# METODE ZA PROCENU ODRŽIVOSTI I POBOLJŠANJA KVALITETA UNTRAŠNJEG VAZDUHA

# SUSTAINABILITY ASSESSMENT METHODS FOR IMPROVEMENT OF INDOOR AIR QUALITY

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*Ljudi provode skoro 90% svog vremena u zatvorenom prostoru, a u određenim zemljama unutrašnji može biti zagađeniji od spoljašnjeg vazduha. Građevinski materijali su glavni izvori isparljivih organskih jedinjenja u unutrašnjem okruženju. Ovi aspekti naglašavaju važnost čistog i održivog unutrašnjeg okruženja. Postoji nekoliko metoda za procenu održivosti koje su uspostavljene i koje uzimaju u obzir aspekt kvaliteta vazduha u zatvorenom prostoru. Ovaj rad ima za cilj da ispita i uporedi relevantne metode za procenu održivosti i liste materijala koji bi pomogli inženjerima tokom procesa projektovanja zgrade da procene predlog projekta i odaberu manje zagađujuće i više održive materijale. Takođe, ovaj rad ima za cilj da analizira korelaciju štetnih jedinjenja sa određenim grupama građevinskih materijala i ispita zamenu materijala za poboljšanje kvaliteta vazduha. Zaključci ovog istraživanja pokazuju da metode procene održivosti pružaju inženjerima snažne smernice u fazi projektovanja kako bi stvorili zdravo unutrašnje okruženje*

***Ključne reči:*** *kvalitet vazduha u zatvorenom prostoru; metode procene održivosti; građevinski material.*

*Humans spend almost 90% of their time indoors and in certain countries the indoor air can be more polluted than the outdoor air. Building materials are the main sources of volatile organic compounds (VOCs) in the indoor environment. These aspects stress the importance of a clean and sustainable indoor environment. There are several sustainability assessment methodologies which are established that take into account the aspect of the indoor air quality (IAQ). This paper aims to examine and compare relevant sustainability assessment methodologies and material lists which would assist the engineers during the building design process to assess the design proposal and choose less polluting and sustainable materials. Also, this paper aims to analyse the corelation of harmful compounds to certain groups of construction materials and it examines material substitutions for improvement IAQ. The findings of this research show that the sustainability assessment methodologies provide the engineers a strong guidance in the design phase in order to create healhty indoor environment.*

***Key words:*** *indoor air quality; sustainability assessment methods; building materials.*

## 1 Introduction

Humans spend almost 90% of their time indoor and in certain countries the indoor air can be more polluted than the outdoor air [1]. The improvement of the airtightness of buildings, due to the energy-efficiency demands in buildings, increased the problem of CO2 concentration [2]. According to some studies, indoor air can be up to five times more polluted than outdoor air [3].

Also, building materials are the main sources of volatile organic compounds (VOCs) in indoor sources [4]. Hydrocarbons and their derivatives, phthalates, ketones, terpenes, aldehydes etc. have been identified as potential indoor air emissions from various materials such as: wood-based materials, fibreboards, paints, panels, adhesives, resins, polymer materials and cement even.

Studies show that the indoor environmental quality (IEQ) can play an important role in work performance, productivity and the health of building users [5,6]. Therefore, Indoor Air Quality (IAQ) is one of the essential criteria for evaluating the quality of a building, according to the U.S. Environmental Protection Agency (EPA) [7].

There are several sustainability assessment methodologies which assist architects and engineers to evaluate in a simplistic and prompt manner the quality of the indoor air.

Therefore, this paper investigates the harmful compounds which are related to common building products. Further, several sustainability assessment methodologies have been examined, such as, LEED [8], BREEAM [9], Living Building Challenge [10], DGNB [11], Declare[12] etc. Also, novel sustainable materials certification systems were examined, such as the Declare label, which allows manufacturers of sustainable and non-toxic materials to be transparent in their ingredients and more visible to the broader construction market

These assessment methodologies evaluate the buildings` performance or building materials regarding the IAQ according to a given set of criteria, while taking into account the buildings materials. The aim of this paper is to investigate the criteria which are considered in the forementioned methodologies during the building assessment process.

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## 2 Indoor Air Quality

### *2.1 Indoor Air Pollutants*

The indoor air may contain a variety of contaminants, including particulate matter, tobacco smoke, radon, biological contaminants and more than 400 organic and inorganic chemical compounds, with associated health effects [13,14]. Additionally, indoor air pollutants can reach concentrations of up to 10 times their levels in outdoor air, regardless of the building location [14]. Such pollutants are emitted by indoor activities (e.g., cooking and cleaning), products or materials (e.g., in furnishings and structures). Also, the internal atmosphere is an extension of the external atmosphere, i.e., the outdoor air quality directly influences the indoor air quality, such as CO, CO2, or SO2, O3 which quickly deplete indoors [15].

The analysis identified harmful compounds which corelate to certain groups of construction materials. Hence, the formaldehyde compound is identified in the wood panels, adhesives, resins, particle boards and other types of wood products. These can cause serious health issues, such as irritation, asthma and even cancer.

The BTEX compound is also found in wood based materials and particle boars, as well as in paint, laminate and furniture products. This compound is corelated with serious health issues such as anaemia, cancer, vital organs damage, immunosuppression etc. The phthalates are found in paints, plastics, vinyl floor and even wall coverings, while the health issues that arise are problems with male reproductivity, male hormone problems etc.

The terpenes are found in wood based materials and cause irritation, while the chlorinated compounds are found in PVC polymers causing irritation and being possibly carcinogen. Also, energy-efficient buildings require large amounts of insulation. However, thermal insulation comprising chemicals can have harmful emissions and can cause health issues.

Considering that many insulation materials are organic based, there can be residual harmful chemicals that are not polymerized and can be emitted indoors, thus decreasing the air quality. For example, TVOCs were mostly found in Phenol formaldehyde insulation and EPS, while to a much lower degree in XPS and PIR insulation.

Harmful chemical groups/classes were identified in certain groups of construction materials and the health issues they cause, such as: alkylphenols and related compounds, antimicrobials, asbestos compounds, chlorinated polymers, solvents, CFCs, HCFCs, phthalates, VOCs, various wood treatment chemicals and others. They were be analysed regarding where they most commonly can be found, such as in various construction materials and/or furniture, building treatment products etc. Hence various products were examined, such as: wood based products, particle boards, polymer based materials, paints, wallpapers, resins, adhesives, insulation materials etc.

The analysis of pollutants in relation to the type of space in a building and the activities within the space gave a significant inisght and findings. The pollutants are classified according to the room type in a residential building they are most commonly found, such as:

- in the garages and basemenets there are most commonly: CO, mould, radon from soil, VOCs from paints, solvents, pesticides and herbicides;
- in the kitchen most commonly found are: CO, NO2, PM from stoves, VOCs from cleaning products;
- in the living areas: VOCs and formaldehydes from carpets/paints/glues/furniture, tobacco smoke, NO2 from wooden stoves, air fresheners, BTEX; in the bedrooms: dust, mildew, bacteria, VOCs and cleaning product chemicals;
- in the attic: dust, formaldehyde, textile fibres, outdoor air pollutants, asbestos; in bathrooms: mold, VOCs;
- in construction materials: HCHO, asbestos, VOCs etc.

### *2.2 Sustainability Assessment Methodologies*

The comparison of several sustainability assessment methodologies, such as LEED [8], BREEAM [9], Living Building Challenge [10], DGNB [11], Declare[12] etc. gave significant insight regarding inclusion of IAQ criteria.

For example, in BREEAM there are 5 headings in the guidance are considered as a minimum, an Air Quality Plan documentation is needed as well as testing. In BREEAM, the criteria Minimising sources of air pollution adds 4 credits in the assessment, and demands : Remove contaminant sources, Dilution and control of contaminant sources, Procedures for pre-occupancy flush out, Third party testing and analysis and Maintaining indoor air quality in-use. Also, treating VOC is assessed in products as well as post construction, compliant with British standards.

In the LEED standard there are two options for assessing the IAQ to be implemented after construction ends and the building has been completely cleaned, where first option is a flush out (before or during occupancy) and the second option is air testing in which the maximum concentration levels are prescribed along with the contaminant and testing method. The WELL method mostly focuses n PM particles, VOCs as well on CO, ozone etc. The Living Building Challenge Standard is being the strictest in meeting a healthy IAQ and eliminating toxic and hazardous chemical groups.

Studies [16] show that the average contribution of indoor air quality to green building schemes worldwide is 7.5%. There are two steps in the review procedure, as shown in Fig. 2. In step 1, the objectives are to analyze how and to what extent IAQ is taken into account in green building certifications. In step 2, detailed analysis focuses on IAQ management.

Depending on whether the facility is new/just renovated or already existing, the council sets different requirements for air quality monitoring. So, here we will divide buildings into two groups:

1. First group: newly built or renovated;

2. Second group: already occupied for more than a year.

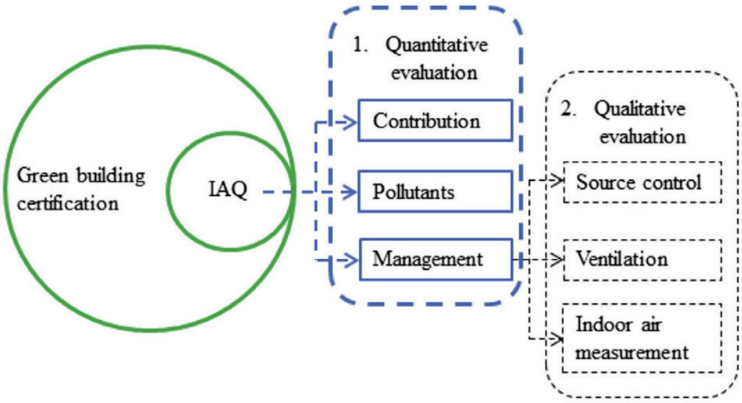


*Figure 1. Review procedure for the IAQ section within certifications [16]*

Monitoring air quality can earn two points for both new buildings that just have been built or renovated (Building Design and Construction, or BD+C) or commercial interiors such as office spaces or hotels that are a complete interior fill-out (Interior Design and Construction, or ID+C).

Indoor Air Quality Assessment scores 2 points both for BD+C and ID+C.

| 0 | 0 | 0 | | Indoor Environmental Quality | 16 |
|---|---|---|---|---|---|
| Y | | | Prereq | Minimum Indoor Air Quality Performance | Required |
| Y | | | Prereq | Environmental Tobacco Smoke Control | Required |
| | | | Credit | Enhanced Indoor Air Quality Strategies | 2 |
| | | | Credit | Low-Emitting Materials | 3 |
| | | | Credit | Construction Indoor Air Quality Management Plan | 1 |
| | | | Credit | Indoor Air Quality Assessment | 2 |
| | | | Credit | Thermal Comfort | 1 |
| | | | Credit | Interior Lighting | 2 |
| | | | Credit | Daylight | 3 |
| | | | Credit | Quality Views | 1 |
| | | | Credit | Acoustic Performance | 1 |

*Figure 2. LEED Indoor Air Quality criteria, [17]*

*Table 1. Concentration limits for LEED Indoor Air Quality criteria, [17]*

| Contaminant (CAS#) | Concentration Limit (μg/m³) | Allowed Test Methods |
|---|---|---|
| Carbon monoxide (CO) | 9 ppm; no more than 2 ppm above outdoor levels | ISO 4224<br>EPA Compendium Method IP-3<br>GB/T 18883-2002 for projects in China<br><br>Direct calibrated electrochemical instrument with accuracy of +/- 3% of reading and resolution of 0.1 ppm<br><br>NDIR CO Sensors with accuracy of 1% of 10 ppm full scale and display resolution of less than 0.1ppm |
| PM 10 | ISO 14644-1:2015, cleanroom class of 8 or lower<br><br>50 μg/m³ | Particulate monitoring device with accuracy greater of 5 micrograms/m³ or 20% of reading and resolution (5 min average data) +/- 5 μg/m3 |
| PM 2.5 | 12 μg/m³ or 35 μg/m³** | |
| Ozone | 0.07 ppm | Monitoring device with accuracy greater of 5 ppb or 20% of reading and resolution (5 min average data) +/- 5 ppb<br><br>ISO 13964<br>ASTM D5149 -- 02<br>EPA designated methods for Ozone |

**Projects in areas with high ambient levels of PM2.5 (known EPA nonattainment areas for PM2.5, or local equivalent) must meet the 35 ug/m³ limit, all other projects should meet the 12 ug/m³ limit.

Fully operational buildings or those occupied for more than a year are evaluated according to the LEED Operations and Maintenance rating system (O+M). The building owners should conduct a yearly occupant satisfaction review and air quality evaluation. Based on these rates, the human experience score is calculated and adds up to a maximum of 20 points:

– Occupant satisfaction score (50%);
– CO2 score (25%);
– TVOC score (25%).

The Declare label [12] is a voluntary self-disclosure program for certifying a construction material or product and being fully transparent with the ingredients and compounds. More specifically, Declare contains the "Red List" which is a list of banned compounds and the product ingredients are 100% disclosed to 100 ppm and must not contain any Red List chemicals.

Each ingredient must be reported with the chemical name, its Chemical Abstract Services Registry Number (CASRN) and the percentage or percentage range by weight for each ingredient in regards to the finished product. However, naturally occurring impurities, and process chemicals do not need to be reported, will not be listed on the label and also biological ingredients such as wood does not require disclosure of a CASRN.

The Red List represents the "worst in class" materials, chemicals, and elements known to pose serious risks to human health and the greater ecosystem and the list is continuously been updated throughout the years. The current Red List includes 22 chemical groups, represented by over 800 individual CASRN. The specific CASRN list was created in collaboration with the Healthy Building Network and the Pharos Chemical and Materials Library. In order to be certified as a sustainable building according to the Living Building Challenge standard, the building should not have any of the Red List compounds, such as: alkylphenols, asbestos, bisphenol A, cadmium, chlorinated polyethylene, chlorobenzenes, CFC and HCFCs lead, PVC, PVDC, PCBs, PFCs, VOCs etc. In the analysis all of the Red Listed compounds were investigated in which types of construction materials/products are most commonly found and the findings will be summarized in a research paper. However, there are some exceptions, such as phenol formaldehyde is allowed in composite structural members, such as glulam beams or rigid mineral wool insulation for exterior applications.

Next, possible substitutions for materials with toxic emissions were examined. The PVC can be replaced with biobased plastics, while also there are several systems for VOC free materials (FloorScore, GreenGuards, GreenLabel Plus etc.).

Certain companies put efforts in removing heavy metals in their products etc. By using materials such as concrete and recycled tile it is possible to significantly reduce the amount of formaldehyde concentration in a home, while also preserving natural resources such as wood commonly used for flooring; salvaged wood should be used or products that are certified with the Forest Stewardship Council (FSC)-certification label.

However, another issue is that new chemicals are introduced into the marketplace with little to no testing, posing health issues. Such an area of concern are the nano-materials. Such can be the antimicrobials which are used in paint to inhibit mould, applied carpets, curtains, wallcovering, wall protection etc., while in some products, metals, such as silver or copper, are impregnated into fabric.

Epoxy resin is the primary compound used to make epoxy paint coatings, adhesives etc. and has two chemicals of concern: bisphenol A (BPA) and epichlorohydrin. Studies show that nanoparticles may have toxic properties and the scientific community and organizations call for more regulated testing and assessment of the emerging nanomaterials.

## 3 Conclusions

This research examines sustainaiblity assessment methodologies for buildings in terms of how they assess the IAQ. Also, an analysis is performed regarding harmful compounds corelated with certain materials and most common building spaces they are frequently found.

From the research it can be concluded that the sustainaiblity assessment methodologies which are most commonly used take to certain extent the IAQ in the assessment with varying criteria and quality demands. It can be noted that in the Living Building Challenge standard the issue of toxic compounds found in materials/products in buildings is the most difficult criteria to be met in the assessment.

Due to the large array of pullutants which are present in the buildings indoor air, regular air quality monitoring is a recommendation for the building owners as it guarantees constant monitoring of occupants' wellbeing and the opportunity to take immediate actions on improving air quality if the monitoring system especially if it is integrated with the HVAC system. Future research is required on new and healthy materials as sustainable substitutions for the conventional materials which emit harmful pollutants in the indoor environment.

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