Determining environmental indicators related to the propagation of contagious diseases and health issues: A Systematic Literature Review

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Abstract — **The environmental indicators provide significant information in order to describe the state of a phenomenon, environment or area [1]. This paper addresses the indicators present in the air and their relationship in the accommodation and transmission of viruses, as well as how these environmental indicators can lead to health problems. Therefore, the main goal of this work is to review the scientific contributions in the literature in order to determine and select the potential environmental indicators present in indoor environments which have an impact on the health of people who work and live within these spaces. For this purpose, we carried out a Systematic Literature Review (SLR) related to environmental monitoring, COVID-19, Internet of things, air pollution and environmental indicators within indoor spaces. This SLR allowed us to identify indicators that according to their level of presence can represent a high risk for people´s health. Therefore, the process of planning, conducting and reporting the Systematic Literature Review enabled us not only to identify some environmental indicators, but also their corresponding monitoring advantages and disadvantages, and multiple perspectives and approaches of each contribution in the literature. Further on, this study will be the basis for the proposal of an automatic and intelligent platform based on Internet of Things for monitoring indoor environments in order to detect high risk levels for the contamination of contagious diseases.**

Keywords - IoT, COVID-19, air contamination, environment monitoring, transmission of COVID-19.

I. INTRODUCTION

According to the World Health Organization [2], the world is currently experiencing a pandemic of COVID-19, a disease caused by the new coronavirus known as SARS-CoV-2. Two years after being declared a pandemic, the virus has been mutating over the months, passing through the alpha, beta, gamma, delta mutation until reaching the omicron variant, which is more contagious than the previous ones. Therefore, after the vaccines became available, the immunized population experienced minor effects or symptoms. However, since each immune system is different and reacts differently based on one´s overall health, no person is exempt from re-infection. Regarding the reports published in the Center for Disease Control and Prevention [3], they suggest that the factors that increase the risk of SARS-CoV-2 infection in these circumstances include: closed spaces with inadequate ventilation or handling airspaces within which the concentration of exhaled respiratory fluids, especially very fine droplets and aerosol particles, may accumulate in the airspace and prolonged exposure to these conditions, generally more than 15 minutes. In fact, poor air quality can ease the spread of Covid-19 virus, as well as other health problems such as irritated eyes, dry eyes, sore throat, headache, irritability, dry skin, tiredness and loss of concentration [4].

This paper is structured as follows: Section 1 introduces the protocol applied to carry out the Systematic Literature Review (SLR); Section 2 discusses the main contributions and answers to research questions as a result of the LSR; Finally, Section 3 presents the conclusions and future works.

II. RESEARCH METHODOLOGY

This research uses the methodology "Systematic Literature Review", (SLR) [5] also known as Systematic Review, which aims at identifying, evaluating and combining evidences from primary studies using a rigorous method. In this paper, the Systematic Literature Review (SLR) methodology was used in conjunction with the Parsifal online tool [6], which facilitates comprehensive reviews, in a digital and accessible way. This tool can be used collaboratively by creating free accounts for each user.

A. Objectives

The main goal of this systematic research is to carry out a bibliographic review of the literature in order to obtain a solid perspective of the scientific contributions concerning the environmental indicators related to the propagation of contagious diseases, how polluted indoor spaces affect people:

- Analyzing the findings in the literature to determine their relevance and contribution to select the potential indicators that pollute the air, as well as to find out

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different concentration levels of these indicators that jeopardize people's health;

- Detecting and listing which devices and technologies were used by other researchers for their experiments to determine the most used and reliable devices and technologies, and;
- Identifying the challenges involved in monitoring contagious environments in order to face them objectively.

B. Research Questions

The main research questions proposed for this SLR are:

RQ1. Which are the indicators considered in the monitoring of contagious environments?
RQ2. How the contagious scenario can be characterized based on the considered environmental indicator?
RQ3. How can the level of risk be established in this scenario?
RQ4. Which monitoring environment was tested?
RQ5. Which devices are used to monitor contagious environments?
RQ6. Which paradigms/technologies have been used in monitoring contagious environments?
RQ7. What are the main challenges in monitoring contagious environments?

C. Selection Criteria

The main selection criteria adopted in this SLR were related to the scope of this research, therefore the papers should be related to the monitoring of environments conducive to COVID-19 and to e-health. In opposite, the exclusions criteria for the papers were: duplicate studies, studies outside the scope of the research, secondary or tertiary studies and finally papers with missing or incomplete text.

D. Quality assessment questions

The purpose of defining questions for quality assessment are: To validate the contribution of the paper and its usefulness according to their objective and context; To determine the scope of the study; To identify the depth of the research; To ensure the consistency and veracity of information, and; finally, to outline the importance of the findings and the contribution of the research, as well as its continuity in the study. The main quality assessment questions proposed are:

ID	Questions
Q1	Does the article have a clear objective concerning the scope of the research?
Q2	Does the study present the limitations and/or difficulties identified concerning the detection of environments conducive to COVID-19 propagation?
Q3	Was the data analysis rigorous enough and the results were clearly presented?
Q4	Does the study have scientific value or a relevant contribution to the problem?
Q5	Are future works or breaches indicated?
Q6	Does the study adequately explore the technique adopted to detect environments conducive to the spread of COVID-19?

E. Study selection

The first step of the LSR different papers are collected from scientific repositories (ACM: 50 papers, UPAEP Library: 11, Google: 10, IEEExplorer: 100, Scopus: 541, PubMed: 1, RIARTE: 1, ResearchGate: 3). In this step the total of 717 papers were collected. Scopus was the repository with the highest number of papers collected.

The second step of the LSR is the Study Selection. This step consists of cross validating the collected papers according to their redundancy. In this step only 76 papers were rejected as being duplicated in different sources. In this moment, 641 papers were left to the next step. In the third step the selection study was carried out allowing the selection of papers that were evaluated according to the inclusion and exclusion criteria. In this step all the papers that did not meet the selection criteria (papers published after 2019, papers published in languages different from English, Spanish or Portuguese, primary studies, studies out of scope, paper unavailable or incomplete). In this moment the total of 558 papers were rejected, leaving 53 papers to the next step. In the fourth step the papers approved previously were assessed according to the assessment questions, and those with a score higher than 3.9 are approved. In this step, 31 papers were rejected, leaving 22 papers to the final analysis in order to answer the research questions.

F. Data Extraction and Response and discussion on research questions

Data extraction and analysis were carried out over the 22 papers that had a score above 3. These papers were published in different countries such as India, Spain, Italy, Brazil, Japan, Switzerland. These countries had a major focus and attention on the study of environments conducive to COVID propagation during the first years of the pandemic.

RQ1. What are the environmental indicators considered when monitoring environments susceptible to COVID propagation and modify the indoor air quality?

The indicators considered when monitoring environments susceptible to COVID propagation and health issues were Carbon Dioxide (CO2) [7, 8 and 9], Ozone (O3 [10 and 11], Particulate Matter (PM) [8], PM2.5 [9 and 11], PM10 [9 and 11], Temperature [7,8, 9, 12 and 13], Humidity [7, 8, 9 and 13] and Total Volatile Organic Compounds (TCOV) [9 and 13].

RQ2. How are the propagation scenarios characterized?

In all the considered papers, the characteristics of the monitored environments are: it considers modern buildings with little ventilation, counting with combustion-based heating, rooms with synthetic or chemical materials [14]; In [15], the authors refer to crowded offices and classrooms with poor ventilation,

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manual lighting, as well as manual opening and closing doors, and; The researchers [16] focus on shopping malls, streets, schools, crowded public areas, which are the type of environment prone to the development of infections and where people carry out their daily, educational and work activities.

RQ3. How can the level of risk be established in these scenarios?

The level of risk is determined differently in the assessed papers: In [17] the environments with high risk of contamination are those crowded ones where the distance between each individual is less than two meters; In [13] the authors focus on environments with persistent air pollution or with different existing pollutants such as cleaning products, paints, aerosols (Volatile Organic Compounds - VOCs) that are usually available at home, where people spend more time exposed; The authors of [12] indicate the risk associated with interior spaces where objects, doors, railings, buttons to turn lights on or off are manually handled, there is little or poor ventilation, polluted or unsafe air with levels of carbon dioxide (CO_2), and; In [16] the negative aspect is the presence of people who do not use their personal protective equipment or use it incorrectly.

RQ4. Which monitoring environments are tested?

According to the literature review, the interior spaces tested were Offices, studying rooms [17], rooms, kitchen and bathroom [8], laboratories [10], houses [7] and crowded environments [10].

RQ5. Which devices are used to monitor contagious environments and polluted indoor environments?

In the case of [17] The authors designed a smartwatch as a digital Personal Protective Equipment (PPE), they used a Received Signal Strength Indicator (RSSI) value to monitor users' proximity to one another, to encourage 2m social distancing.

Medeiros and Girao [11] created an IoT-based system to monitor pollutants in the air through multi-sensors capable of measuring Particulate Matter (PM2.5 and PM10), Ozone, Carbon Monoxide, Nitrogen Dioxide and Ammonia.

Likewise, in [18] a COVID-19 Internet of Things platform called IoCT is presented offering two main contributions: The design and development of comprehensive, real-time, low-cost situational awareness for workplace reopenings after of COVID-19, and; Interoperability through Open Geospatial Standards for Indoor COVID-19 Risk Assessment of People and Places. The implemented IoCT architecture included proximity-based contact tracing, people density sensors, a COVID-19 risky behavior monitoring system, and the contextual building geospatial data.

RQ6. Which paradigms/technologies have been used in monitoring contagious and polluted indoor environments?

Different technologies were applied by the authors to enable them to carry out the corresponding monitoring and assessment of indicators, as to enable the reception of the signal in the devices, software control, data management, programming of sounds and alerts, allowing a greater precision and scope. Technologies applied to measure environmental indicators are: Received Signal Strength Indicator (RSSI) [17], IoT-fuzzy based on AQM system [8], NodeMcu (system brain) [19], LoRaWAN network, IOT, InfluxDB, MicroPython [20], Multisensor, IoCT in real time, IndoorGML or global navigation satellite system (GNSS)-SensorThings AP, audio sensors, alarms notifications and cameras [18].

RQ7. What are the main challenges in monitoring contagious and polluted indoor environments?

After the experiments being carried out, the authors detected and reported several challenges, such as battery capacity, device calibration, interference, energy levels, etc. These records are useful to support decision making when sorting out the technologies that might be adopted, for instance, for IoT monitoring within indoor environments. The main challenges found in the reviewed papers were Battery life of portable devices [17], calibration of data according to the indicators to be measured [10], carrying out more tests in different risk scenarios [8], testing with only two people in a room (in the outbreak of the disease, more people were not allowed in the same space) [13], different voltage supply for each sensor for data transfer [9], short data range and high-power consumption [20], internet connection required, reviewing data individually and no more than one simultaneously [15], environments with no ventilation [21], relating the physical environment with the digital one, which means designing and installing a complete network of sensors and data acquisition devices to monitor, control and visualize the behavior of the space [22], battery states produce different signal strengths [18].

The indicators of risk that eases COVID contamination and modify the indoor air quality

Following the systematic review of the literature, vital information was obtained on the environmental indicators and risk levels that may facilitate the transmission of infectious diseases or present health discomforts as the presence of the indicators in varying amounts modify indoor air quality. The main indicators identified are: Carbon dioxide (CO_2 >800 ppm) [23], Volatile Organic Compounds (TCOV>660 ppm) [24], Particulate matter (PM2.5 >45), Particulate matter (PM10 >75) [25], Temperature (<17ºC and >27ºC), Humidity (<30 and >65%) [26].

According to the literature, COVID-19 RNA lodges in particulate matter, high levels of carbon dioxide cause indoor spaces to lack air renewal, viruses are dispersed in indoor spaces and if these places are crowded, people are at a high-risk level.

III. CONCLUSIONS AND FUTURE WORKS

It is well-known that pollution and climate change are variables that directly affect the health of indoor environments specially crowded ones, facilitating the propagation of contagious diseases. This fact can be reinforced if no personal protection

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measures or monitoring systems are applied. Even though COVID-19 started in 2019 and its variations came out throughout these two years, these viruses present the same propagation behavior, therefore, alternative measures to safeguard population are essential and should not only be personal, but also be extended to the environments where people carry out most of their daily activities (such as working and studying).

The problem is the lack of further knowledge of the environmental indicators that affect people´s health. Therefore, based on the literature review, it was possible to identify the indicators that might affect directly the quality of air, and consequently would facilitate the propagation of COVID-19, and also contagious diseases in general. These indicators were: Carbone Dioxide (CO2) (with a high level greater than 800 ppm); Total Volatile Organic Compounds (TCOV) (with a level higher than 660ppb); Particulate Matter (PM2.5) (with a level greater than 45ppm); Particulate Matter (PM10) (with a level higher than 75ppm); Temperature (<16°C o >28°C), and; Humidity(>40% o <40%).

As for future works, we should carry out a model for predicting the level of risk in indoor environments by means of Fuzzy Logic for application in different indoor spaces. Proposed by Lotfi A. Zadeh [27], Fuzzy Logic employs an approximate reasoning method capable of efficiently dealing with information uncertainty. Thus, it allows designing intelligent controllers that make computers, driven by precise and binary reasoning, able to manipulate vague, imprecise and qualitative verbal expressions and simulate human beings diffuse or nebulous deductive reasoning, Due to its flexibility, robustness and fault tolerance, intelligent control systems based on Fuzzy Logic are widely recognized and used in the solution of complex problems based on decision making and control.

In the sequence of this work the authors are developing a fuzzy control system capable of estimating the risk of spreading contagious diseases based on the main environmental indicators raised in this literature review. For this purpose, the following functional blocks of the fuzzy controller are under construction: the fuzzification interface (input variables from IOT sensors), the knowledge base (consisting of a database with linguistic membership functions and a base of fuzzy rules linguistics), the decision-making logic (incorporated into the inference structure of the rule base, uses fuzzy implications to simulate human decision-making) and the defuzzification interface (to transform the output fuzzy value into a discrete value).

This proposed solution represents an autonomous operational architecture which is composed of the following modules: the acquisition module (sensor databot 2.0), a web server for the reception and download of files (MinIO), cleaning and storage module (phyton), a database module (MySQL) and a data modeling software (fuzzy control system) which feeds a dynamic dashboard for data analysis and interpretation.

The first preliminary results obtained with fuzzy logic are shown in Table I.

TABLE I. RESULTS OF FIRST EXAMPLE OF RISK DETERMINATION.

Id	*PM10*	*PM2.5*	*TVOC*	*CO2*	*Temperature*	*Humidity*	*Risk*
Values	13	11	67	400	23	37	High Risk - 37.7%

As shown in Table I, the environmental indicators such as PM10, PM2.5, CO2 and temperature contain stable and normal values, however, TVOC presented a high concentration and the humidity percentage is less than 40%, so the evaluation determined a 37.7% high risk. In Figure I, the black line is located at the threshold between normal and high because it was indicated by the humidity rule that the characteristic of the environment is dry.

As a first result the determination is correct, the graph indicates the level of environmental risk in an interior space.

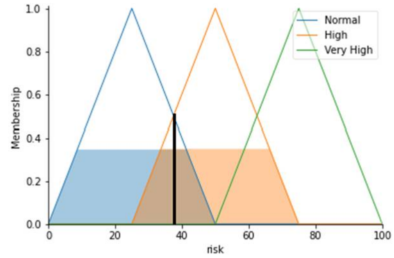

Figure 1. Risk level using fuzzy logic for the environmental indicator TVOC and humidity.

Tests will continue to be performed to adjust the rules in the fuzzy logic and determine the percentage of risk level within indoor spaces; the results of each scenario will be analyzed individually to verify the percentage of risk shown by the model. In addition, the implementation of the real-time monitoring system will continue with the devices to compare the concentration levels obtained through the Databot 2.0, the PMS5003 sensor and the INK BIRD air quality detector.

Thus, the project will continue, as it is a topic of broad scope and research based on the literature and results obtained, the presence of these environmental indicators in high concentrations can affect the health of those present, in addition to modifying the comfort of the spaces.

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