissions. The presence of urea-formaldehyde (UF) adhesives with products used for interiors deteriorates the indoor air quality because of formaldehyde emissions. Phenol-formaldehyde (PF) resin is an excellent water resistant material which is used to manufacture plywood for exterior applications and tends to be more chemically stableand less susceptible to hydrolysis than UF or melamine-urea formaldehyde resin (MUF). (Bohm)

Plywood: It is largely used in interior spaces particularly for built in and non-built in furniture, solid wood and engineered floorings. It is consist of PLY with a coating of thin veneer bonded with UF or MUF resins as hot press adhesives. In addition many times to avoid melamine-based resin systems PVAc in order to reduce the FEs from the adhesives used between plywood and veneers.

Block board: It is another material which is in large scale use in modern building interiors particularly for shelves, doors, panelling and partitions. It is a softwood strip-core joinery board having a veneer finish which is made from a central core of 25-mm wide strips individually interlocked with vertically arranged growth rings generally painted on both sides to equalise the surface tension.

Particle boards: Safety is an important aspect for manufacturing and use of a material both. It has been noticed that fine dust and chemicals are released in the machining process of particleboard which include sawing or routing. Research indicated that cutting process of particle board involves release of formaldehyde, carbon monoxide, hydrogen cyanide in the case of amino resins, and phenol in the case of phenol-formaldehyde resins. It has been found that Particleboard (PB), medium density fibreboard (MDF), oriented strand board (OSB), and laminated flooring have been major sources of formaldehyde emissions. In many countries to save people who are working in construction sector as well as users PB and MDF are made available in no added formaldehyde (NAF) versions.

3. Formaldehyde as an Environmental Pollutant

Formaldehyde was identified as an indoor air pollutant based on observation of the post-manufacture release of formaldehyde from particleboard in year 1962.Research established that formaldehyde is one of the primary products in the process of combustion of biofuels and its presence in areas with heavy vehicular traffic is found at a higher level. In indoor environment high concentration of Formaldehyde has been noticed as a result of the hydrolysis of urea–formaldehyde resins in 1960s and 1970s. (Salthammer, 2013)

Formaldehyde (CH_2O) is the reactive of all aldehydes which exists as a colourless gas at room temperature with a strong pungent smell.Environmental sources of Formaldehyde include automobile engines using biofuels, manufactured wood products, furniture, carpets, paper products, fiberglass, household cleaners, permanent press fabrics as well as smoke from cigarettes and forests burning.(Zhang 2007)

As compared to formaldehyde Omnipresentharmful pollutants are Carbonyls, aldehydes and ketones which play active roles in atmospheric reactions adversely affect human health (WHO, 2010). Carbonyl compounds are the direct precursors of peroxyacylnitrates and ozone (O_3) from photolysis or reactions of carbonyls with a hydroxylradical (OH) to generate peroxy-radicals. Carbonyls contribute majorly to photochemical smog in the urbanenvironment. Carbonyls in nature generate through photochemical degradation while airborne carbonyls are emitted from incomplete combustionof fossil fuels in industrial plants, incinerators, automobilesand burning anthropogenic biomass. (Ho, 2016) Other sources of pollution include industrial resins used in manufacturing ofpolymeric products like paints and adhesives. Wooden furniture, building materials, and household products release carbonyls in indoor environment which are generated through reactions between indoor volatile organic compounds (VOCs) e.g., alkenes and oxidants e.g., O_3 (Morrison etal., 2002)

As per the International Agency for Research on Cancer Formaldehyde and benzene are classified in Group 1 of human carcinogens which are considered as one of the major pollutant . Indoor concentration of individual VOCs ranges between 5 mgm_3 to 50 mgm_3 while indoor concentrations of Formaldehyde indoor concentrations were varied between 38 and 310 mgm_3.It has been found that the aldehyde concentrations are usually 2e10 timeshigher in indoor environment than outdoors. In a new building the VOCs concentrationlevels are very high. In indoor environment aldehydes is emitted from building materials, plywood, hardwood, laminate floorings, adhesives, paints and varnishes and in some instances they are formed by ozone- initiated reactions. It is found that interior coatings, oil-based varnish increase indoor airpollution due to VOC emissions that include ethylbenzene,m,p-xylene, o-xylene and formaldehyde (Missia, 2010)Formaldehyde and volatile organiccompounds (VOCs) from building materialsadversely effect on indoor air qualitydue to emissions. (Xiong 2011)

4. People's Perception about indoor environmental Hazards

In urbanized society people spend most of their time (90%) indoors and are constantly exposed to indoor pollutants and consequent adverse health effects. Research established that asthma is related to exposure to nitrogen dioxide (NO2), environmental tobacco smoke and house dust mites. It has been found that formaldehyde which is present in indoor environment emitted from indoor paint is not only an environmental irritant but also associated with respiratory illness like attacks of breathlessness.(Rumchev, 2002)

In a study conducted in public buildings in Tianjin high CO2 concentration and high formaldehyde concentrations found as a result of insufficient ventilation, lack of regular hygiene and maintenance of HVAC systems in offices and shopping malls .(Sun, 2015)

Research established that people are not generally concerned about health risks resulted by polluted indoor air and they rather perceives outdoor environment to be riskier than indoor environment. People's least concern towards indoor environmental risk is a matter of serious concern as they spend approximately 90% of their time indoors. Motivation to act resulted in expected outcome which in turn depends of certainty of a particular occurrence or happening of a phenomenon. Lack of knowledge and awareness regarding indoor environmental hazards affects people's interest in indoor environmental quality and relevant protective health behaviours and resulted in risk avoidance behavior. This aspect calls for adequate communication of indoor environmental hazard risk focusing on improving public awareness as a component of science and health literacy. (Rosenthal, 2011)

5. Role of Government Regulatory Bodies

Building materials such as furniture finish, carpeting and caulking urea-formaldehyde foam insulation also emit formaldehyde which is classified by the WHO as a known human carcinogen are banned in Canada. To address the issue of high indoor levels of formaldehyde in new manufactured homes in year 1984 United States Department of Housing and Urban Development set construction standards. A Virginia-based hardwood flooring Retail Company has reportedly been ordered to pay a criminal penalty of $33 million for the charges that claimed it misled investors by downplaying the safety risks of laminate flooring that contained high levels of carcinogen, formaldehyde. (New York Post)

Health Canada has developed an indoor air quality guideline to address presence of formaldehyde in interior spaces. The guideline present recommended maximum formaldehyde levels for two types of exposure:

- **The short-term exposure limit**: It is aimed to protect occupants against health problems that may arise from exposure to high levels over a short time period (e.g. one hour). This type of exposure generally occurs when working with paint or varnish containing formaldehyde.
- **The long-term exposure limit**: It protects against health problems that may be caused by repeated exposure to lower levels of formaldehyde over a long period (days, weeks, months, etc.).

6. Methodology

Survey conducted to find out knowledge and awareness of Practicing architects and interior designers in city of Pune. Pune is second largest city in the state of Maharashtra located about 200 kms from Mumbai. In the wake of industrial and economic development the city has experienced unprecedented building development. This aspect resulted in increased number of practicing architects as well as interior designers who are responsible for shaping the built environment that include indoor and outdoor environment both. The survey tool is based on the concept of Knowledge, Aptitude, Practice (KAP) survey which was

administered with a random sample of 154 architects, interior designers practicing in the city of Pune. The questionnaire is designed with questions addressing respondent's knowledge about formaldehyde its properties and effect on human, their aptitude to use green materials and save interiors environment from exposure to chemical like formaldehyde and the practice of using the same. The result and analysis of the survey is presented in the next section.

Practicing architects and interior designers use different materials that may be a source of Formaldehyde in interior spaces. The use of such materials is investigated and the large scale use of such material reported as shown in Fig 1.

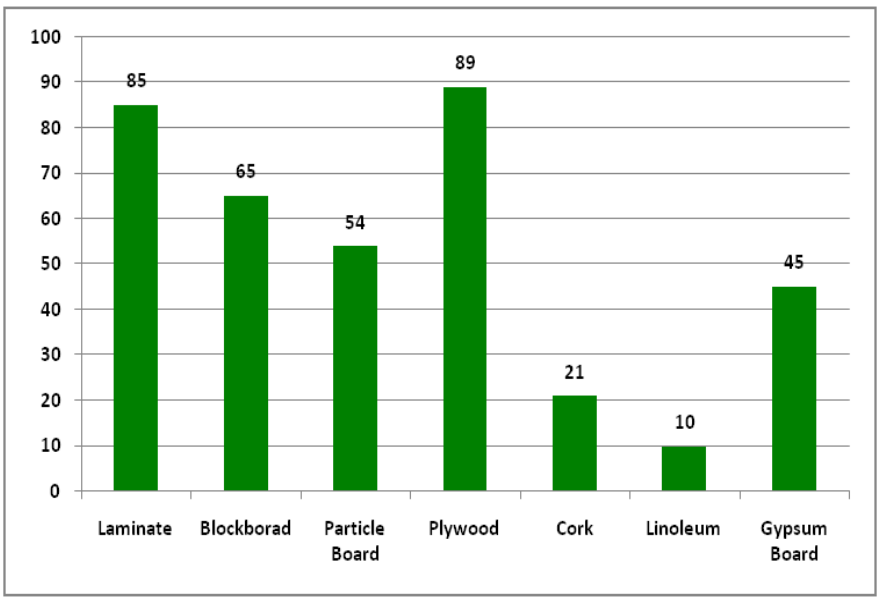


Fig. 1 .Use of Building materials in building interiors.

7. Analysis

Risk from harmful Chemicals in Indoor environment: The perceived risk from exposure to harmful chemicals indoors is not found serious as just 23% respondents rated it serious (Fig 2).

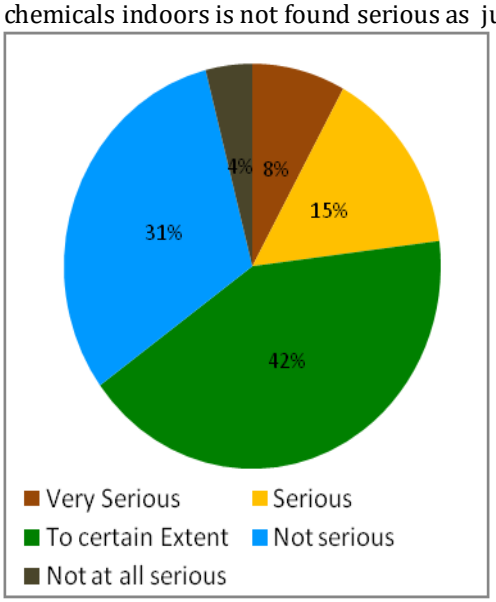


Fig.2. Perceived Risk.

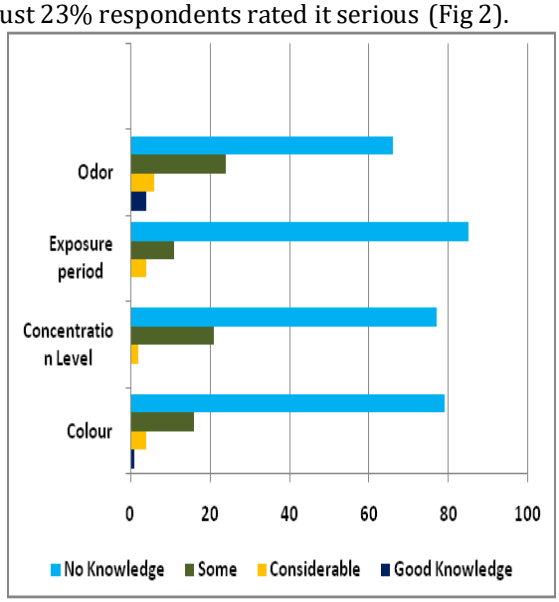


Fig.3. Knowledge

Knowledge about presence of formaldehyde in different building materialsin terms of odour, colour, exposure period and concentration level was extremely less (fig 3)

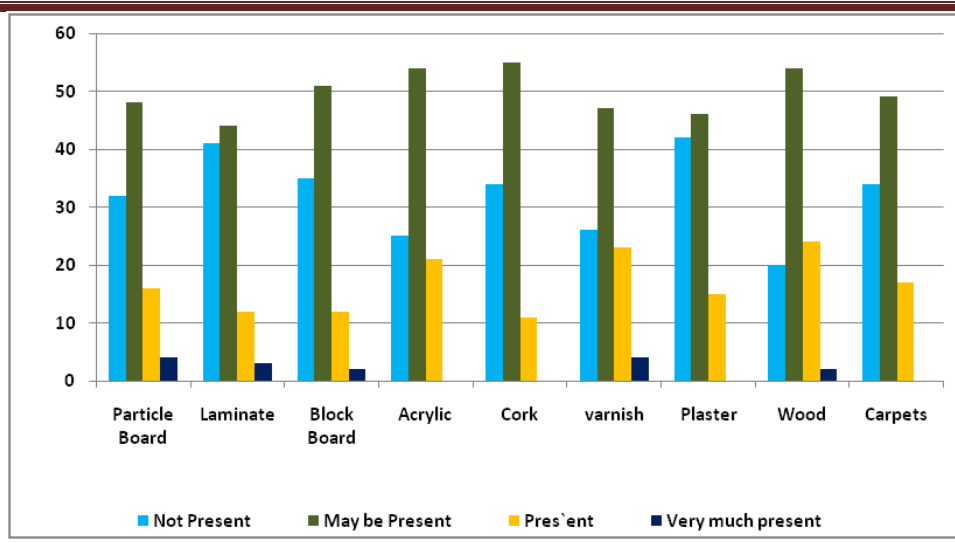
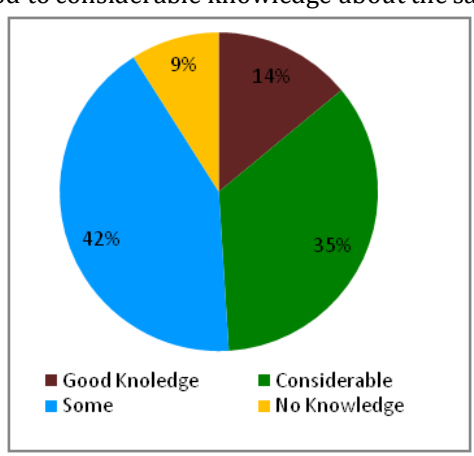


Fig.4. Properties of commonly used building materials.

Knowledge about materials in context of their association with emission harmful chemicals was investigated. Majority of the respondents were not sure about this aspect while a larger number denied the association of commonly used building materials with chemical exposure (Fig.4)

Knowledge about availability of green building materials is found satisfactory as 77% of the respondents possessed good to considerable knowledge about the same. (Fig 5)



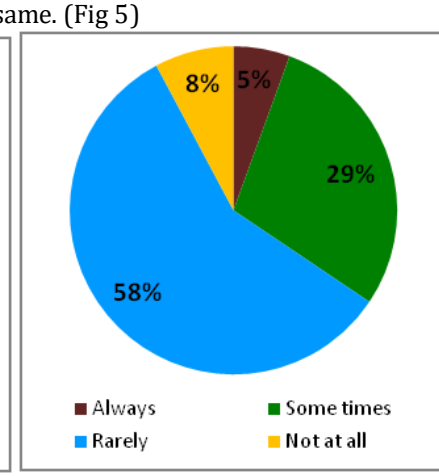


Fig.4 Knowledge about green building materials Fig.6. Use of Chemical safe materials

While selecting or specifying a building product an architect or interior designer it is important that they must consider ill effect on indoor environment. This aspect is largely ignored by majority of practicing architects and interior designers. (Fig 6)

8. Remedial Measures

In order to reduce formaldehyde present in the interior spaces is it suggested to open windows for a few minutes every day to let fresh air in. Use of exhaust fans as much as possible is recommended. In addition it is necessary to keep the temperature and humidity inside at the lowest comfortable setting and assure that the interior environment remain smoke free. It is important for architects and interior designer to specify furniture, wood cabinetry, or flooring made without urea-formaldehyde (UF) glues. Select pressed-wood products that meet ultra-low emitting formaldehyde (ULEF) or no added formaldehyde (NAF) requirements. Use products labeled “No VOC/Low VOC” (volatile organic compound).

9. Conclusion

Formaldehyde exposure is harmful to human health which is emitted by a number of building materials largely used in modern interiors. In the urban environment, people inhale indoor air most of their time where research indicated that on average, indoor formaldehyde levels are still higher than outdoor levels. It

is stressed that architects and interior designers should be interested in reducing human exposure to the myriad indoor environmental hazards. This research established that this aspect is hampered by limited understanding and knowledge regarding such hazards and relatedhealth risks and action taken from government bodied in India.The trends in formaldehyde concentrations in the indoorand outdoor air require a change of paradigm shift in terms of use of materials that are safe. Theincreasing use of bio fuels combined with the continuouslyincreasing traffic density provides a potential source of formaldehyde, acetaldehyde, saturated and unsaturatedhydrocarbons needs to be reduced. There is a need for growing public awareness regarding the risk associated with poorindoor air quality (IAQ) in dwellings and the workplace.

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