Design of an action protocol for bioconstruction

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Abstract
Numerous elements are to be considered when designing a comfortable and healthy building. We are mainly referring to the site, different construction materials, layout orientation, the presence of power lines and nearby mobile phone antennae, among others. There is an increasingly recognized relationship between where we live or work and our overall health. Along these lines, we have undertaken several studies and measurements of the most influential factors, from the point of view of Geobiology and Bioconstruction. Based on the results obtained and the accumulated multidisciplinary experience, both from the perspective of engineering and architecture, a protocol is proposed to study Biohabitability in differently built containers such as high-rise buildings, houses and inhabited areas in general.

Keywords: bioconstruction, biohabitability, radiations, health.

Introduction

Humans have always felt the need to improve quality of life, and pursuing this goal also meant optimizing the surroundings where we develop an activity, whether for work, leisure or rest. There is a close relationship between the elements involved in a building, such as where it is located, the building materials used, the orientation of the housing, the presence of power lines, etc., and the health or physical and psychological balance of the people who occupy it (Abdullah, Hamid, Shaif, Shamsuddin and Wahab, 2016).

Geobiology is defined as the science that studies the interactions between energies from the earth and the organisms living there (Shu Cheng and Hong Fu, 2014). Its scope has been expanded in recent years to cover all elements or factors involved in life processes, especially those affecting the health of living beings, particularly humans. This science studies, among others, electrical or electromagnetic pollution, materials used in construction and the effects of earth radioactivity on any given project. To these we must add the natural radiation besides those generated by the activity of human beings. Applying this science to housing construction, i.e. Bioconstruction or Bioarquitecture, means that the design and construction are based on health and harmony criteria for its occupants. Moreover, allowing the so-called Biohabitability studies to analyze and connect the influence of the building characteristics and its surroundings on inhabitants. Tied together with people's health and quality of life, it is increasingly common to refer to the so-called "sick building syndrome" and everything to do with indoor air conditioning, radioactive construction materials, carcinogenic insulations, toxic chemical substances, poor lighting, poor ventilation, orientation and sun exposure, noises, etc. (Ortiz Terán and Haro Haro, 2015).

From a biohabitability point of view, the radiations that can potentially affect a building and consequently its residents, are very important factors to consider when designing such a building. Without attempting a rigorous classification, we have grouped radiations based upon a source-effect criterion, thus resulting more useful due to its practicality. Hence, we will differentiate between cosmic, telluric and electromagnetic radiations.

Cosmic radiation comes from interstellar space and consists of X-rays, microwaves, infrared, natural light, ultraviolet radiation, etc. They can become very dangerous for the health of living beings; however, Earth's atmosphere, especially the ozone layer, is a relatively effective barrier.

Telluric radiation, also called ground radiation, originates from various causes related to geological or telluric processes (natural radioactivity, geological faults and fissures, soil friction, groundwater, etc.) and, most notably, from a system of radiation bands which are considered the force lines of the Earth's electromagnetic field. Included in the telluric radiations, there are a series of underground energies, due mainly to the emissions of radioactive materials from the Earth's crust, which primarily emits gamma and infrared radiations. Radioactive gases such as radon are also emitted. This gas concentrates especially in poorly ventilated areas and it causes breathing disorders that can lead to lung cancer (Brauner et al., 2013). The influence of telluric radiation is enhanced by the presence of geological faults and fissures, groundwater veins, and by the so-called geomagnetic lines (Hartmann, Curry, etc.).

Electromagnetic radiation can be both natural (cosmic, solar, terrestrial magnetism, etc.) and artificial (high voltage power lines, transformers, appliances, mobile phone antennae and communication networks, etc.). The higher the frequency of radiation, the greater the energy associated therewith. Thus, high frequency radiation (over 3 MHz), and especially from 3 PHz or more, can ionize atoms, so they are the most dangerous and worrying. They can affect both organs and the immune system, altering the central nervous system which may cause stress, insomnia, migraine, depression, etc., even hereditary genetic mutations (Havas, 2017). Problems caused by electromagnetic contamination are more and more abundant and documented among the different construction types (high-rise constructions, houses, civic buildings, etc.) located near high voltage power lines, substations and power distribution transformers, mobile phone antennae, along with others.

Moreover, government agencies are already analyzing and regulating the harmful effects that these sources are producing on the health of living beings.

In this work we have carried out measurements, from a *Geobiological* point of view, of the main factors influencing Bioconstruction, such as noise, lighting and air conditioning, besides those already mentioned above, which will enable an action protocol to develop *Biohabitability* studies as efficiently as possible.

Methodology

To carry out this work, different sources have been consulted and field measurements have been made to analyze the influence of different parameters on the human being.

So, to analyze and quantify the natural radioactivity emitted by some of the materials used in the project we handled an Inspector Alert equipment, Nuclear Radiation Monitor, by International Medcom.

The terrestrial geomagnetic field was quantified with a Geo-magnetometer BPM 2010, by Bio-Physic Technology. The levels of radon gas in houses were determined by an Air Things Corentium Home, by Corentium Canary.

Also, measurements of electromagnetic radiation levels at low and high frequencies were performed, respectively, with a Teslameter TM 40 whose measurement ranges between 0-1999 nT, by Elce, and Electrosmog 92 TES, TES Instruments. The electric field was determined with a computer Electrosmog SFT 20, HC-Electronic.

Finally, sound measurements were performed with a computer Sound Level Meter PCE-999, PCE Group. In addition, temperature, relative humidity and light measurements were performed with an Auto Ranging Multimeter MS8209, by Kaise.

Results and discussion

To address a complex problem such as Bioconstruction, three fields of action have been selected: the environment, the contaminating factors and detecting and assessing geophysical, energy alterations, etc.

The choice of a site to execute a building, is a process of great importance, as evidenced by the procedures developed by different associations such as Green Building Council España (GBCe, https://gbce.es/), International Initiative for a Sustainable Built Environment (IISBE, https://www.iisbe.org/), as well as the data collected in the bibliography of this work.

When choosing a land or a site to build on, several key factors that can determine its proper suitability should be taken into consideration. It mainly comes down to assessing the environmental situation, electromagnetic pollution, cosmoteluric energy, orientation, topography and geotechnics. Construction should avoid sites near harmful areas or those with a potentially high impact on the environment, such as polluting industries or waste disposal plants. In contrast, the presence of abundant vegetation (forests, parks or gardens) is an undeniable element of wellbeing. Electromagnetic pollution, caused by power lines, transformers and electrical distribution lines near buildings, are a source of discomfort and undesirable distress. Similarly, disturbances and alterations of telluric radiation must also be considered when selecting the land to build; as well as trying to avoid as far as possible geological anomalies and groundwater. These areas should only be used for transit places and not as a home.

Meanwhile, the correct orientation of the building must meet very important functions such as the use of solar radiation, protection from the cold and wind, energy savings and optimum thermal and lighting comfort. It must be in line with the so-called *Bioclimatic Architecture*, which seeks rationality and construction optimization based on the use of environmental conditions of the surroundings.

Environmental pollution, in its different aspects, is a factor of great importance. Methods such as the prediction model, the transparencies method, the green method, etc. (Zhang and Liu, 2020; Ziehe, 1994), allow the evaluation of the incidence of polluting industries, waste treatment centers, hospitals, incinerators, etc.

The noise pollution caused by heavy traffic, firefighters, ambulances, trains, buses, nightclubs, are worthy of a comprehensive and detailed study, which avoids or failing to alleviate the undesirable effects that they cause on health.

A factor of great interest is the pollution caused by telecommunications (mobile phone antennas, radio or television antennas, wireless networks, radars, etc.)

Once the pollutant sources are determined and valued, it is necessary to establish, in those that can be quantitatively measured, the optimal biohabitability intervals. Biohabitability, healthy habitat, or quality of a habitable space free of polluting agents (radiation, electromagnetic fields, radon gas, etc.).

Another prominent factor to consider, both in new buildings and existing homes, is the disturbance or the Earth’s magnetic field variations (geomagnetic field) whose vertical component can be measured using a geomagnetometer. Figure 1 shows the measurement of a large geomagnetic disturbance in a house in the city of Badajoz (Spain), caused by a vein of underground rocks or minerals. We can observe a significant deviation (78 µT, approx.) from the mean value (35 µT) indicated by the Nuclear Safety Council of Spain for that area (Figure 2).

Owing to the implications on the health of living beings, it is particularly relevant to understand and evaluate underground emissions or radiations as well as some of the materials frequently used in housing construction. Figure 3 shows the map of Spain with the values of radioactivity (µSv/h) at various observatories in the country. Materials which, unaltered by any technological activity, present a radiation above safety level and may pose a health risk. Paradoxically, they are considered high quality construction supplies, namely granite, some types of sand and certain clay such as stoneware. However, it is common that non-radioactive elements become enhanced by others which are, such as uranium, thorium, potassium, radium or radon.

Figure 1. Geomagnetic disturbance (nT) caused by a streak of rocks or minerals in the subsoil. Source: by the author.

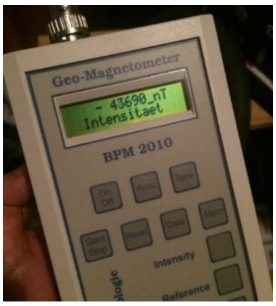


Figure 2. Mean values (µT) of geomagnetic field intensity in Spain. Source: Nuclear Safety Council of Spain.

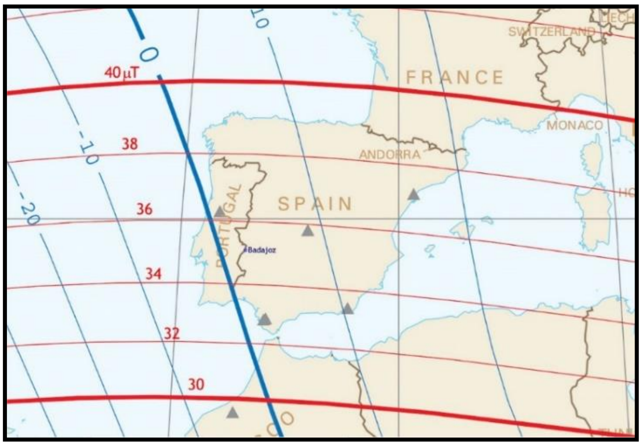
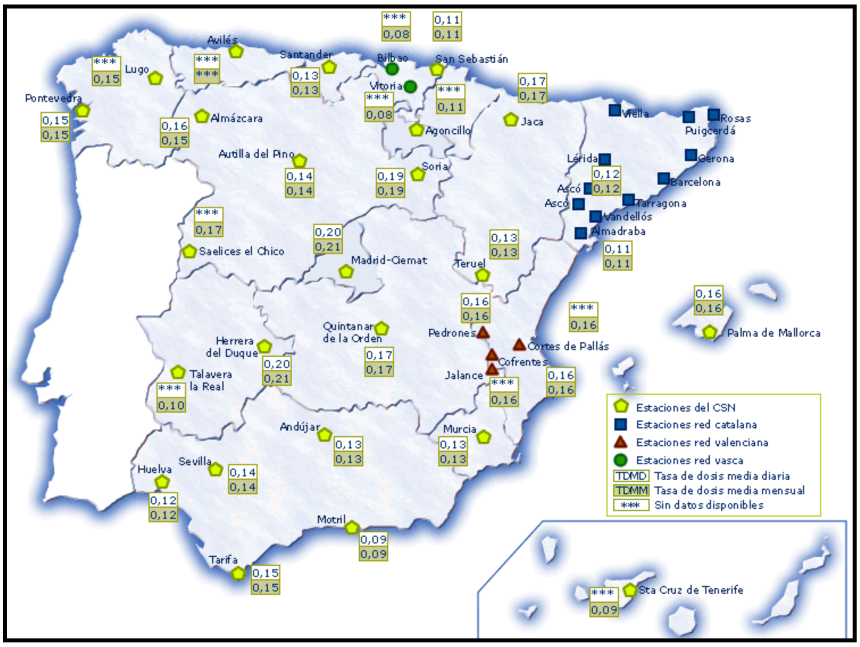


Figure 4 shows the different values obtained with a radioactivity meter. Four materials frequently used as construction coverings were studied: stoneware tiles, terrazzo and two varieties of granite. Figure 4a shows the radiation accumulated on a ceramic tile, widely used as flooring in humid areas. Its value is 0,377 µSv/h, which is higher than the mean value throughout Spain (0,140 µSv/h), and above the one deemed safe or low risk for people's health (from 0.150 to 0.170 µSv/h) (Royal Decree, 2001). Terrazzo emission is slightly below these safety values, as shown in Figure 4b. Finally, Figures 4c and 4d show the radiation values for two varieties of granite, both exceeding more than three times the recommended value.

Figure 3. Average values (µSv/h) of natural radioactivity in Spain. Source: Nuclear Safety Council of Spain.

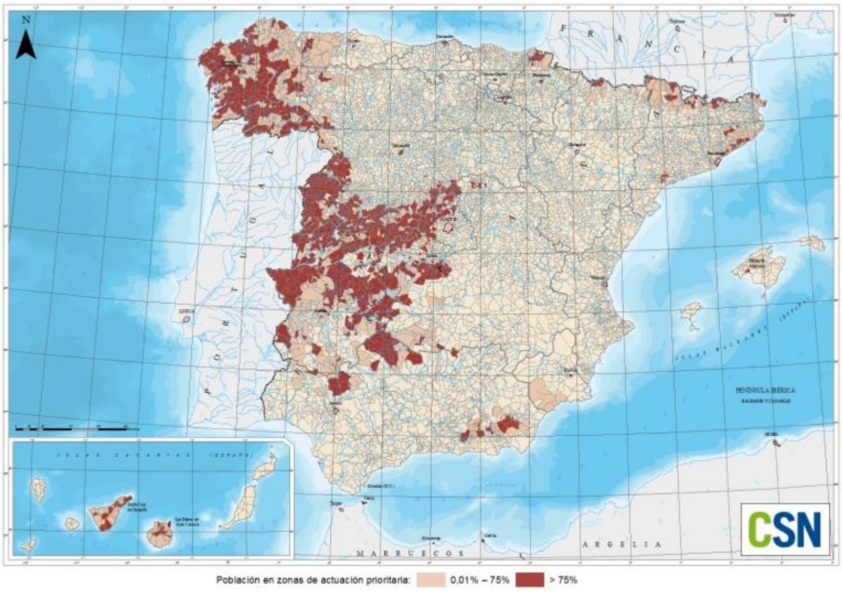


The European Union, through the European Atomic Energy Community (EURATOM), limits the effective dose for workers exposed to radioactivity, in addition to establishing limits for specific areas of the body or for pregnant and nursing women; and provides safety rules against exposure to ionizing radiation (Council Directive, 2013). However, the legal limit for EU population stands at 1 mSv per year. Thus, the radiation value for any building without exposure to ionizing radiation should not exceed that of the geographical area, with an average radioactivity in Spain of approximately 0,140 µSv/h. Anything above those levels entails a health risk, even though low-dose effects remain unclear to this day. At pilot level, and due to our own experience, safety limit is established at 0,170 µSv/h, including environmental radiations as well as those caused by other elements, natural (a radioactive metal vein) or artificial.

Radon is a noble, colorless, tasteless and odorless gas, with high mobility and solubility in water. It is a radioactive gas that poses a health risk. The World Health Organization (WHO) estimates that between 3-14% of lung cancers may be due to inhalation of this gas, thus being the second leading cause of death from lung cancer after tobacco. The National Security Council (CSN in Spanish), along with some universities and research groups, has been measuring natural radiation in the terrain as well as radon gas inside homes for years. Figure 5 shows a map of Spain with the different areas of potential exposure to radon gas, establishing three categories of risk-based exposure.

Figure 4. Radioactivity values (μSv/h) in different building materials: ceramic tile (a), terrazzo (b), granite (c, d). Source: by the author.

Figure 5. Map of Spain with different categories of potential exposure to gas radon. Source: Nuclear Safety Council of Spain.



The European Union in its Recommendation 2013/59/EURATOM, to protect against the dangers of radon exposure inside buildings, establishes two levels of concentration expressed in becquerels per cubic meter (Bq/m^3): newly constructed residential buildings should not exceed 200 Bq/m^3, and the existing residential buildings must not exceed 400 Bq/m^3. Figure 6 shows the measurement of radon gas inside a house, observing relatively high values in some rooms.

Problems caused by electromagnetic pollution in any type of buildings are increasingly abundant, as well as in offices and houses near power lines, substations, power distribution centers, mobile phone antennae, etc. When carrying out measurements it is necessary to differentiate between low (40 Hz to 100 Hz) and high frequency fields. The former is measured with equipment able to detect the magnetic induction (nT) caused by the electromagnetic field. On the other hand, in high frequency ones, we determine the intensity of the electric field (V/m), the intensity of the magnetic field (mA/m), or else, the irradiance (mW/m^2).

Figures 7a and 7b show, respectively, the measurement of a low frequency electromagnetic field caused by a power transformer on the other side of the property enclosure, and the results of a high frequency electromagnetic field measuring tool. Although when setting recommended values an agreement has not been reached among government agencies and independent associations, based on these recommendations and experimental practice, it is established that it is advisable not to exceed 100 nT for low frequency electromagnetic fields, and 100 nW/cm^2 for high frequency ones.

Figure 6. Measurement (Bq/m^3) of gas radon inside a house. Source: by the author.

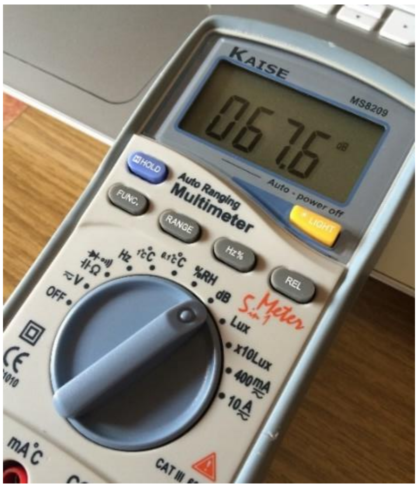
Figure 7. Measurements (nT and nW/cm^2) of the electromagnetic field: low frequency (a), high frequency (b). Source: by the author.

Likewise, *Bioconstruction* principles must be observed on electric fields caused by artificial sources, i.e., those caused by any given electrical or electronic device. For these electric fields there is also no agreed official criteria to establish a recommended safety limit. Nevertheless, if considering the information given by several authors and independent organizations, this limit could be set at below 100 V/m. Figure 8 shows the intensity of an electric field caused by a domestic lamp, which is approximately 450 V/m.

Figure 8. Measurement (V/m) of the electric field intensity. Source: by the author.

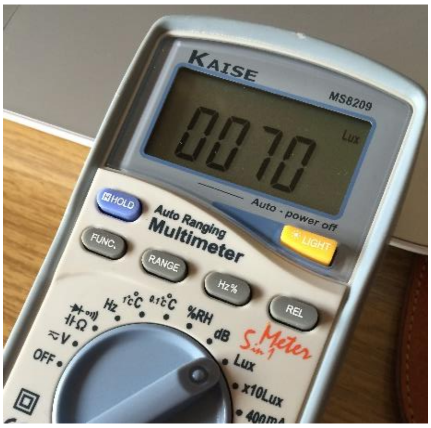
Noise pollution denotes unwanted sounds that interfere with domestic activities and people's periods of rest and can be detrimental to physical and mental health (Kyoung-Bok and Jin-Young, 2017). Noise protection standards, in addition to indicating how to quantify and qualify noise, establish insulation and reverberation time limit values. The effects of noise levels are apparent and detrimental from 70 dB; thus, Spanish legislation has set the ceiling at 65 dB. Figure 9 shows the reading done with a multimeter set on sound level meter function, recording a slightly greater value than that stated by the norm.

Figure 9. Measurement (dB) of noise with a multimeter in the sound level meter function.
Source: by the author.



A perfectly lit space fosters a proper development of activities and positively contributes to the health of its inhabitants. As well as for noise, there are regulations that analyze and define the intensity of light in different spaces. In general, a lighting installation should be able to provide a minimum illuminance of 20 Lux in outdoor areas and 100 Lux for indoor areas, measured at ground level, whereas for a work environment at least 500 Lux is recommended (Royal Decree, 2006). Figure 10 shows the light coming in through a window in a library study area of the Industrial Engineering Faculty at the University of Extremadura, observing a level somewhat lower than recommended for this type of activity.

Figure 10. Measurement (Lux) of light intensity with a multimeter. Source: by the author.



Climate control is about providing suitable temperature, humidity and air cleaning conditions for thermal comfort or convenience inside inhabited spaces. Even though thermal comfort is a relative concept, as it depends on individual sensitivity, it has been established between 19 ºC and 22 ºC. When designing and optimizing climate control in a home, we must consider the concepts and recommendations of *Bioclimatic Architecture*, while also relying on modern technology and increasingly efficient HVAC systems.

Conclusions

To provide a document as a protocol allowing to perform the study and exploration of a place (Huisman, Morales, van Hoof and Kort, 2012), as well as to support the housing design under the principles of *Bioconstruction*, we will conclude that *Biohabitability* studies must be directed to:

- Assess the habitat surroundings: location, property type, etc.
- Measure environmental polluting factors: noise, electromagnetic fields, natural radioactivity, etc.
- Detect geophysical disturbances, energy lines and geopathogenic zones.

In conclusion and in summary, a protocol is developed to determine the main sources described above and present a study of *Biohabitability* in a building:

Environmental assessment

- Environmental pollution: landfills, incinerators, hospitals, polluting industries, etc.
- Noise pollution: heavy traffic, night clubs, fire stations, ambulances, trains, buses, etc.
- Electromagnetic pollution: power lines of high and medium voltage, substations, transformers, etc.
- Telecommunications: mobile phone, radio or television antennae, radars, wireless networks, etc.

Detecting and measuring anomalies (maximum levels recommended)

- - Radioactivity: less than 0.170 µSv/h.
- - Geomagnetic field: ± 20 µT (as per latitude).
- - Low frequency electromagnetic field: less than 100 nT.
- - High frequency electromagnetic field: less than 100 nW/cm2.
- - Electric field: less than 50 V/m.
- - Lighting for resting: less than 20 Lux.
- - Lighting for activity: 100-500 Lux.
- - Relative humidity: less than 80%.
- - Radon gas: less than 200 Bq/m³.

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