

EFFECTS OF INDOOR AIR QUALITY, HUMIDITY AND TEMPERATURE ON EMPLOYEES HEALTH AND PERFORMANCE

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Abstract:

For optimal safety of human health and their performance in ensuring higher productivity, certain constituents needs to be adequately harnessed together. Some of these are the quality of air, humidity and temperature, which serve as metrics, which guarantees quality life style. For this purpose, this paper becomes cardinal as it explains the significance of having a quality indoor air with the perfect humidity and temperature as predictors for fostering an atmosphere that enhances human health and productivity. This paper is underpinned by endogenous growth theory, whose principle posited that human productivity is a function of industrial development, since productivity of human reflects their capacity and output ratio. Thus, irrespective of how human productivity is being determined temperatures, humidity and indoor air quality plays dominant roles in enhancing human health and productivity. This paper concluded that for productivity to be increased, the quality of indoor air, humidity and temperature are metrics that must be continuously maintained; any lacunae left unturned in this regard can hamper productivity and consequently have negative results on human health.

Keywords: Indoor Air Quality, Humidity, Temperature, Human Health and Productivity.

Introduction

Human productivity and their health status constitute the most relevant and significant topics in modern day society, particularly, when indoor air quality, humidity and temperature are indispensable. Therefore, as considerable amount of human lives are being spent inside the buildings, their comfort from the realm of thermal indoor quality of air becomes very essential.



According to Bueno, de Paula Xavier and Broday, (2021), health and comfort of humans are everyday issues since most humans spend their everyday lives in environments that are closed; which some of it requires good ventilation to promote a quality working life. This brings to fore the importance of having an environment that is comfortable to increase the rate of human productivity. This presupposes that every aspect of human lives and endeavor, the evaluation of thermal comfortability and indoor quality of air are sacrosanct.

According to Kierat, Melikov, Markov and Bivolarova, (2022), the health and productivity of human under diverse environmental dimensions has been investigated in past decades. Going forward, one of the core and primary important metrics of evaluation is quality of indoor air, humidity and temperature as it is perceived among US based residents; and this manifests in the evaluation of the degree of concentration of carbon dioxide and its level of implications or durations. The principal need for having good spaces for the purpose of enhancing health and productivity of human is very pertinent and this makes this current paper very outstanding as it present an understandable reason to the thrust of having an indoor air quality, humidity and temperature and how much they impact on the health and productivity of human. From the view point of The Swedish Work Environment Authority (2020) and ASHRAE Standard (2013), the concentration of indoor CO₂ should stand below 1000 ppm to avoid the negative consequences of poor air quality.

For instance, according to scholars such as Vardoulakis, Dimitroulopoulou, Thornes, Lai, Taylor, Myers, Heaviside, Mavrogianni, Shrubsole and Chalabi, (2015) projected that come 2020, the mean global temperature surface will be 1.02_C and that implies that the temperature will be more warmer than the previous baselines within the year 1951-1980. The position of these authors is that there exists several effects that directly impedes on human health like increased risks of hyperthermia which occur due to human exposure to exposure to high temperatures; this also constitutes an indirect health consequences stemming from bad air quality. Yang, Javanroodi and Nik, (2021) opined that increased rate of temperature can lead to higher concentrations of indoor airborne pollutants which causes higher risk of cancer, allergies and disruption in endocrines.

Consequent on the forgoing statements, the thrust of this paper Effects of indoor air quality, humidity and temperature on human health and productivity using the United States of America as a focal point.

Literature Review

This section establish a ground to better understand previous scholarly opinions on the topic under review. This is in a bit to observe what has been previously done and areas requiring further investigations.

Conceptual Explications

Air quality

Air quality Context Issues at stake Atmospheric pollutants from energy transformation and energy consumption, and from industrial processes, are the main contributors to regional and local air pollution. Major concerns relate to their effects on human health and ecosystems. Human exposure is particularly high in urban areas where economic activities are concentrated. Degraded air quality can have substantial economic and social consequences, from health costs and a lower quality of



life to infrastructure maintenance, reduced agricultural output and forest damage. In the atmosphere, emissions of sulphur and nitrogen are transformed into acidifying substances such as sulphuric and nitric acid. When these substances reach the ground, acidification of soil, water and buildings occurs which cause severe environmental damage. Nitrogen oxides (NO_x) also contribute to ground-level ozone formation and are responsible for eutrophication, reduction in water quality and species richness. They are associated with adverse effects on human health because high concentrations cause respiratory diseases. Fine particulate matter ($\text{PM}_{2.5}$), is another serious pollutant globally from a human health perspective. Chronic exposure even to moderate levels of PM substantially increases the risk of heart disease and stroke, the leading causes of death in OECD countries. It also increases the risk of respiratory diseases, including lung cancer, chronic obstructive pulmonary disease and respiratory infections. Emissions from transport, industry, electricity generation, agriculture and domestic (household) sources are the main contributors to outdoor air pollution.

Emissions can be reduced by substituting dirty fuels for cleaner ones, focusing development on cleaner industries, reducing consumption of polluting products and adopting cleaner technologies. Behavioural and lifestyle changes are also important. Policies that provide incentives across a broad spectrum of firms and consumers (e.g. emission or energy taxes) tend to be more cost-efficient than those that target a specific product, fuel or technology (e.g. subsidies for electric cars). Both the sources of air pollution and severity of exposure vary across and within countries. Hence it is important to tailor policies to specific local circumstances. For example, more stringent measures are required in densely populated areas or for emission sources located upwind from urban areas. Such spatially heterogeneous policies help achieve environmental objectives at lower costs than measures that apply uniformly to sources in all locations and to populations at all risk levels.

Humidity

Humidity implies the quantity of water present in the atmosphere in the form of water vapour. Humidity is the concentration of water vapor present in the air. Water vapor, the gaseous state of water, is generally invisible to the human eye.^[2] Humidity indicates the likelihood for precipitation, dew, or fog to be present.

Humidity depends on the temperature and pressure of the system of interest. The same amount of water vapor results in higher relative humidity in cool air than warm air. A related parameter is the dew point. The amount of water vapor needed to achieve saturation increases as the temperature increases. As the temperature of a parcel of air decreases it will eventually reach the saturation point without adding or losing water mass. The amount of water vapor contained within a parcel of air can vary significantly. For example, a parcel of air near saturation may contain 28 g of water per cubic metre of air at 30 °C (86 °F), but only 8 g of water per cubic metre of air at 8 °C (46 °F).

Three primary measurements of humidity are widely employed: absolute, relative, and specific. **Absolute humidity** is expressed as either mass of water vapor per volume of moist air (in grams per cubic meter)^[3] or as mass of water vapor per mass of dry air (usually in grams per kilogram).^[4] **Relative humidity**, often expressed as a percentage, indicates a present state of



absolute humidity relative to a maximum humidity given the same temperature. **Specific humidity** is the ratio of water vapor mass to total moist air parcel mass.

Humidity plays an important role for surface life. For animal life dependent on perspiration (sweating) to regulate internal body temperature, high humidity impairs heat exchange efficiency by reducing the rate of moisture evaporation from skin surfaces. This effect can be calculated using a heat index table, also known as a humidex.

The notion of air "holding" water vapor or being "saturated" by it is often mentioned in connection with the concept of relative humidity. This, however, is misleading the amount of water vapor that enters (or can enter) a given space at a given temperature is almost independent of the amount of air (nitrogen, oxygen, etc.) that is present. Indeed, a vacuum has approximately the same equilibrium capacity to hold water vapor as the same volume filled with air; both are given by the equilibrium vapor pressure of water at the given temperature. There is a very small difference described under "Enhancement factor" below, which can be neglected in many calculations unless great accuracy is required.

Temperature

Temperature is a physical quantity that expresses quantitatively the attribute of hotness or coldness. Temperature is measured with a thermometer. It reflects the kinetic energy of the vibrating and colliding atoms making up a substance. Thermometers are calibrated in various temperature scales that historically have relied on various reference points and thermometric substances for definition. The most common scales are the celsius scale with the unit symbol °c (formerly called centigrade), the fahrenheit scale (°f), and the kelvin scale (k), the latter being used predominantly for scientific purposes. The kelvin is one of the seven base units in the international system of units (si). Absolute zero, i.e., zero kelvin or -273.15 °c, is the lowest point in the thermodynamic temperature scale. Experimentally, it can be approached very closely but not actually reached, as recognized in the third law of thermodynamics. It would be impossible to extract energy as heat from a body at that temperature. Temperature is important in all fields.

Employees Health

Employees' health also known as human health in the management parlance can also be affected if nitrate from polluted drinking water is ingested. Nitrate oxidizes iron in hemoglobin in red blood cells to methemoglobin. Most people convert methemoglobin back to hemoglobin fairly quickly, but infants do not convert it back as fast. This hinders the ability of the infant's blood to carry oxygen, leading to a blue or purple appearance in affected infants – a condition called methemoglobinemia, or blue baby syndrome. Low blood oxygen in adults can lead to birth defects, miscarriages, and poor general health. Nitrate has also been linked to higher rates of stomach and esophageal cancer (Bowman et al., 2000). To protect human health, the US Environmental Protection Agency (USEPA) has set maximum contaminant levels for NO_3^- and NO_2^- in drinking water at 10 and 1.0 mg l^{-1} (as N), respectively.

Human health is one of the most important factors influencing economic development in any economy. Most important and immediate consequences of environmental degradation in the world take the form of damage to human health. Economic analysis of health impacts assumes



importance in the context of market failures or distortions. This is mainly due to public good nature of the resources and the externalities associated with the resource. Environmental economics provides appropriate methods and methodologies to overcome most of these issues. Health impacts due to environmental changes are considered very important and have become integral to the assessment of development projects. Economic analysis of environmental health impacts has become critical for social cost–benefit analysis as well. Economic analysis of these impacts would provide avenues for investments for mitigating the adverse impacts. Cost–benefit analysis of projects that mitigate adverse impacts can be worked out for policy purposes.

Employees Health and Performance

Employees working in industrial environments face many Health, Safety and Environmental challenges. Managers are tasked with ensuring that employee performance is at its best, which is only possible by making sure that workers are healthy, alert, and ready to perform their roles at a high level. So much priority is placed upon Safety and Environmental stewardship that general employee health can feel like an afterthought or just not command the attention it deserves. Following are three important areas of focus for industrial managers to help keep employee Health as a priority in your company culture.

One of the most important factors in the health and safety of employees is the workplace culture cultivated by their employer. If it is clear to your employees that you value a healthy and productive workforce, they will tend to view these as important qualities, as well. Employers often underestimate just how much influence they can have in forming their workplace culture and the lives of their employees (even outside of work). Employers should encourage healthy behavior in general. This can take a variety of forms, from giving employees opportunities to express their concerns to encouraging healthy behaviors and rewarding personal health goals. Create and maintain a workplace “buzz” around health campaigns such as rewarding weight loss goals, sponsorship of company teams in local fitness events, posting and celebrating employee health accomplishments. By capitalizing on employee concerns for their own health and the health of those they work with, managers can go a long way toward ensuring that the workplace is constantly increasing in general health and associated productivity.

The most important part of this process is making sure that your employees feel comfortable expressing their health goals and keeping general health as a topic of discussion. If employees do not feel like they will be heard or worse that managers don’t want to waste energy on the health conversation, they will tend to keep quiet and the positive chatter will die down. A lack of public enthusiasm makes it increasingly difficult to improve the health of a workforce. To help make your employees more comfortable generating a buzz, make sure to give them both formal and informal opportunities to contribute. A good way to invite employee contributions is to form a “Health & Activity Committee.” Invite people who are eager to lead and zealous for the cause to lead the committee with the express purpose of generating participation from the general employee base; and don’t neglect their families.

As with Safety and Environmental compliance, proper employee training is vital to the health of employees in any workplace. Be sure to include personal health topics in your Health, Safety and Environmental training. Examples of topics that deserve attention are the impact of diet on weight control; the benefits of daily exercise routine; proper hydration; the impact of tobacco and alcohol



over time. Routinely provide health data to employees designed to encourage moving to a more healthy lifestyle. This will provide reference materials to refresh themselves on various best practices and encourage healthy choices by individuals at their own pace. Our workplaces tend to support the axiom, “hard drives out soft.” It means some hard requirements will always take priority over less pressing activities. The focus on General Employee Health tends to get pushed around by the more regulatory controlled issues of Environmental and Safety compliance. But Employee Health should be taken seriously. Employee Health has a direct correlation to business costs, productivity, safety performance, and employee engagement. A more physically fit workforce will be more productive with lower incidence of lost time.

Effects of Humidity on Human Health and Productivity

According to Quraishi, Berra and Nozari, (2020), humidity is a principal component in buildings and other environmental facilities. Humidity from the external realm has huge propensity to affect human health and productivity. This expresses why humidity requires stringent monitoring and maintenance to protect the health of humans from diseases and enhance their degree of productivity. The level of relative humidity (RH) affects individuals’ hygiene and thermal comfort and as such, an iota of dryness orchestrated by low rate of humidity encourages blood clotting which is very detrimental to human. This brings to bare that it is very critical to monitor humidity as a means of safety and safeguarding of human health and improving productivity (Memarzadeh, 2011). Accordingly, the outcome of a study by Hernandez, Berry, Wallis and Poyner (2017) provided that controlling and condensation of humidity in the building reduces cross contamination, spread of disease, and promote good hygiene for better productivity.

Effects of Temperature on Human Health and Productivity

The comprehension on how the health and productivity of human is affected by temperature has continue to dominate the center stage. According to *Blaauw, Maina and O'Connell, (2022)*, *the effect temperature of human health and productivity is in no small measure and as a result makes both human health and their productivity more susceptible based on anomalies associated with temperatures.* In corroborating the assertion above, Tan and Abdul-Samad (2022) also made known that when the degree of temperature is operating at an extreme rate, it decreases productivity and hinder health growth.

Since temperature helps us to adequately, understand the degree of coldness and warmth at every point in time in a building using Celsius and Fahrenheit as metrics for measurement. The determination of heat intensity from the purview of humidity, which tells of whether the level of air content in the atmosphere is conducive and favour or otherwise. Temperature is a very significant concept when examining the productivity rate of human including their health and safety status (Hernandez, Berry, Wallis & Poyner, 2017).

Furthermore, this will hinder progress by causing reduction in efficiency and effectiveness and finally operations could be shut down if temperatures continues to operate beyond control. To further have an understandable perception of the significant nature of temperature on health and productivity, Watts, Amann, Arnell, Ayeb-Karlsson, Belesova, Boykoff, (2019), anomalies in temperature can impede on health and productivity of man and as a result establish for both a highly adverse and vulnerable circumstances. This helps us to better comprehend that houses in



the United should follow the new realm of sustainability referred to as green building. This to a large extent can help to correct so many anomalies arising from either temperature or humidity and promoting high level of air quality.

Effects of Indoor Air Quality on Human Health and Productivity

There are considerable degree of effects of indoor air quality on human health some of which are irritation in the throat, nose and eyes. It also involves headaches which manifests in the area of fatigue, dizziness and so forth whose resultant effect if not quickly managed could bring severe respiratory diseases, in form of cancer as well as other heart related diseases (The National Institute for Occupational Safety and Health, 2013).

Indoor air quality is closely linked with health and well-being of the occupants in such environments. In corollary to the above statement, Cheung, Schiavon, Graham and Tham, (2021) affects the health and psychology of human in the following four dimensions satisfaction, comfortability and wellbeing, cognitive functionality and productivity. According to Wang, Zhang, Wang, Doyle, Hancock and Mak, (2021), indoor air quality is significantly connected with the usage of energy and efficiency of the environment of a building. Therefore, in as much as the aesthetics of a building alone is not a validation of its contributions to the enhancement of human health and productivity; then the indoor air quality remains a valid point of reference to avoid stress and ensure safety (Wang, Zhang, Wang, Doyle, Hancock and Mak, (2021).

Indoor air quality, humidity and temperature on human health and productivity: A Link

A consistent decrease in the productivity of human has been attributed to the quality of air, temperature and humidity of buildings as creating thermal comfort or otherwise. Studies in recent times have provided evidences that comfortability of occupants of a building is a strong point for validating their level of productivity and health safety. For instance, health and productivity can be enhanced by ensuring that temperatures in the room are highly comfortable and follows stipulated guidelines, in the same vein, ventilation must be increased at times above normal recommendations; all of which will allow for a reduction in indoor pollution and promote air vitality. Basically, as occupants of buildings in the United States increase ventilations, stress are reduced and productivity becomes increased Wang, Zhang, Wang, Doyle, Hancock and Mak, (2021).

According to The National Institute for Occupational Safety and Health, (2013), humidity causes a reduction in the circulation of air, which denotes that pollutants as well as other harmful particles could be trapped in the air; which further increases the risk of bacteria and viruses having around the homes. In the same way, high level of humidity can also increase the chances for breeding viruses and bacteria, which can have deleterious effects of human health, and thus lowering their productivity.

To further enhance this points, Tan and Abdul-Samad (2022) asserted that the connection between humidity and temperature as well as the formula giving reference to both opined that they are inversely proportional, meaning that, an increase in temperature leads to decreased relative humidity, therefore, the quality of air becomes dryer whereas when there is an decrease in temperature, the quality of air becomes wet which implies that relative humidity will rise.

Cognitive and work performance is optimal between 22 °C and 24 °C for regions with temperate or cold climate, but both higher and lower temperatures may deteriorate the performances and learning efficiency. Low temperature may favor virus viability, however, depending on the status



of the physiological tissue in the airways. Low indoor air humidity causes vulnerable eyes and airways from desiccation and less efficient mucociliary clearance. This causes elevation of the most common mucous membrane-related symptoms, like dry and tired eyes, which deteriorates the work performance. Epidemiological, experimental, and clinical studies support that intervention of dry indoor air conditions by humidification alleviates symptoms of dry eyes and airways, fatigue symptoms, less complaints about perceived dry air, and less compromised work performance.

Evidence has accumulated that shows that the quality of indoor environments can affect the health and productivity of adults and children. One consequence is that a movement has emerged to promote the design of schools that have fewer adverse environmental effects. To examine the potential of such design for improving education, several private organizations asked the NRC to review and assess the health and productivity benefits of green schools. This report provides an analysis of the complexity of making such a determination; and an assessment of the potential human health and performance benefits of improvements in the building envelope, indoor air quality, lighting, and acoustical quality. The report also presents an assessment of the overall building condition and student achievement, and offers an analysis of and recommendations for planning and maintaining green schools including research considerations (National Academies of Sciences, Engineering, and Medicine, 2007)

Theoretical Base of the Study

The theory underlying this paper is the endogenous growth theory by Romer, (1990). The theory was found suitable for the study based on its proponent in establishing a clear stance on nexus between indoor air quality, humidity temperature and how much significance they share with human health and productivity.

Endogenous Growth Theory

The base of this theory explained that human health and their level of productivity can be greatly influence by indoor air quality, humidity and temperature owing to the fact that human health and productivity *reflects the capacity and output of individuals from the dimension of efficiency and efficacy. Stemming from the notion of the economic labor productivity concept, no matter the dimension by which productivity is measured, primary components militating against its effectiveness are Indoor air quality, humidity and temperature; all of which must be strictly monitored and controlled (Hanna, Taylor & Sullivan, 2005).*

To further, expand the argument of this theory, Matsumoto (2019), productivity and human health under a medium temperature zone is a bit higher, this helps to validate the stance of this theory. This stance was also confirmed by Burke, Hsiang, and Miguel, (2015) whose study outcome proved that the productivity and functionality of human health are associated with indoor air quality, humidity and temperature, indoor air quality, humidity and temperature to a significant extent affects human health and productivity.



Conceptual Framework

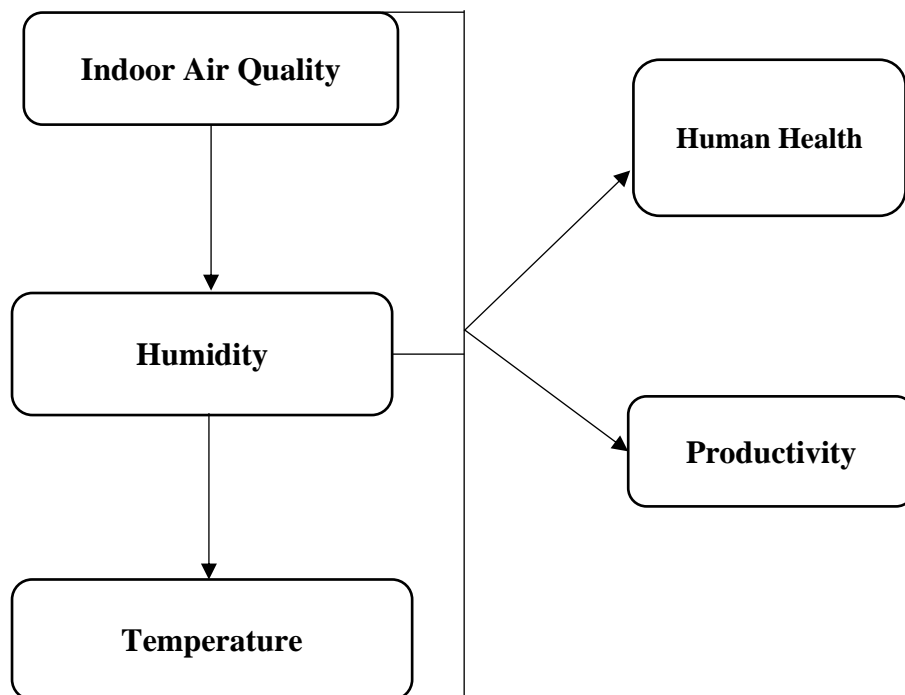


Fig I: Research Framework, (2023)

Source: Researchers Schematic Model, (2023)

In conceptualizing the above framework, indoor air quality hinged on the state of humidity and temperature has attendant consequences. This expresses why there should be a control panel that maintains the process of both humidity and temperature as failure to appropriately regulate them can heinously bring dissatisfaction and affect both human health and productivity negatively.

Conclusion

Studies have shown that human health and productivity cannot operate successfully without a touch on the quality of indoor air, humidity and temperature, indoor air quality, humidity and temperature. This is because substantial social and economic burdens are being imposed by these factors; which requires a maintenance and control mechanism to be instituted to avoid harm. This paper have assisted in properly understanding how crucial and important indoor air quality, humidity and temperature are and why their combination may be affecting your individuals’ health and productivity. Temperature and humidity represents some of the most pertinent climatological concerts which allows for the determination of the level of heat present in an object or building which defines the level and contents of moisture in the air. Based on this fact, the study concluded that the improvement of the environment lies significantly on the degree of monitoring and controlling mechanisms targeted towards an effective and cost-efficient solution in the aspect of in indoor air quality as a means for fostering adequate humidity to shape the rate temperature on the health and productivity of human.



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