

# COVID-19 and Living Spaces challenge. Well-being and Public Health recommendations for a healthy, safe, and sustainable housing

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**Abstract.** *Background and aim of the work:* The ongoing pandemic of COVID-19 is a strong reminder that the lockdown period has changed the way that people and communities live, work, and interact, and it's necessary to make resilient the built environment, both outdoor and mainly the indoor spaces: housing, workplaces, public buildings, and entertainment facilities. How we can re-design the concept of Well-being and Public Health in relation to the living places of the future? *Methods:* According to the previous statements and scenario, this paper aims to integrate the building hygiene and wellbeing, focusing the possible responses, both existing and for the new buildings, taking home a strong message from this "period" of physical distancing. *Results:* The Well-being and Public Health recommendations for a healthy, safe, and sustainable housing are framed into the following key points: 1. Visible and accessible green elements and spaces; 2. Flexibility, adaptability, sharing, and crowding of living spaces, and compliant functions located into the buildings; 3. Re-appropriation of the basic principles and archetypes of sustainable architecture, thermal comfort and Indoor Air Quality (IAQ); 4. Water consumption and Wastewater Management; 5. Urban Solid Waste Management; 6. Housing automation and electromagnetic fields; 7. Indoor building and finishing materials. *Conclusions:* The Well-being and Public Health recommendations for a healthy, safe and sustainable housing may provide a useful basis for Designers, Policy Makers (fostering tax incentives for building renewal), Public Health experts and Local Health Agencies, in promoting actions and policies aimed to transform living places in healthier and *Salutogenic* spaces. ([www.actabiomedica.it](http://www.actabiomedica.it))

**Key words:** COVID-19 Living Spaces; COVID-19 Housing; COVID-19 Built Environment; Public Health Recommendations; Healthy Living Spaces; Safe and Sustainable Housing; Sustainable Architecture; Indoor Air Quality; Water Consumption; Wastewater Management; Urban Solid Waste Management; Housing Automation

## Was the Italian housing context ready to face the pandemic impact?

Prior to the COVID-19 pandemic, the Italian population spent roughly 60% of their time in the home. (1). However, following the imposition of lock-

down measures nationwide, this increased to 100% for most members of the 25.7 million Italian families [Istat, 2019] for a period of up to 2-3 months.

What are the characteristics of Italian homes? A recent survey by the Italian Fiscal Authority [Agenzia delle Entrate, 2019 - report *Gli immobili in Italia*]

discovered that average apartment size is 117 m<sup>2</sup>, but with a very large range. Milan, the second largest in size of the 14 metropolitan cities, has the smallest average apartment size, just 88 m<sup>2</sup>. According to the most recent Italian census of people and homes [Istat, 2011 - Censimento popolazione e abitazioni], more than one third of apartments (3,232,000) are below 60 m<sup>2</sup>. The crowding index shows that 20.7% of the apartments housing more than 4 people measure less than 80 m<sup>2</sup>. In 2018, 28.8% of the population (16.8 million) lived in overcrowded apartments [Istat, 2019 - 2<sup>nd</sup> report *SDGs*]. In addition to overcrowding, Italian apartments in general suffer from a limitation of primary services and a serious inadequacy in terms of structural requirements. Despite improvements in the previous 4 years, in 2018 almost 8 million people (13.2% of the total population) were living in apartments with damp on the walls. According to the 2011 census, up to 415,400 apartments had no running water, 250,600 no water heating, 2,081,000 no central heating, 35,900 no toilet, 138,100 no shower/bathtub, and up to 6,458,400 had no separate kitchen. Lastly – but very critical in the lockdown period – in 2018, 11.4% of the apartments, corresponding to 2,650,000 families, were lacking balconies, terraces or gardens [Istat, 2018 - report *Aspetti di vita quotidiana*]. It must be said that apartments provided with such benefits can reach an extra monetary value of up to 8%.

Considering the above situation, it is easy to understand that the “individual isolation” of people within their living spaces, to avoid reciprocal viral shedding via air (2), contact or fomites (3), was particularly difficult in overcrowded apartments, inhabited by the poorest people, including children, the elderly and the most fragile. During the lockdown period the in-house transmission of the virus became a problem, aggravated by the frequent inadequacy of the apartments (1-2).

Such a situation prompted the researchers to retrieve some chapters of the classic environmental hygiene, in particular those applying to civil constructions (2-4), often neglected in the last few years, such as the need for an optimal air exchange, for sufficient natural lighting, the latter having been found an effective means to reduce the half-life of the coronavirus in the environment (5-6).

The lockdown and the consequent confinement of people inside their homes has contributed to the worsening of non-communicable diseases, such as some chronic diseases (e.g. cardiovascular diseases and diabetes) and mental problems such as anxiety, insomnia, depression, and learning problems in children. This was mainly due to overcrowding, sedentarity, an increased intake of food and beverages (both often of an unhealthy nature), and supposedly also an increase of tobacco smoking and consumption of drugs (7-10).

The lockdown, which has undoubtedly had the merit of having reduced the impact of the pandemic, has however been detrimental to the physical and mental health of the population, weighing particularly on the most vulnerable (11); and has brought to everybody's attention the housing crisis of the whole country. This housing crisis is due to a progressive deterioration of both public and private real estate assets, which has been insufficiently (or not at all) contrasted by renovation efforts from politicians which have proven too bland and unsystematic (12).

The consequences of the pandemic, and the imminent risk of its repetition, highlight the need to apply a new concept of health, in terms of indoor well-being, to housing policy. The present paper, taking the above considerations as a starting point, will aim to give practical ideas and key-solutions for a rethinking of the living spaces, focusing on some elements necessary for protecting the health and indoor well-being of the inhabitants. An attempt will be made to compile a list of meaningful recommendations for a safe, healthy and sustainable housing. Our goal is to provide planners, architects and public health officers with a series of practical indications for their future efforts in the field of housing.

### **Which strategies are required for both existing and for new buildings?**

#### **The well-being and Public Health recommendations for a healthy, safe and sustainable housing**

##### *1. Visible and accessible green elements and spaces*

Numerous studies have documented how the level of exposure to natural environments affects physical

and mental health. The presence of green elements, in addition to having an important role in mitigating the impacts of the built environment on the climate and improving the ecological-climatic conditions of the cities, brings a wide range of health benefits for all age groups (13-14).

One of its main effects is the mitigation of the urban climate, helping to reduce the health impacts of heat waves, to increase the humidity content in the air and to lower the temperature in the hottest periods. In the absence of greenery, depending on the morphological characteristics of the city, the average maximum summer temperatures can be 1-3 ° higher than in the countryside, with possible higher variations, especially at night (15). This entails an inevitable increase in the demand for energy for cooling indoor environments in summer. In rethinking the living space, it is therefore necessary to ensure the use of suitable materials to control the albedo of the ground in open spaces and to maximize the summer shading of the buildings in order to reduce surface temperatures with positive effects on external comfort, on the reduction of solar loads and, consequently, on the need for air-conditioning in closed spaces. Furthermore, providing for the installation of green walls and roofs, in addition to urban microclimatic control, could favor evaporation, the absorption of polluting agents, the reduction of fine dust, the limiting of noise pollution, the protection of the natural environment local and urban bio-diversity.

Numerous international experiences put forward the creation of green roofs as a possible solution to the problem and as an opportunity to increase green areas in urban contexts. Chicago, Toronto, Seattle, as well as Paris and other EU cities have recently carried out significant redevelopment projects at urban scale, based on increasing the number of green roofs to improve the quality of life (16) and to reduce the urban heat island. The interest focuses on the recently published *"Roadmap for green roofs, walls and facades in Australia's urban landscapes 2020-2030"* which calls for strong government leadership, policies combining incentives and regulation, and education and advocacy to ensure standards in design, installation and maintenance.

In addition, green elements offer greater opportunities to practice physical and leisure/recreational activities thus helping to promote well-being and social

relationships, as well as reducing the frequency of various pathologies such as coronary heart disease, skeletal disorders, anxiety, depression, diabetes, etc. (17).

One of the most widely studied effects of greenery is the psychological effect. Some studies highlight its contribution in reducing stress and mental fatigue, in mitigating emotional states such as anger, anxiety, sadness and depression, acting on various levels- promoting physical activity, providing meeting places for residents, encouraging social ties (18). Introducing vegetation into the courtyards of buildings or in the immediate vicinity provides spaces useful for socializing and relaxing. It also helps to produce a greater sense of belonging and to reduce crime rates (19).

Following the COVID-19 pandemic, confinement at home has also revealed that it is necessary to understand if being able to view greenery from their homes or even the possibility of growing plants in their home could contribute to the well-being and health of the residents. The lockdown period has underlined the importance of increasing greenery within both existing and new buildings, by measuring the quality and quantity of green infrastructures, such as green roofs, walls, and common gardens.

The interest stems from the fact that most of the research exploring the psychological benefits of the natural environment has focused on direct exposure to the outside. However, people spend most of their time indoors, especially in office buildings and, in this particular period, in their home. On this specific topic, some studies highlight how viewing greenery from the windows of a building can have beneficial effects in reducing stress especially if natural elements or landscapes are visible (20) and this can even contribute to accelerating the healing process of hospitalized patients (21-22).

An experience-based study conducted by the authors from the Polytechnic University of Milan relating to exposure to nature (balcony, terrace, private garden, shared garden, etc.) for the population and health personnel has shown how 20-25 minutes spent in a natural environment, can positively influence the well-being of users, especially for those under 30 and those over 60 years of age. It has also been observed that in a period of great stress for healthcare workers, a break of 20-25 minutes spent in a green area can

positively affect the operator's energy and performance levels. Similarly, several studies in recent years have highlighted different strategies for implementing the performance and perceptual aspects of confined environments, including the *Biophilic Design*, a scientific approach aimed to improve occupant connectivity to the natural environment through the use of direct or indirect natural elements, and conditions of space and place (23).

In addition to psychological and perceptible benefits, with positive influences on housing quality and the population's quality of life, the benefits of environmental sustainability (e.g. reduction of noise pollution, absorption of electro-smog, mitigation of the microclimate and curtailment of fine particles) should be taken into consideration.. Within a large scale urban redevelopment project, green roofs bring economic benefits, including a reduction of peak water demand and saving of energy costs, since green roofs provide good heat insulation in winter and cooling in summer, allowing significant savings in the costs of heating and cooling buildings.

Equally interesting is the role of gardening, both in educational terms and in terms of well-being. This activity appears to increase life satisfaction, vigor, psychological well-being, positive personal intra-personal relationships, sense of community, and cognitive function of the individual, especially in certain age groups (24). It also contributes to reducing stress, anger, fatigue, depression, and anxiety (25). Consequently, the commitment to gardening is increasingly recognized not only as a profitable health intervention (26), but also as a therapy for people with psychological health problems, the so-called "horticultural therapy" (27).

In this regard, a recent meta-analysis highlights how a regular engagement in gardening and the care dedicated to it, already considered an effective therapy for people with psychological health problems, could today become an efficient design strategy to improve public health (24).

For the aforementioned reasons, it of utmost importance to consider these elements for the purpose of creating new settlements and, where possible, in the recovery of existing ones.

## *2. Flexibility, adaptability, sharing, and crowding of living spaces, and compliant functions located within the buildings*

According to WHO, living space must be such as to guarantee adequate privacy in order to meet the needs of the occupants, be accessible and usable for extended users and be large enough to comfortably accommodate people of different ages (28).

It must therefore meet ergonomic requirements, so as to safeguard the safety of users, without requiring special protective measures and it must meet the need for privacy and have characteristics that enable it to be used to carry out daily activities in total safety and well-being.

The housing units must satisfy different needs that have expanded over time, also in light of the current situation linked to COVID-19, including not only the increased life expectancy of the population, climate changes, immigration - topics which have already been widely discussed in the literature (9-12) - but also other aspects such as adequate and flexible spaces for possible isolation or for working from home, are examples of problems to which today's homes must respond, both in qualitative and quantitative terms (29).

In fact, having an adequate space in the home is a fundamental aspect of well-being and health, because interpersonal distance and spatial relationships between people and the environment play a fundamental role in feeling comfortable or uncomfortable in a certain situation.

From a dimensional point of view, ISTAT reports that more than a quarter of the Italian resident population lives in overcrowded conditions (30) and 20% of housing shows problems of degradation from damp and significant structural problems (31). These problems are much more prevalent with regards to the immigrant population (32). Similar situations are also found in other countries, as described, for example, by the CABA study, which highlighted how many individuals consider the space available in the home to be insufficient or inadequate for carrying out the basic activities of daily life (33).

The non-compliance of the living space with the physical characteristics and needs of the user can pose obstacles to the full use of the rooms and, in some

cases, may even represent a real source of danger. The health impacts of an inadequate living space are varied: several are associated with overcrowding, others with accessibility (28).

The overcrowding of a home does not only depend on the number of people sharing it, but is also conditioned by their age, relationship and gender. Several studies have shown a direct association between crowding and certain negative health outcomes, such as infectious diseases (including tuberculosis and now COVID-19) (2,9,11) and mental health problems (psychological distress, alcohol abuse, depression and unhappiness, social isolation, reduced school performance in children) (8-9,34).

It is therefore necessary to adopt targeted strategies and appropriate design solutions for living spaces, paying particular attention to room size, to ensure their health, accessibility, and internal flexibility, in order to allow adaptability to any changes in distribution structure, both in the short and long term (33,35).

Space affects how and where people prepare and consume food; how they socialize; how they manage domestic waste and recycling; how they store goods; how much privacy they have for studying, working, relaxing or free time; how much and how they can adapt to new needs (e.g. isolation, disability), etc. (36).

In a situation such as the one in which we currently find ourselves, inadequate spaces in terms of size and lack of flexibility, not only accentuate health risks, but also interfere with productivity in remote working and school performance (37).

Finally, it is necessary to ensure in co-housing situations or in condominium areas, the maximum flexibility of the spaces (ground floors, basements, free floors) (38-39) in order to be able to easily adapt them in the case of a necessity to increase the areas available to the inhabitants (for example in order to have a temporary quiet work station) and to maintain social distancing, always taking into account the specific regulatory requirements (40).

Moreover, the lockdown emphasized the functional inconsistencies and interferences within the same building and, at the same time, highlighted the need to have common spaces for collective use such as sport and recreational activities. Looking both at the outdoor spaces close to the building and at the ground

floors, it is crucial to plan and program the neighborhood functional mix, as already described in a previous article (29). These proposals have attempted to offer an adequate level of quality of life at a short distance, taking into account some essential urban social functions such as living, working, supplying goods and services, providing care and assistance, learning, and enjoying recreational facilities.

At the same time, as regards the indoor common spaces of the dwellings, to guarantee the safety and privacy of residential units and working spaces, it would be appropriate to evaluate in advance the possible impact of the simultaneous presence, in the same building, of units and spaces with incoherent functional use, with particular attention to the sources of noise and atmospheric pollution. The design criteria should, among other things, favor the choice of activities that are complementary and compatible with the health and well-being of the occupants, limit interference through a careful study of the ways in which the spaces are used, and define such distribution layouts to minimize the negative impacts that the presence of different activities can generate.

### *3. Re-appropriation of the basic principles and archetypes of sustainable architecture, thermal comfort and Indoor Air Quality (IAQ)*

Starting from the recent pandemic, the importance and the need to re-appropriate the architecture sustainability archetypes related to the building shape and orientation become a priority for investigation. The housing units and living spaces, even if small when located in densely built-up areas, should be designed in accordance with at least the minimum, basic principles of building hygiene.

Strategies include requirements for correct orientation, to make best use of sunlight and natural heat and light, thus in temperate climates like Italy's, the following orientations are favored: southeast-, south- and southwest-facing for the living spaces; east-facing for the bedrooms; and the north-facing for the working areas to ensure diffused natural lighting and avoid the glare effect.

Moreover, it is important to take into account the natural lighting through glass surfaces for an adequate



level of illumination in the room, considering also the external view and, at the same time, to use light colors for internal surfaces to increase reflection and also to ensure, where possible, an adequate view of the neighborhood, and possibly of green areas (23).

Finally, it would be appropriate to move from a merely prescriptive-based approach of the buildings codes to a performance-based design approach that takes into consideration - at least - the Daylight Factor (DF) in defining the quality objectives of natural daylighting (41).

Another strategic topic is thermal comfort and indoor air quality (IAQ), of particular relevance during the lockdown when the population was confined to the home. However, as in periods of high pollution rates in cities, residents must not make the mistake of keeping the windows closed, in order to guarantee regular natural air change rates (42). In fact, it is known that the quality of the air in confined spaces plays a direct or indirect leading role in health prevention. In addition to the quality of the outdoor air, IAQ also depends on the presence of internal sources of emission and diffusion of contaminants, with the concentration of chemical and biological pollutants that can influence their features (43).

Starting from the issue of indoor air conditioning systems, mainly during the summer season and the possible increase of the risk of COVID-19 transmission among occupants (44), it is preferable to suspend mechanical systems, guaranteeing natural ventilation through more frequent window opening, especially if some rooms have been adapted as remote working and homework stations (44-45).

The necessity and frequency of opening windows may vary according to the number of people and the activities carried out in the rooms. It is advisable, especially in winter, to open the windows even for few minutes several times a day, and in the spring and summer seasons to keep them open, or at least ajar, to ensure a regular air flow from outdoors, according to solar exposure and the absence of possible noise sources.

Environmental units without windows (such as bathrooms, closets, etc.) must be equipped with air extractors. However, it should be remembered that during the SARS epidemic of 2003 in Hong Kong, virus transmission was demonstrated through engineering

plants from toilets equipped with extractors; therefore, it is necessary to clean them regularly (44).

In the presence of ventilation, cooling and/or heating systems, it is appropriate to maintain suitable microclimatic conditions by avoiding air which is too dry and ensuring an adequate level of relative humidity (35). In any case, constant cleaning of the components and grids is necessary to eliminate all the dust and compounds where favorable conditions to the development and survival of bacteria and mold can occur, and air filters should be replaced regularly (46).

In addition, to ensure proper thermo-hygrometric well-being, natural and/or mechanical ventilation, and adequate IAQ, home automation systems (smart homes) could play a strategic role with suitable and programmed actions, also supported by on-site detectors, which can guarantee optimal conditions for the living environments with the automatic opening of windows for regular air changes.

#### *4. Water consumption and Wastewater Management*

The recent lockdown measures were the consequence of the absolute necessity of ensuring health by avoiding the contagion, but keeping people confined to the home for weeks also requires that the sanitary conditions of the dwellings be maintained at their best (32). In particular, the co-presence of sick individuals during home isolation represented the biggest challenge, as the other family members must be protected: therefore rethinking dwellings as places that comply with safety recommendations is essential.

In this context, if, on the one hand, the availability of properly treated and distributed drinking water is decisive to guarantee a source of a safe supply for consumption (47-48), on the other hand, the management of both liquid and solid municipal wastes becomes an additional critical point.

In particular, liquid waste is currently being studied by the international scientific community, given its possible role as a vehicle for infection.

Recently, the Italian Institute of Health (ISS) has documented the presence of genetic material of SARS-CoV-2 in urban wastewater, confirming the epidemiological opportunity of using wastewater as an indicator of the presence of the virus in the area (48-49). The US

Centers for Disease Control and Prevention (CDC) have confirmed this evidence (50). It must be said that the technique employed merely demonstrates the presence of one or more sequences of the genetic material – not infectious – of the virus, and not necessarily the presence of the infectious particle. However, it has been recently hypothesized (51-52) that the virus could survive in stools and, therefore, that droplets of wastewater could transport infectious particles, exposing the individuals (both sewage workers and also inhabitants) to contagion. At the moment, the situation is still uncertain and constantly under debate. In any case, the ISS is activating an environmental surveillance network on the national territory of Italy, to acquire useful knowledge for the assessment of the real role of wastewaters in viral transmission or, at least, to demonstrate the availability of a useful monitoring indicator (53).

As far as drinking water is concerned, according to the World Health Organization (WHO) “Interim Guidance on Water, Sanitation, Hygiene, and Waste Management for the COVID-19 virus” (54), the most important practices to be implemented in places where centralized water treatment and safe piped-water supplies are not available, regard the safe management of water, which should be safely collected and stored at home in regularly cleaned and covered containers. In addition, when the available water is not safe, household water treatment technologies (such as boiling, solar irradiation, UV irradiation and appropriately dosed free chlorine) must be made available and effective in removing or destroying the virus.

Furthermore, on ascertaining the drinking water quality, which depends on proper treatment and disinfection processes, it is desirable to undertake an adequate communication to the citizens, aimed at emphasizing the safety and security of the resource, to contrast the well-known distrust that the population has towards this precious asset (55-59). The current epidemic could offer further inspiration to underline the positive aspects of tap water which, we recall, is constantly monitored, unlike other alternative sources of supply (i.e., wells, springs, etc.). For the latter, an important recommendation regards the need to always implement appropriate water disinfection before using it for human consumption.

On the other hand, particular attention should be paid to the treatment of liquid waste, especially when the recovery of such water is envisaged. Monitoring and constant disinfection are strongly recommended, especially in light of the studies currently in progress, aimed at deciphering the role of possible sources of viral diffusion, in addition to the due technical-plant engineering measures (i.e. well-maintained plumbing, sealed bathroom drains, backflow valves on sprayers and faucets), necessary to avoid possible exposures in domestic environments. Finally, as far as wastewaters are concerned, it would be desirable for individuals with suspected (or confirmed) COVID-19 to be provided with separate bathrooms to be cleaned and disinfected at least once a day, using personal protective equipment. If home toilets are not connected to sewers, hygienic on-site treatment systems should be provided.

##### *5. Urban Solid Waste Management.*

The quarantine policies, imposed in most countries, have brought about a series of behavioural and environmental consequences that have to be taken into consideration in future solid waste management policies.

First of all, consumers modified their habits, with an increased demand for online shopping for food or other products with home delivery, all shipped or distributed packed, causing an increase in both organic and inorganic waste production. Furthermore, medical waste rose with an increase in the use of personal protective equipment such as masks and gloves (29). As a result of the pandemic, some US and European cities have suspended recycling programs, as authorities have been concerned about the risk of COVID-19 spreading in recycling centers.

Italy has prohibited infected residents from sorting their waste (60): in buildings with SARS-Cov-2 positive or suspected subjects, under isolation or in mandatory quarantine, the recycling program has been stopped and all domestic waste, including organic waste, glass, metal, plastics, paper tissues, paper rolls, disposable sheets, masks and gloves, has been treated as “unsorted” (54,61).

Although the “*23 Global Cities and Regions Advance Towards Zero Waste*” (62) stated the commitment

to avoid, by 2030, the disposal of - at least - 87 million tons of waste, the new worldwide situation created by the lockdown period has underlined the high topicality of the urban solid waste (USW) problem, especially in densely built-up contexts, where sanitation has taken on a crucial role in tackling the spread of COVID-19.

Therefore practical, feasible, repeatable strategies and actions are crucial and include:

- programming innovative digital and smart devices, capable of facilitating differentiated waste collection and making citizens conscious and active participants in the processes of reporting anomalous situations, thus obtaining a capillary control over the whole city, increasing the efficiency of the system;
- disseminating “returnable” practice like the Milan and Stockholm experiences, which allow an immediate and significant reduction of waste;
- replacing regular bins with smart bins, which could allow a careful and continuous monitoring of waste collection, especially in public spaces, which are neglected on numerous occasions;
- increasing pneumatic networks like the Automated Vacuum Waste Collection System (Oslo and Stockholm).

Starting from the recent pandemic, the presence of an adequate garbage area, protected from rodents and pests, within the condominium spaces with a flexible configuration enables a response to various uses over time.

#### *6. Housing automation and electromagnetic fields*

In the face of the COVID-19 epidemic, the role of home automation, better known as smart home, becomes strategic: the larger the housing unit, the more a smart home system is necessary. In fact, computer systems, supported by detectors and sensors inside the environment and by mobile interface devices, can guarantee an easy control and management of the home, improving comfort (air quality, temperature and humidity, air changes, etc.), planning various activities in advance (watering gardens/terraces, activating washing machine, dishwasher, oven, portable vacuum cleaners, etc.), increasing security (anti-theft systems, fire prevention systems, remote environmental video

control, systems for opening and closing windows, doors and shutters, etc.), as well as generating economic and energy savings by monitoring consumption, activating and deactivating systems when they are not needed (lighting system, space heating and/or cooling, etc.) (32), although the system itself requires minimal consumption for 24/7 monitoring. However, it is not excluded that the presence of home automation (sensors, detectors, cameras, technological equipment for lifting the user and/or stair lifts, etc.), in housing units with elderly and/or sick people, who live alone, could guarantee their greater safety and immediate assistance in case of need.

It is therefore clear that these systems require the presence of internet and Wi-Fi networks for their operation and remote control.

In addition, with the onset of the COVID-19 pandemic, the population, confined to their homes, transformed their living environments into places for recreation, work, study, physical activity, etc. putting the flexibility, versatility and resilience of spaces to the test (44). Responding to a series of different needs, but above all for smart working or online lessons for students, and in the face of the mandatory social distancing due to the health emergency, the presence of Internet and Wi-Fi connections becomes strategic and fundamental (11-12).

The presence of IT systems in each housing unit and, given the restrictions due to COVID-19, the excessive use of this network from morning to evening (from smart-working and online lessons to video calls, streaming movies, etc.), used by several family members at the same time, has resulted in and entails the need for ever better performing IT systems in new homes.

This measure to ensure an adequate computer connection is fully part of the current scientific debate relating to electromagnetic fields and the introduction of new, increasingly high-performing computer networks (5G). This mobile phone technology will give rise to new scenarios of exposure of the population to radio frequency electromagnetic fields which will be emitted in different frequency bands from those currently used for mobile telephony. One of the particularly novel aspects of 5G consists in the fact that various wireless devices communicate directly with



each other, in particular using electromagnetic waves, known as “millimeter waves”, although the latter correspond more precisely to frequencies between 30 and 300 GHz (wavelengths between 1 and 10 mm) (63).

Nowadays, the evidence regarding health effects linked with exposure to wireless technologies are not conclusive. WHO and several international institutions will review scientific evidence related to potential health risks from 5G exposure as the new technology is deployed, and as more public health-related data become available (64).

### *7. Indoor building and finishing materials*

Following the experience of the COVID-19 pandemic, designers and users have observed starting with their own living environments, that building materials, and in particular the finishing materials and furnishings, have a strategic role for health promotion and for the cleanliness of domestic environments.

Finishing materials of the floors, walls and ceilings are very varied, and for example the same house can have very different flooring among the environmental units, each different properties, treatments and compositions (65). Among these, it must be underlined that several finishing and furnishing materials emit VOCs, and in the presence of high temperatures and/or due to the solar exposure of the environments, their emissions increase (66).

Currently the market offers innovative materials to reduce the bacterial load on the finishing surfaces also with eco-active materials and photocatalytic paints, but with no demonstration on the viral load.

In fact, although it has not yet been shown that the transmission of viral loads derives directly from contact with commonly used objects, evidence shows that viruses belonging to the same group (coronavirus, SARS virus and MERS virus) can persist on inanimate surfaces for up to several days depending on the material, the quantity of biological fluid and the initial viral concentration, the air temperature and relative humidity, even though their infectious capacity has not been proven (35).

More recent data relating to the SARS-CoV-2 virus (67) confirm that on plastic and stainless steel, under experimental conditions (therefore with mi-

croclimatic conditions in the laboratory), the ability of the virus to persist is similar to that of the SARS virus (SARS-CoV-1), however, it showed an exponential decay of viral capacity over time (half of the viral particles were no longer infectious after a few hours). Indeed, from the laboratory data, van Doremalen et Al. (67) observe that copper and cardboard have a complete reduction of the viral load in reduced times (respectively about 4 hours and 24 hours).

However, the absence of antibacterial and antiviral materials can be easily overcome by careful, regular and constant disinfection of spaces (35). It is clear that particular attention must be paid to the surfaces most frequently touched (e.g. doors, door handles, windows, tables, light switches, toilets, taps, sinks, desks, chairs, cell phones, keyboard, etc.) (68), and that not all detergents can be used on all surfaces and materials (44). In fact, in homes we also find materials and/or furnishings that cannot be washed (e.g. rugs, carpets and mattresses), and therefore it is necessary to use steam appliances (35).

In general, as evidenced by the Scientific Community, airing the environments both during and after the use of cleaning products is optimal to ensure healthy environments.

### **Take-Home Messages and Research Outlooks: Challenges and Opportunities**

The lockdown due to the COVID-19 pandemic forcefully put on display again the importance of housing conditions on people’s health and well-being, underlining the vast inequalities in housing registered in Italy, particularly in metropolitan areas. The lack of adequate space, terraces and gardens have contributed to increased stress and aggressivity, especially among the disadvantaged.

Therefore, the policymakers should consider housing as a major priority for the potential relapses in public health related to it.

The issues previously described regarding overcrowding and the quality of dwellings underlines some, as yet unresolved, past problems (69). First of all, it is necessary to provide updated and rigorous requirements for the built environment and in particular

for residences (01,11), taking into account that in Italy the demand for public housing is increasing, as is the demand for buildings with high energy efficiency.

Table 1 summarizes some recommendations prompted by the quarantine imposed during the COVID-19 pandemic which should be taken into ac-

**Table 1.** Indications for a healthy, safe and sustainable housing

Investigated areas	Pre-existing constructions	New constructions
<b>1. Visible and accessible green elements and spaces.</b>	<ul style="list-style-type: none"> <li>• use of suitable material to control the albedo of the flooring of open spaces</li> <li>• implement the building with green roofs and walls, or small balconies, where possible</li> </ul>	<ul style="list-style-type: none"> <li>• use of vegetation for the summer shading of buildings</li> <li>• use of suitable material to control the albedo of the flooring of open spaces</li> <li>• provision of green roofs and walls</li> <li>• emphasize the presence of balconies and/or terraces</li> <li>• view of greenery from windows</li> </ul>
<b>2. Flexibility, adaptability, sharing and crowding of living spaces, and compliant functions located within the buildings.</b>	<ul style="list-style-type: none"> <li>• usability and accessibility at least in terms of adaptability of living spaces</li> <li>• flexibility of the indoor spaces</li> <li>• quality of living spaces: furniture, dimensional standards</li> <li>• compatibility between different functions in the building</li> <li>• flexibility of the condominium spaces (ground floors, basements, free floors)</li> </ul>	<ul style="list-style-type: none"> <li>• usability and accessibility of living spaces</li> <li>• flexibility of the indoor spaces</li> <li>• quality of spaces: furniture, dimensional standards, views</li> <li>• compatibility between different functions in the building</li> <li>• flexibility of the building common spaces (ground floors, basements, free floors)</li> </ul>
<b>3. Re-appropriation of the basic principles and archetypes of sustainable architecture, thermal comfort and Indoor Air Quality (IAQ).</b>	<ul style="list-style-type: none"> <li>• adequate orientation of the living spaces</li> <li>• regular natural air change rates</li> <li>• regular maintenance of ventilation, cooling and/or heating systems, where present</li> </ul>	<ul style="list-style-type: none"> <li>• correct orientation of living spaces, according to the solar radiation and to the natural heat and lighting supplies</li> <li>• regular natural air change rates</li> <li>• regular maintenance of ventilation, cooling and/or heating systems, where present</li> </ul>
<b>4. Water consumption and Wastewater Management.</b>	<ul style="list-style-type: none"> <li>• ease of access to household water storage</li> <li>• implementation of household water treatment technologies</li> <li>• installation of backflow valves on sprayers and faucets</li> </ul>	<ul style="list-style-type: none"> <li>• ease of access to household water storage</li> <li>• implementation of household water treatment technologies</li> <li>• implementation of technical-plant engineering measures (i.e., well-maintained plumbing, sealed bathroom drains, backflow valves on sprayers and faucets)</li> <li>• installation of more than one bathroom</li> </ul>
<b>5. Urban Waste Management.</b>	<ul style="list-style-type: none"> <li>• flexibility of the garbage area or specific spaces in the courtyard or common spaces</li> <li>• differentiation of access to the waste collector area</li> <li>• application of “returnable” practice which allow an immediate and significant reduction of waste;</li> <li>• replacement of regular bins with smart bins.</li> </ul>	<ul style="list-style-type: none"> <li>• presence of a garbage area</li> <li>• flexibility of the garbage room</li> <li>• more than one access to the garbage room to respond to various uses over time</li> <li>• development of innovative digital and smart devices, to facilitate differentiated waste collection;</li> <li>• replacement of regular bins with smart bins;</li> <li>• development of pneumatic networks where possible.</li> </ul>

*(continued on next page)*

**Table 1.** Indications for a healthy, safe and sustainable housing

Investigated areas	Pre-existing constructions	New constructions
<p><b>6. Housing automation and electromagnetic fields.</b></p>	<ul style="list-style-type: none"> <li>• introduction of smart home systems with detectors and sensors</li> <li>• control and management of indoor air quality, temperature and relative humidity, air change rates, etc.</li> <li>• mechanical window opening and closing, where possible</li> <li>• control systems for elderly and/or sick people, in case of need</li> </ul>	<ul style="list-style-type: none"> <li>• introduction of housing automation and smart home systems with detectors and sensors</li> <li>• control and management of indoor air quality, temperature and relative humidity, air change rates, etc.</li> <li>• mechanical window opening and closing</li> <li>• control systems for elderly and/or sick people, in case of need</li> </ul>
<p><b>7. Indoor building and finishing materials.</b></p>	<ul style="list-style-type: none"> <li>• introduction of high performance furnishing materials</li> <li>• use of adequate detergent and cleaning products</li> <li>• regular cleaning activities</li> </ul>	<ul style="list-style-type: none"> <li>• introduction of high performance finishing and furnishing materials</li> <li>• selection of low VOC materials</li> <li>• use of adequate detergent and cleaning products</li> <li>• regular cleaning activities</li> </ul>

count both for the renovation of pre-existing constructions and for the construction of new buildings.

What emerges from the scientific literature (01,12,35,70-72) is that, in order to guarantee good health standards, nowadays it is indispensable to direct political and administrative choices to improve the overall conditions of the neighborhood and of the buildings within. Therefore, evaluating a healthy living environment implies taking into account, not only the single housing unit, but also the environmental context within which it is inserted, paying particular attention to the solutions adopted regarding environmental sustainability and adaptation to climate changes. We have addressed several of these topics related to the COVID-19 pandemic in a previous paper (29).

Many aspects included in Table 1 are considered essential by WHO (72) and are accounted for in many European building codes (73). In Italy, the introduction in 2016 of the National Building Code (74), already adopted by some Italian Regions, attempted to bridge this gap by integrating several regulations into a single one. However, regarding health standards related to housing, it refers to a previous ministerial decree (11), which requires updating, given that 45 years have passed since it was approved. Therefore, without a clear national legislation on hygienic requirements, it is easy to understand how difficult the daily practice for both designers and Public Health Officers is (11). To these latter, in particular, the current legislation at-

tributes a limited role regarding the design and construction choices for new buildings and restorations. Consequently, the relevance attributed to health in the design solutions proposed mainly depends on the competence of designers and on the responsibility of the builders (29).

The COVID-19 pandemic also underlined the crucial need for a strong interdisciplinary and trans-disciplinary approach between researchers and practitioners, from both technical and health backgrounds, in order to address the main Public Health issues related to the built environment (35,75-77) and to the housing demands.

For this reason, taking into account the previous work of the authors (29) involved in the Building Hygiene Working Group of the Italian Society of Hygiene (SIItI) it becomes important to improve stakeholders' awareness of the factors affecting health in living spaces, and to inform both the citizens and the policymakers - both building code legislators and tax incentive providers - about the design strategies for people's psychophysical and social well-being, for the protection of the environment and for the safety of the occupants of the dwellings.

It is also important to consider there is little shared vocabulary among disciplines (78), which poses a problem since cities are multi-dimensional systems influenced by trends and processes operating at local, national or supranational levels, e.g. global initiatives

(79) that address urban issues, such as the Sustainable Development Goals (SDGs).

It is necessary to pool the knowledge from the technical field and Public Health expertise, identifying exportable and scalable best practices: in order to reach this goal, the professional figure of the previously defined Health City Manager (75), who may be included in the team of Public Administrators, could bring together the competences of the Municipal Department of Construction and the Public Health experts (80) working in the Local Health Agencies, to make the building and hygiene regulations, although sometimes still conflicting, work more cohesively, taking into account both local and global trends .

In conclusion, as underlined by WHO (9), building healthy housing is a complex issue and a multisectoral responsibility, achievable only if a contribution is made by all relevant players and the COVID-19 pandemic has placed the country's profound housing crisis under the spotlight, and further highlighted the need to address it in a systematic way.

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