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BUILDING DESIGN AND MAINTENANCE AND INDOOR AIR
POLLUTION

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SYNOPSIS

This paper examines some designs which lead to indoor air pollution and exhorts mandatory maintenance of all building services which determine the health and safety of the building occupants as an integral part of our city bylaws. Effect of poor maintenance of some of these systems on the indoor air quality is examined together with the effect of the interruption of the ventilation fans for energy conservation purposes, not always done legally. Among the examples considered are the effect of underground parking and its ventilation system, proximity of the fresh air intakes to exhausts of the building and/or adjacent buildings and the drains of the plumbing system. The author's denied appeals to ASHRAE committees regarding adoption of ASHRAE Standard 62-1981R, done to ensure that the ventilation fans are not turned off when such buildings are occupied are discussed together with the City of Westmount's maintenance bylaw for apartment buildings adopted June 1989 which incorporates such a requirement. Our laws must ensure good air quality in our habitat as an environmental human right with the citizens' right of access to the information necessary to determine the quality of their indoor air environment for their health and safety. Examples from present Québec legislation are presented.

1. INTRODUCTION

This paper is a sequel to the author's summary¹, "Building Codes designed for ensuring good indoor air quality" presented at AIVC's 8th Anniversary Conference, an expanded and updated version of which was presented at the "Healthy Buildings '88" Conference held in Stockholm last year².

Naturally building codes can not encompass all the complex system of multi-disciplinary parameters that determine the indoor air quality in buildings, namely: quality of the outdoor air, percentage of the outdoor air in the ventilation air, design characteristics of the Heating, Ventilating, and Air Conditioning (HVAC) system structural and nonstructural materials used in the building, its furnishings, the use and activities within the building, and the age, maintenance and management characteristics of the building. Other bylaws and education must do their share to ensure good air quality indoors. And up-to-date codes are not much use if they are not respected or enforced. These papers^{1,2} presented what the codes can and must do to guard against indoor air pollution.

That "Buildings like people can be sickly" and the "Sick Building Syndrome" has become a recognized and accepted fact is evidenced by its' recent coverage in the staid "The Economist" (May 13) in an article entitled "Architect, heal thyself." Therein, the "most radical building doctors" are reported recommending that "buildings should be designed for the people who work in them not for developers or design awards". To qualify as "most radical" such a requirement is most revealing. More often than not the architect considers

the office building as an investment for his client. Maximizing profits would require maximizing the rental floor area thus dictating as limited as possible vertical and horizontal space be allocated to the HVAC system. Such restrictions do not lead to the best HVAC systems and can lead to minimum separation, if that, between the building's air intakes and exhausts & possibly contamination of the fresh air intakes^{3,4}.

Grant it, healthy buildings with spacious, well lit and well ventilated offices, preferably with openable windows, do cost more money than the conventional, sealed rectangular boxes we call our work place. But the health and welfare of the building users throughout the life-time of the building and its maintenance ought to be considered in the cost analysis of the building at the design stage. And advertised as such, because healthy buildings improve productivity of their users and that can save their employers more than the additional cost of the building. Judging by the response to the Healthy Buildings Conference in Stockholm last year¹ and in London, as noted in The Economist article cited, earlier this year, there is increasing realisation that such buildings are good business too.

Building codes and ASHRAE Ventilation Standards are deemed to apply only to the design and construction of the building but not its maintenance^{1,2,4,5}. Ironic indeed, considering the building codes and the ventilation standards have their very raison-d'être in protecting the health safety and welfare of the building users. Many indoor air pollution problems arise from the bad maintenance of the essential building services especially the HVAC system. That is why the author has been advocating since 1981 that good maintenance of such services ought to be an integral part of our building codes and city bylaws⁶. This is among the major areas of emphasis in this paper, introducing the relevant clauses of Westmount's such bylaw⁷.

It is apropos to mention here that concurrently with our conference, "Building Pathology 89" Conference is taking place at Trinity College, Oxford. According to its advertising pamphlet, it is the first international scientific conference on the inter-relationship of the building structure and materials with their environments and the living organisms within them concentrating on the environmental control of biodeterioration in building materials and aspects of the building environment affecting the health of the occupants". Thus although some aspects of building pathology were known to certain specialists, it is only now that the first such multidisciplinary scientific study of building performance in order to improve design is taking place. There is still much to do to reap the benefits in practice.

2. BUILDING DESIGN AND INDOOR AIR POLLUTION

The Sick Building Syndrome is sometimes called "OPEC's Revenge" by those who believe it is mainly the result of our buildings being built increasingly more airtight than before to prevent heat loss through air infiltration and thus saving fuel costs. But the matter is even worse because this trend was accompanied by a reduct-

ion of the fresh air intake in the ventilation requirements when ASHRAE Standard 62-81 replaced ASHRAE Standard 62-73, a trend strongly objected to by the author^{1,2,4-6} and reversed with the recent adoption of ASHRAE Standard 62-1981R. Thus under these circumstances, it was more important than ever before that the fresh air intake be really that, an indispensable first step.

2.1 Contamination of the Fresh Air Intake

Short-circuiting contamination of the fresh air intakes with exhausts of the building or adjacent buildings or contamination of the fresh air intakes due to their badly chosen locations, warned against in most codes⁸⁻¹⁰ is more common cause of indoor air pollution than is suspected or admitted. Yet, as noted for one in the author's earlier paper¹, many papers on indoor air quality in buildings with prolonged complaints from the occupants, information is lacking on the location of the fresh air intakes and exhausts of the building and the nature of the exhausts. This is especially important in hospitals and university medical, science or other buildings where exhausts from research laboratories or other rooms may contain toxic chemicals and/or microbes or viruses not to mention organic or inorganic wastes' emanations.

Aerodynamic interaction of winds with the building may cause such contamination of the fresh air intakes with the exhausts under unfavourable atmospheric conditions-is not specifically warned against in the codes and needs to be. Earlier this year in the Feb-1st, The McGill Reporter published by the McGill University Relations Office, in an article, "Making the McIntyre Medical Building Well Again- Complaints finally bear fruit", it was reported this building occasionally suffers from this phenomenon during "air inversions" peculiar to Montreal because the site being next to the mountain, downward wind around the building brings exhausted air back through the air intakes. The article also noted that the same problem was so severe at the Stewart Biology Building that its exhaust stacks were recently extended to increase the distance between them and the air intakes, adding that the feasibility of doing the same for the McIntyre building was still being studied.

A critical analysis of this cause of indoor air pollution and requirements of the Canadian and ASHRAE Standards is given elsewhere^{3,4}. Important buildings like the ones noted above especially at sites near mountains or downtown surrounded by other buildings would greatly benefit from model testing in boundary layer wind tunnels to determine the optimum design of their fresh air intake and exhausts and their locations³. An example of such testing to determine air infiltration in multi-storey buildings was given elsewhere¹¹. Such tests could also give additional information for more economical structural design for the wind loads and the savings could well pay for the tests, if not more over the lifetime of the building.

Buildings housing PCB-filled transformers and/or capacitors. For such buildings as already noted earlier¹, contamination of the fresh intakes with the exhausts takes a special dimension of urgency when

the exhaust is from an area housing PCB-filled transformers and/or capacitors, because in case of a fire due to incomplete combustion of the PCBs, dioxins and furans are produced among which are some of the most toxic compounds created by man. Recent examples and recommendations are given elsewhere⁴. Suffice it to mention here that the sooner they are removed from our buildings the better as the total cost of fires involving such units can be catastrophic especially if they occurred when such buildings were occupied. For the now famous 1981 Binghamton, N.Y. fire, the cost of the cleanup and renovations for the building - still unfinished - is almost three times the original \$17 million cost of the building - still higher than reported last². Fortunately, that building was unoccupied at the time of the fire. How often can we be as lucky as that?

For this section, the following example is apropos. The building, to be referred to later on²⁻⁶, is an air conditioned 16-storey office apartment complex built in the midsixties with three levels of underground parking and capped with rooftop mechanical room, laundry room and swimming pool. The "Bylaw Concerning Health and Sanitation in Buildings" governing the design of buildings then, and operative till 1987 when updated^{1,2}, for the City of Westmount, Québec, Canada where the building is located, stipulated,

"All air sources for ventilating purposes shall be drawn from the exterior of the building, any intake being so located that the air entering the system will contain no more bacteria, dust, odors, toxic substances or moisture than the normal exterior air for the locality in which the building is situated."

But one fresh air intake of the building was located practically immediately adjacent to the kitchen exhaust of a public restaurant in the complex and the ventilation pit of the garage levels which also was the recipient of the exhaust from the electrical room, on the second garage level, housing a PCB-filled transformer and four capacitors. Moreover the building overhang of about 1½ metres covered the restaurant kitchen exhaust and the fresh air intake, the centre of which was within 6 metres from where the building's garbage was collected. To boot, this fresh air intake was next to the loading backdoor where trucks used to iddle, for one, collecting the garbage thus additionally contaminating the fresh air intake with their exhausts. The restaurant was closed in 1980. This has been used as a classical example²⁻⁶ where not to put a fresh air intake.

2.2 Underground Garages as Air Pollution Sources

That pollutants generated by automobiles can infiltrate into the floors above the underground garages through the stairwells and the elevator shafts of the building is well known. Often they are among the contributors to the sick building syndrome as noted in the examples given elsewhere¹², where levels of Carbon Monoxide as much as ten times the outdoor ambient levels and well above the accepted norms had been recorded. And Carbon Monoxide is not the only toxic pollutant generated in car exhausts!

That is why it is imperative that the garage ventilation system efficiently and continuously ventilate the pollutants to the out-

side. Not only for the automobile exhausts but also because the underground levels, depending on the site, if the basement floors and walls are not properly designed, can be traps for radon and its progeny, infiltrating from the foundation soils, whose levels must be kept through ventilation to the outside to acceptable minimum levels^{1,2,13}. Exhausts from garages ought to be as far removed from fresh air intakes of buildings as possible to ensure against contamination and indoor air pollution.

For the building quoted as an example in the preceding section, alterations were carried out to improve indoor air quality^{2,4}. For one, all the ventilation pits were fitted with metallic caps that had flow grills in the vertical plane in compliance with the building code. For the specific garage ventilation exhaust pit mentioned there, a further improvement was effected when its cap was replaced with another whose exhaust grill was so oriented so as to be the furthest from the fresh air intake. This latter change came after the author's official application under Québec's Access to Information Act to examine the engineering drawings of the building's ventilation system to determine the locale of the fresh air intakes and exhausts, including their nature, of the building - and some months after the event described below.

Careless Construction and Inadequate Inspections can also lead to indoor air problems and even deaths. Complaints from the offices on the second floor of the building mentioned above with the occupants of one taken to hospital because of dizziness and nausea and the Westmount's Firemen's measurements of high levels of Carbon Monoxide (CO) lead to evacuation of the offices till the CO levels had subsided to acceptable levels that same day. The blood tests of the persons affected had also confirmed the CO exposure. It was reported that an unblocked opening in the concrete structure had provided direct access of the CO from the garage ramp to the offices. The fatal potential for such carelessness can not be overemphasized. How often and for how long had the occupants of these offices been suffering ill-health and malaise due to this carelessness till its correction?

Faulty Design and/or Poor Maintenance of Systems other than the HVAC System can be the cause of serious and even catastrophic indoor air pollution. While on the subject of pollution emanating from garages two further examples are apropos. Until the middle of last year, the Saturday test runs of the diesel-fueled emergency generator caused fumes to infiltrate the underground garage area of the same building and its ventilation system because of bad maintenance and- as was found by the fire inspectors after a power outage then- faulty design. The garage ventilation fans were not connected to the emergency generator.

Another example concerns uncorrected water leaks due to faulty design and/or poor maintenance that lead to short-circuiting fires in circuit breakers housing PCB-cooled transformers, for example, with potentially catastrophic consequences as noted earlier.

3. ENERGY CONSERVATION AND INDOOR AIR QUALITY

The strong objections to the energy conservation measures in our buildings presented earlier at the start of section on building design and indoor air pollution and voiced for long now by the author¹⁻⁶ need not be repeated here. This was accompanied by objections to outdated building codes^{1,2,4-6} and inaction of the author's City to act against the shut-off of the ventilation fans at night in his apartment building based on the premise- never accepted by the author- that the City's relevant bylaw governing ventilation was for design and construction but not maintenance of the building^{4-5,1-2}.

That these strong objections bore fruit is evident because now the City of Westmount has one of the most up-to-date building design and construction bylaws¹⁴ and also maintenance bylaw for apartment buildings⁷ which prohibit such ventilation fan shut-off. Also with the adoption of ASHRAE Standard 62-1981R, the trend towards reducing the fresh air intake in our buildings has been reversed as this Standard has gone back to requiring mean values of the recommended outdoor air intake specified in ASHRAE 62-73. In this latter, for offices, for example, the minimum outdoor air intake was specified as 7½ L/sec.person, it was reduced in ASHRAE 62-81 to 2½ L/sec.person when no smoking was observed even though that standard had noted that the "supply of outdoor air shall never be less than 2.5 L/sec.person" because this was "supply of the outdoor air necessary to dilute the CO₂ produced by metabolism and expired by the lungs". In Scandinavia and W. Germany such low fresh air intakes as 2.5 L/sec.person were not even contemplated on basis of preserving Acceptable odour conditions⁵.

It appears that the battle cry of the seventies- "Energy Conservation is the moral equivalent of war" was taken too literally as horror stories abound. For one, ventilation fans are sometimes turned-off under the guise of energy conservation to cover up malfunctions in the HVAC system and/or poor maintenance such as inadequate temperature control at peak loads^{1-3,5,6}. The two following horror stories, the first in the U.S. and the second in Canada illustrate its geographic scope and democratic strike:

The first occurred in Birmingham, Alabama in a three storey office building with non-openable windows. After continued health complaints from the occupants, investigations revealed "to conserve utility costs the building owner had elected not to install outside make-up air ducts on the building's HVAC system" without having contravened the local building bylaws!¹⁵ Unfortunately, not all cities in the U.S. require compliance with the most recent ASHRAE recommendations, if at all. Private enterprise or criminal negligence?

The second as reported by the April 1987 issue of "Québec Science" in an article entitled "Ces Immeubles Qui Nous Etouffent", hit no less than the offices of the Prime Minister of Québec in 1985. Apparently then, smell of "latrines" filled these offices to the embarrassment of the occupants. For a month and in vain, the search

went on in vain for the source of the emanations. Finally, an inspector was called in from 'Commission de la santé et sécurité au travail' and a major fault in the ventilation system was identified: the fresh air intake was practically nil. Previously where the fresh air met the exhaust air, a drain pipe had been installed to discharge the resultant water condensation through a double-goose neck "S" connection into the sewers ("vers les égouts"). The "S" neck connection was to prevent the odours feeding back indoors. This worked as long as there was enough condensation flowing through the drain pipe to fill the "S" neck. But as there has been practically no fresh air intake, the water in the "S" neck had dried up, and thus a free passage had been produced for the unwelcome odours not to mention the pollution into the Prime Minister's offices!

3.1 SWITCH-OFF OF THE VENTILATION FANS

Complaints to the City of Westmount in November 1985 concerning turning off at night till the early hours of the morning the exhaust fans servicing the bathrooms and also the air intake fans servicing the public corridors and thus the apartments for the apartment-office complex discussed earlier, revealed that the City's then applicable 'Bylaw concerning Health and Sanitation in Buildings' are complied with when the ventilation equipment having certain capacity is installed in the premises in question - but that the "Bylaw regulates design rather than maintenance".

On January 20th, 1988, this switch-off of the fans was brought up by the author at the Québec Rental Board - Regie du logement - as being detrimental to the health and safety of the occupants and in contravention of the provisions of Québec's Act respecting the conservation of energy in buildings¹⁶, where it is clearly specified that the reduction in the ventilation requirements shall be allowed only when the building is not occupied. Thus according to this regulation which is based generally on the provision of ASHRAE Standard 90 "Energy Conservation in New Building Design" and the minimum ventilation requirements of ASHRAE 62-1981⁹, while the fans' shut-off could be acceptable for the first five office floors, it is not for the top eleven apartment floors, especially at night when all the tenants are sleeping.

The fans were not turned back on 24 hours a day till February 3rd 1988 that being two days before a hearing at Québec's Commission d'accès à l'information where the author was contesting the City's decision to deny him access - in compliance with the building's owner's instructions - to the reports based on which the daily schedule of the fans' shut-off was approved.

At that hearing however, the City's Director of Services claimed that they did not have "the" reports in question but "a" report - comprising of extracts of the reports - supplied to them by the owner of the building. The Commission accepted the City's claim and after a further hearing and almost a year after the first, the Commission ruled in my favour indicating that the documents sought were not proprietary technical information but proof of compliance with the relevant Bylaws. But the extracts received showed results of CO

and CO₂ measurements prior the period of the fan switch-off! These two pages of measurements were CO records of less than 2 ppm for the second floor offices referred to earlier in section 2.2 & after that CO-scare-evacuation described therein. The second sheet showed CO and CO₂ measurements for "Etages résidentiels" and "Air extérieur" for another day: with the CO levels given as a stark zero and and 1-2 ppm respectively and the CO₂ levels given as 400 and 300ppm respectively without giving information as to where exactly they were measured nor the duration of the sample. Thus it is hard to imagine how based on this scant information the shut-off of the fans at night as described earlier was allowed for more than two years in the apartment building!

Westmount's Bylaw 1031⁷ Concerning Safety and Sanitation in Apartment Buildings adopted June 19, 1989 specifies that the "ventilation system(s) in such apartment buildings is (are) maintained in good working order and is (are) in operation at all times". One wonders why it was not enacted years earlier when asked for by the author? But this still leaves office workers unprotected. The City officials noted that under Québec Cities and Towns Act, the City Council is not empowered to apply the same law to office buildings!

The effect of interrupting ventilation fans is not well known and, even less, documented^{1,2,5,6}. Both ASHRAE 62-1981 & ASHRAE 62-1981R provide guidance for interrupting the use of the outdoor air when the buildings are used intermitently. The nature of the contaminants must be known. If they are result of outgassing of material or other sources within the building, it must be ventilated prior to occupancy. How often is there recorded reliable proof that the ventilation fans' switch-off after business hours has not compromised the indoor air quality on return of building occupants?

Appeal to ASHRAE: Following his presentation at the IAQ 86 Conference in Atlanta Georgia⁴ and based on his bitter experience with the ventilation fans' switch-off in his building, on Dec.3,1986, the author recommended on the official "Form For Commentary" on the Proposed ASHRAE 62-1981R that "the outdoor air requirements specified therein be qualified as continuous supply when the tenants and /or building users are therein. And that the ventilation fans be maintained and operated capable of this need". Contrary to expected and inspite of my subsequent letters for response, I did not get it till June 5, 1988 and then to be informed by Mr. John E. Janssen, Chairman of SPC 62-1981R that my request will be reported as "an unresolved issue". My appeal against publication of the Standard without such a qualification was denied by both the Standards Committee and the Board of Directors Appeal Panel on the grounds that, "There is no indication that that any ASHRAE Standards' Committee Procedures were violated" and this was finally confirmed by the vote of the BOD on June 25, 1989, even though on "substantive grounds" there was good reason behind my appeal.

4. BAD MAINTENANCE AND INDOOR AIR POLLUTION

The author has for long advocated the need for maintenance bylaws to ensure the good maintenance of all essential building services

necessary for the health, safety and wellbeing of the tenants and/or users of our buildings¹⁻⁶. The new Westmount maintenance bylaw⁷ for apartment buildings ensures that they are maintained "in a clean and sanitary condition at all times" including as presented earlier that the ventilation system be in operation at all times. Inadequate maintenance and nonchalant attitude of some building managers regarding the needed good air quality can be a serious cause of indoor air pollution. In the early eighties, the ventilation of the corridors supplying the apartments in the building referred to earlier was often switched off for several weeks, due to among others, inadequate temperature control and chemical smells caused mainly by a defective oil-fired boiler whose exhausts on the roof also contaminated the fresh air intake there under unfavourable winds^{1,2,6}.

Legionaire's disease and humidifier fever are well known now. It was only recently, however, that a conference was convened to treat the maladies caused by poor maintenance of air-conditioners and humidifiers¹⁷.

Other examples are not well known as noted elsewhere^{1,2} and the examples given here. A badly maintained swimming pool, especially one on the roof of a building, or an incorrectly designed and/or badly maintained plumbing systems- witness the experiences in 1985 in the offices of the Prime Minister of Québec- can result in serious problems. Water leaks can become host to algae and fungal growth in places unknown to the tenants but that effect their indoor air quality and health and even lead to deaths. So can badly maintained saunas or poor drainage of roofs cause such growths in partition walls, among others. And if such microorganisms are carried by the ventilation system other areas can be affected.

Infact, it is only recently that the consequences of these microorganisms on our indoor air have received the inter-disciplinary examination needed in order to improve building design¹⁸- witness, for one, my comments on the "Building Pathology 89" Conference in the introduction. An extensive study on mycotoxins and extreme fatigue syndrome for St. François d'Assise hospital in Québec City is given elsewhere¹⁹. But no doubt good building design and good maintenance of, among others, the HVAC system is a first essential to "Healthy Buildings".

5. ACCESS TO INFORMATION ON VENTILATION SYSTEMS

In order to determine the locale of the fresh air intakes and the exhausts of the building referred to in the examples earlier, the owners were subpoenaed three times in 1979 by the Québec Rental Board to bring the relevant engineering drawings, but they were not. In 1985, the author tried again this time through Québec's "Commission d'accès à l'information" after the City of Westmount denied the access on the premis that the owner's permission was not granted. The Commission in a 16 page June 6, 1986 ruling concurred with the city's decision noting that its governing "Act respecting access to documents held by public bodies and the protection of personal information" takes no account of the applicant's status, as a tenant that is, and that these drawings being "technical information

supplied by a third person and ordinarily treated by a third person as confidential" can not be released "without his consent" unless the information "reveals the existence of an immediate hazard to the health or safety of persons or a serious or irreparable impediment to their right to a healthy environment". Our present laws are heavily lopsided towards protecting the rights of property owners and the permit granting cities vis à vis the tenants' environmental right to know^{5,2}.

The Commission interpreted "immediate hazard" as excluding- to my strong objections- potential and probable ones. When the author had countered that such interpretation would even exclude the risk of earthquakes even though the National Building Code requires design for them, the retort was that that was outside the expertise of the Commission. Moreover, that interpretation also excluded immediate risk whose cumulative effects over time could cause "serious or irreparable impediment". Why should demonstration of only "irreparable" impediment to one's right to a healthy environment be required for release of the information sought? (And let it not be forgotten that the Act grants access to only "documents held", which may not contain - even by design- the information sought.) How many "reparable" environmental damages can our physical and social systems withstand? And how is this "reparable" damage defined? Prudence - and yes humility- pays multifold in the long run in environmental protection and our laws must reflect it.

Thus the Act's "right to a healthy environment" must include the citizens' "right to know" about contaminations in their habitat and the tenant's right to know about the design and operation of the building systems that determine his health and well-being, including information necessary- not just any conjured-up documents to comply with the word but not the spirit of the law- to determine the acceptability and legality of the energy conservation measures that affect his indoor air environment. Such were the author's arguments presented in his brief²⁰ submitted to Québec's legislative Committee examining the Access-to-Information Act's mandate.

6. CONCLUSIONS

After the bombing of the House of Commons in 1943, Sir Winston Churchill urging that the Chambers be rebuilt exactly as they were before, because their physical characteristics have formed the very structure of British democracy, dramatically noted, "We shape our buildings, and afterwards our buildings shape us". Yes indeed. Some of our buildings are making us sick now. Not only architect, but also law maker heal thyself! The jurisdiction of our Clean Air Acts must be extended to cover the air indoors which may often be more polluted than that outdoors. And good maintenance of the building systems that determine the health and safety of the occupants must be mandatory part of our codes and part of the initial planning and design of buildings.²¹

7. ACKNOWLEDGEMENT

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