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Indoor air quality assessment criteria in environmental certifications of buildings

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SUMMARY
Considering the environmental certifications for buildings (AQUA-HQE, BREEAM, LEED and WEEL) that have become widespread in civil construction, and which can help in the construction of more sustainable environments, the objective of the research is to investigate the types of pollutants in environmental certifications. evaluated in the indoor air quality categories (IAQ) and analyze the proposed methods to obtain pollutant results. To meet the proposed objectives, criteria related to QAI were researched in each of the certifications. In the AQUA-HQE tool, the guide "Non-residential buildings under construction" (2022) and the "Health Organizations" (2011) were used. In BREEAM certification, the guide released in 2022 was used. In LEED, the "Indoor Environmental Quality" category (2019) was examined. In WEEL certification, the "Air Monitoring" category (2023). Environmental certifications for buildings address IAQ in different ways, but they all contain the subject, which demonstrates its relevance. The limits imposed on air contaminants demonstrate concerns regarding the health of building occupants. In general, the pollutant emission limits indicated in the certifications evaluated have similar values, only the formaldehyde limits showed considerable differences.

KEYWORDS: Indoor air quality. Environmental certification. Construction.

1 INTRODUCTION

Until the 1960s, the matter of indoor air quality (IAQ) in non-industrial environments was not really perceived as a serious environmental issue by the World Health Organization (WHO). With the emergence of questions related to radon and formaldehyde between the 1960s and 1970s, the subject of IAQ made the scientific agenda. Complaints from several users of buildings, concerning the indoor air quality, began to rise, in what has been further described as the 'Sick Building Syndrome'. Presently, there are several studies that highlight the importance of the IAQ and ventilation in the perspective of public health (GOBBI, 2023).

The air volume on indoor environments is composed by a complex mixture, that may contain over 300 sorts of pollutants. These might be classified as: gaseous compounds (also known as molecular or chemical pollutants), particulate matter of 2,5 µm to 10 µm, and bio-contaminants such as fungi, bacteria and viruses (IEA, 2017). In the United States of America, the ASHRAE (AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS) is an organization that stands out. Founded in 1959, its main objective is to develop the technical guidelines and standards on indoor refrigeration. (ASHRAE, 2024). One of the directives proposed by ASHRAE, largely utilized for mechanical ventilation projects are outdoor air rates inserted on indoor environments, based in the necessities to control odor and CO2 levels.

The olfactory characteristic of indoor ambient air has been researched by the Danish professor Ole Fanger, who founded a theoretical and empirical model for the air flow calculation. This model has helped to overcome the problem of identifying the concentration of odorous chemical substances. Such model consists of the correlation between the percentage of people's dissatisfaction with the perceived air quality in a non-industrial environment, under certain level of air pollution, and preset conditions for airflow via ventilation (FANGER, 1988, 1989,1992). In Brazil, indoor air quality has been initially regulated by the resolution 176 of October the 24th of 2000 from Brazilian National Health Surveillance Agency (ANVISA). In 2003 the resolution 09 of January the 16th was published – "Technical guidance on reference standards for indoor air quality on artificially climatized environments of public and collective use".

When a certain environment presents low air renovation rates, there will be IAQ compromising, due to its occupancy, furniture, lining, finishes, and electronic appliances, that release chemical substances on various concentrations. Studies have revealed that indoor air pollutant concentrations might be up to five times higher than outdoors' (Addington, 2004). In health care facilities, for instance, the indoor air quality might influence directly on patient recovery and the occurrence of infections, mainly in places with patients with weakened immune systems, such as ICUs and CCUs. However, until the late 1990s, good airflow alone was considered enough to keep an acceptable IAQ (Chaves, 2016). Over the years there was a change in paradigm, and it was acknowledged that the presence of pollutants was related not only to the occupants and their activities, but also the materials used for building construction, equipment and furniture, heating systems, ventilation and air – conditioning, and outdoor air quality (Bluyssen, 2008).

The indoor environment of the buildings, where people spend most of their time, must be free of intoxicating and noxious compounds. Improving this air quality could be achieved not only with a suitable architectural project but also with a fine selection of materials and constructing methods. Increasing ventilation rates, matched with proper selection of materials, decreases the pollutant concentration in the air. (Guío, 2013).

Low IAQ affects the health and well-being of populations and may be responsible for illnesses such as: cancer (lung, blood, kidney, liver), respiratory disorders (asthma, increased susceptibility to respiratory infections), allergies, eye irritation, cephalalgia, fatigue, lack of concentration, nervous system dysfunctions and infarct, reproductive system problems among others (USBE, 2019). Over the years there was a change in perception, in which it was recognized that the presence of pollutant was related to the occupants and their activities but to the materials used for building construction as well; electronic appliances, furniture, heating systems, ventilation and air – conditioning, and outdoor air quality (Bluyssen, 2008; Chaves 2016).

Several certifications that aim to evaluate the environmental quality of buildings have been developed worldwide, particularly in Europe, Japan, the United States, Canada and Brazil as well. These certifications evaluate impacts based on different methodologies; however, indoor air quality (IAQ) is one recurring theme in almost all of them. Environmental certifications such as BREEAM, AQUA-HQE or LEED, which are currently the best known and most widespread worldwide, aim to promote a project, or the operation of buildings, that highlight environmental quality with emphasis on energy management; residual management; atmospheric impact and greenhouse gas emission, widely accompanied of management or economical aspects (France, 2020).

On the other hand, there are certifications focused on the human dimension and people's health, as in the case of the WELL certification (a member of the Green Building Council, on which LEED is also part). The North American certificate has been implemented in 2014 and is based on monitoring the impacts of the ventures from the perspective of health and well-being of the occupants (WELL, 2023). Evaluation categories are air; water; nourishment; illumination; fitness; comfort and mind. In all mentioned certifications construction materials are taken under consideration with a mandatory guarantee of quality (as an example, by the

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label for emissions of volatile organic compounds (VOC), concepts “A” or “A+”), of at least a certain proportion of the construction materials used in buildings (France, 2020).

It is noteworthy, however, that some certifications permit the neglect of IAQ for granting the label’s achievement. For instance, in LEED, IAQ stands for mere 13,6 % of the final score; for BREEAM the value is just 5% (4 credits out of 145 for IAQ – from the whole “Health and well-being” section), given that a great deal of the criteria are optional, not mandatory (France, 2020; Dodd; Donatello e Cordella, 2021). It is also taken in account that the little importance given to IAQ on these certifications represents more the result of the desire to integrate various subjects, than a real disregard for the sanitary quality of the edifice.

Other certifications correct this issue by imposing IAQ as a prerequisite, as in the case of AQUA-HQE and WELL. Nonetheless, the AQUA-HQE is quite permissive in relation to indoor air quality: according to the classification system, ranging from “A” (very good) to “F”, the minimum required for IAQ is “E”, which, according to the technical report from the French government itself, does not guarantee good air quality on the building. (France, 2020, p. 13). The LEED label has the wider range regarding criteria, but this matter might be easily ignored to favor better final scores. Other than LEED, WELL is the most complete one, but also has its deficiencies such as not considering the effects of constructing materials on IAQ (France, 2020).

2 OBJECTIVES

Considering that the environmental certifications for buildings have been disseminated in civil construction, and that they might help the construction of more sustainable environments, the object of the research is: 1) Probing into the environmental certifications to better understand what types of pollutants are evaluated in air quality categories, and their emission ceilings 2) Analise the methods proposed by each certification to obtain pollutant results. Certificates have been chosen by the number of buildings certified in the country, with LEED, AQUA-HQE, BREEAM being the top three. WEEL certification has also been included on the research for its concern on well-being and health evaluations of the occupants.

3 METHODOLOGY

To meet the proposed objectives, criteria related to IAQ have been researched on each certificate. On the tool AQUA-HQE, the guide “Non-residential buildings under construction”, released in 2021 has been used, (with criteria that took under consideration the context of the COVID-19 pandemic), and the guide “Health Organizations” (2011). Although older, this publication still brings relevant canon related to air quality. On the BREEAM certification, the guide released in 2022 has been used, common to all building typologies.

In the label LEED, it was examined the category “Indoor environment quality”, from hospital typology, published in 2019. The hospital environment was chosen due to the greater number of standards in this given typology, as its higher rigidity of methods. In the WEEL certification, it was used the category Air Monitoring, with standards updated by the tool in 2023.

4 RESULTADOS

4.1 AQUA-HQE

Among the technical guides provided by the Vanzolini Foundation itself, it is possible to notice that some of them have been updated during the phase of the COVID-19 pandemic (officially started in 2020). One of these updates is the "Non-residential buildings under construction" guide (2021). However, the one for "Health Organizations" is still from the year 2011. This does not mean, however, that no update for the guide on health environment has been made, it is important to consider that Vanzolini Foundation does not make all the guides available openly on their website.

Distinguishing the guide "Non-residential buildings under construction" (2021), the category "Air Quality" has 23 points, divided in two criteria: 1. Guarantee of efficient ventilation, focused on environmental air flow and; 2. Control of the indoor pollution sources. The second criterion presents which indoor air pollutants can be measured: nitrogen dioxide (NO2); carbon monoxide (CO); benzene; formaldehyde; TVOC; particulates (PM 2,5µm and PM 10 µm). For reaching level "E", as proposed by the certification, the following pollutant limit values must be respected (Table 1):

Table 1: Emission limits for pollutants in AQUA-HQE certification.

AQUA-HQE "Control of internal pollution sources" criterion	
Pollutant	Limit value
Nitrogen dioxide (NO2)	40 µg/m³
Carbon monoxide (CO)	10 µg/m³ for prolonged exposure
	30 µg/m³ for exposures of up to 1 hour
Benzene	< 5 µg/m³
Formaldehyde	< 30 µg/m³
TCOV	< 300 µg/m³
Particulate matter (long exposures)	PM 2.5 < 10 µg/m³
	PM 10 < 20 µg/m³

Source: Adapted from AQUA-HQE (2021).

The technical guide "Health Organizations" (2011) uses 3 criteria: 1. Guarantee of efficient ventilation; 2. Control of indoor pollutant sources; 3. Control of the external pollutant sources. Within criterion number 2 there is no stated limit on exposition to pollutants, however, it is requested that the sources of indoor pollution throughout the life cycle of the building should be identified, as the level of the sanitary risk linked to mentioned sources. Further recommendations are: to identify the emissions on fibers and particulate matter from products in contact with indoor air; to limit pollution by possible wood treatment; to recognize the sanitary impact of the construction products in the indoor air quality.

4.2 BREEAM

A Version 6.1 of BREEM was published in August 2022. The category 'Indoor Air Quality' is the same for all certified typologies. A 'Plan for indoor Air Quality' must be produced with the aim of facilitating the decision process and project actions, the specification of the materials, and installations that minimize the air pollution during conception, construction and occupation of the building (BREEAM, 2023). The plan must consider the following strategies: removal, dilution and control of contaminating sources; air testing and analysis carried out by third parties; and keeping the air quality during the building's use phase.

The concentration of formaldehyde in the air must be measured after the construction (but prior to the occupation) and must not exceed 0,01 mg/m³ (100 µg/m³), with exposure of up to 30 minutes. The TVOC concentration follows the same measure standard as formaldehyde, with a limit of 0,3 mg/m³ (300 µg/m³), with an exposure of 8 hours (Table 2). If concentration exceed the limits, the project team must retest; If the results are confirmed, the IAQ plan must be readjusted (BREEAM, 2023).

Table 2: Pollutant emission limits for flooring materials in BREEAM certification.

Flooring materials (including leveling compounds and resin)		
Pollutant	Issuance limit after 28 days	Requirement Tests
Formaldehyde	≤ 0.01 mg/m³	ISO 10580; ISO 16000-9; CEN/TS 16516; CDPH Standard Method v1.1
Total volatile organic compounds (TCOV)	≤ 0.3 mg/m³	

Source: Adapted from BREEAM (2023).

4.3 LEED

The version LEED 4.1, released in 2019, comes with the category "Indoor air quality". The evaluated requirements are, just to name a few: indoor air quality performance; low emission materials; indoor air quality management plan. Some pollutants are specified within exposition limits, such as: CO2, CO, TVOC, ozone, formaldehydes, PM 2,5 e PM 10.

TVOC, for example, can have maximum emissions around 0,5 mg/m³. There are also specifications for materials, as flooring, adhesives and sealings. At least 90% of all flooring by surface area, must meet the criteria established for 'VOC maximum emission' (LEED, 2023). The flooring category includes all kinds of surface (rigid or not), for example: carpets, ceramic, vinyl, rubber, solid wood, laminated flooring, etc.; subfloors are not included in this list. For adhesives, glues, sealants and similar, at least 75% of all material used by volume or area must meet the established criteria for 'VOC emissions' (LEED, 2023). This category includes all types of adhesives and sealings applied wet on site.

Formaldehyde, regardless of being a type of VOC, is evaluated individually, as some other VOCs that have proven human toxicity, such as benzene, xylene and toluene, etc. The concentration limit for formaldehyde is 20 µg/m³, following criteria established by ISO 16000-3 e EPA TO-11ª (LEED, 2023). Particulate matter is tracked accordingly to the exposure limits set by the label itself. The long-term exposition ratings for PM 2,5 particles are set in 12 µg/m³ and for PM 10 in 20 µg/m³ for hospitals (LEED, 2023) (Table 3).

Table 3: Pollutant emission limits in LEED certification.

LEED Certification 4.1 Hospitals	
Pollutant	Emission limits
Formaldehyde	20 µg/m³
TCOV	500 µg/m³
PM 2.5	12 µg/m³
PM 10	20 µg/m³

Source: Adapted from LEED (2023).

4.4 WELL

The category Air monitoring (standards updated in 2023) establishes parameter for monitoring some pollutants, such as: ozone, carbon monoxide (CO); PM 2,5 and/or PM 10; TVOC and/or formaldehyde (WELL, 2023). When it comes to particulate matter, the certification presents two score ranges, according to the emission levels (Table 4):

Table 4: Limits for PM 2,5 and PM 10 – WELL certification.

Limits for particulate matter	
Category	**Particulate matter**
1	PM 2.5: 12 µg/m³
	PM 10: 30 µg/m³
2	PM 2.5: 10 µg/m³
	PM 10: 20 µg/m³

Source: Adapted from WELL (2023).

VOC limits are scored in two ways: Either by laboratorial testing, by individual analysis of VOC (benzene, formaldehyde and toluene); or trough environmental measures on real site (Table 5).

Table 5: Emission limits for Volatile Organic Compounds – WELL certification.

VOC emission limits		
Method	Pollutant	Limit
Continuous monitoring	TCOV	< 300 μg/m³
Laboratory analysis	Benzene	10 μg/m³
	Formaldehyde	50 μg/m³
	Toluene	300 μg/m³

Source: Adapted from WELL (2023).

4.5 Comparison of certification emission limits

It is possible to establish a comparison between the emission limits of formaldehyde, TVOC e PM 2,5 (indoor air quality parameters in this study), in the four previously quoted certifications, AQUA-HQE, LEED, BREEAM and WEEL (Table 6).

Table 6: Comparison of the emission limits of environmental certificates for buildings.

Emission limits in environmental certifications for buildings			
Certification	**Formaldehyde**	**TCOV**	**PM 2.5**
AQUA-HQE	< 30 μg/m³	< 300 μg/m³	< 10 μg/m³
BREEAM	≤ 10 μg/m³	≤ 300 μg/m³	-
LEED	20 μg/m³	500 μg/m³	12 μg/m³
WELL	50 μg/m³	< 300 μg/m³	12 μg/m³

Source: Author (2023).

Emission limits for formaldehyde differ from certificate to certificate. BREEAM brings the most restrictive limit (≤ 10 μg/m³); the WELL certificate, presents the highest limit (50 μg/m³). Regarding TVOC, AQUA-HQE, BREEAM and WELL share the same restriction levels (300 μg/m³); LEED is the most permissive, bringing 500 μg/m³. For PM 2,5, AQUA-HQE certificate ranges the lowest of the emission limits (<10 μg/m³); LEED and WELL present the same limit (12 μg/m³); while BREEAM has no indicative of any limit for this particulate pollutant.

5 CONCLUSÃO

As The environmental certificates for buildings approach IAQ in different ways, however, all of them address the subject, highlighting its relevance. The limits set for indoor air contaminants expose the concern related to the mensuration of emission levels and their implication on health issues of the building occupants. In broad terms, the limits for pollutant emissions indicated in the researched certifications (AQUA-HQE, BREEAM, LEED and WELL) present similar numbers, been the formaldehyde limits the noticeable exception.

Some differences may not be ignored in the context of this scrutiny regarding the

Northern hemisphere, either in Europe or the United States of America, when in comparison to the Southern hemisphere. The economically developed regions of the Northern hemisphere have environmental, climatic (temperate climate), social, geographical and housing distinctions, as an example, from the reality of Brazil. Due to its location and history, Brazil presents a predominantly tropical and subtropical climate, among other environmental and sociocultural characteristics, even within the country itself. May the climatic and housing dissimilarities alone be considered, one may see a great difference from the Northern hemisphere countries, whose buildings now implement more and more hybrid ventilation systems. As for Brazil, even on winter, the residences use natural ventilation in basically any given time of the day. However, the construction phase of the buildings, might be considered similar, since the dwell time of the workers at the new environments is pretty much the same. Thus, the air quality in the buildings during the construction phase holds a greater relation in terms of the materials utilized on site.

6 REFERENCES

ASHRAE. **American Society of Heating, Refrigerating and Air-Conditioning Engineers**. About ASHRAE. Disponível em: <https://www.ashrae.org/about>. Acesso em 12 maio 2024.

ADDINGTON, M. History and future of ventilation. In: **Indoor air quality handbook**. Org.: J. D. SPRENGLER, J. M. SAMET e J. F. MACCARTHY, 1448. New York: McGraw-Hill, 2004.

BLUYSSEN, P. M. Management of the indoor environment: from a component. **Indoor and Built Environment**, v. 17, n. 6, p. 483-495, 2008.

BREEAM. **About BREEAM**. Disponível em: <https://breeam.com/about>. Acesso em 12 dez. 2023.

CHAVES, A. L. O. **Sustentabilidade na Arquitetura e o estudo dos Compostos Orgânicos Voláteis emitidos por componentes vinílicos em habitações**. Tese apresentada ao Instituto de Arquitetura e Urbanismo de São Carlos da Universidade de São Paulo, São Carlos, 2016.

DODD, N.; DONATELLO, S.; CORDELLA, M. **Level(s) indicator 4.1: Indoor air quality**. JRC Technical Reports. European Commission, Seville (Spain), 2021.

FANGER, P. O. (1988). Introduction of the olf and the decipol units to quantify air pollution perceived by humans indoors and outdoors. **Energy and Buildings**, n. 12, p. 1-6, 1988.

_________. (1989) **Equation: Health and Comfort**, San Diego, Ca. April 17-20, 1989.

_________. (1992). Projetando a boa qualidade do ar em edifícios com ar-condicionado. **Revista ABRAVA**. n°6, agosto, p. 55-56, 1992.

FRANCE. (2020) DREAL Grand Est. Direction régionale de l'environnement, de l'aménagement et du logement. **CEREMA. Les labels de la Qualité de l'air intérieur Étude des méthodes de prise en compte de la qualité de l'air intérieur des bâtiments tertiaires neufs dans les labels**. Disponível em: <https://www.grand-est.developpement-durable.gouv.fr/etude-sur-la-qai-dans-les-labels-pour-les-a19581.html>. Acesso em 20 out. 2023.

FUNDAÇÃO VANZONLINI. (2011). **Referencial Técnico de Certificação. Edifícios do setor de serviços**. Organizações de Saúde. Versão de Junho de 2011. Disponível em: < chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://vanzolini.org.br/wp-content/uploads/2022/01/6_Edificios-em-Construcao_RT-QAE-Organizacoes-de-Saude-2011.pdf>. Acesso em: 20 out. 2023.

_________. (2021). Edifícios não residências em construção**. AQUA-HQE Certificado por Fundação Vanzolini e Certivéa Referencial de Avaliação da Qualidade Ambiental de Edifícios Não Residenciais em Construção**. Versão de Dezembro de 2021. Disponível em: <chrome-

extension://efaidnbmnnnibpcajpcglclefindmkaj/https://vanzolini.org.br/wp-content/uploads/2022/01/RT_AQUA-HQE-Edificios_nao-residenciais-2021.pdf>. Acesso em 20 out. 2023.

GOBBI. M. E. **A influência dos Materiais de Construção na Qualidade do Ar Interior: caso do Piso Vinílico em Ambiente Hospitalar.** Tese (Doutorado). Universidade Federal do Rio de Janeiro, Faculdade de Arquitetura e Urbanismo, Programa de Pós-Graduação em Arquitetura. Rio de Janeiro, 2023.

GUÍO, L. M. P. **Compostos Orgânicos Voláteis em tintas imobiliárias: caracterização e efeitos sobre a qualidade do ar em ambientes internos construídos**. Dissertação de Mestrado em Arquitetura, Universidade Federal de São Paulo. São Paulo, 2013.

IEA. (2017). International Energy Agency. **Indoor Air Quality Design and Control in Low-energy Residential Buildings**. Disponível em: <https://www.iea-ebc-annex68.org/>. Acesso em 21 abr. 2024.

LEED. **LEED credit library. Indoor Environmental Quality**. Disponível em: <https://www.usgbc.org/credits?Category=%22Indoor+environmental+quality%22&Rating+System=%22Hospitality+-+New+Construction%22>. Acesso em: 21 out. 2023.

USBE. (2019). Unidade de Saúde Pública Barcelos/Esponsende. **Qualidade do ar interior**. Disponível em: <http://usp-be.blogspot.com/2019/03/qualidade-do-ar-interior.html>. Acesso em: 27 dez. 2023.

WELL. **WELL Performance Rating, Q1-Q2 2023**. Indoor Air Quality. Disponível em: <https://v2.wellcertified.com/en/performance-rating/indoor%20air%20quality/feature/3>. Acesso em: 21 out. 2023.