ORIGINAL ARTICLE

CORRECTION OF INDOOR RELATIVE HUMIDITY IN COLD SEASON WITH A SIMPLE HUMIDIFIER

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Background: The perception of 'dry air' was correlated to mucous membrane irritation of the eyes and upper airways. Perceiving changes in relative humidity is difficult without sensory receptors for humidity in humans. **Method:** Here we have attempted to correct indoor humidity by putting a simple water container on the gas heater during cold season. A container with dimensions matching the surface of the gas heater or radiator and 15 Cm height was built from stainless steel. The role of each water container in regulating indoor relative humidity was evaluated. **Results:** An increase in indoor relative humidity could be obtained by putting a container on the radiator. However, indoor relative humidity could not be corrected by maintaining normal level ranges in every temperature condition. **Conclusion:** These two humidifier models could be used as an alternative energy-saving humidifying system in houses by adding a simple container to the current gas heater and radiators by manufactures.

Keywords: Gas Heater, Radiator, Indoor Relative Humidity, Container, Air-conditioning

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INTRODUCTION

Indoor thermal environment in the building is very important because people spend most of their time in buildings. Major factors affecting indoor thermal environment are air temperature, relative humidity, air movements and radian temperature.[1] The perception of 'dry air' was correlated to mucous membrane irritation of the eyes (e.g., dry eyes) and upper airways (sensory irritation), which is an important component in the classic 'sick building syndrome' in non-industrialised buildings.[2] Dry air has been associated with poor indoor air quality (IAQ) or a sub-standard indoor environment since the 1980s. Energy crisis in 1970s lead to maintaining indoor environment more efficiently by sealing up the building and thus less ventilation rate to save the electricity. Indoor air in buildings can be compromised by microbial contaminants (mold, bacteria), chemicals (such as carbon monoxide, formaldehyde), allergens, or any mass or energy stressor that can induce health effects. Low relative humidity (RH) may be the main risk factor related to dryness of the skin, mucous membranes, sensory irritation of the eyes and upper airways. In contrast, growth of micro-organisms and house dust mites may be associated with high RH.[3] In comparison with temperature regulation in indoor environment, regulation of RH has been noticed recently. Most people think of good air conditioning as just the control of temperature or ventilation, but there are so many people in such environment who suffer from SBS symptoms including nose irritations, stuffy or runny nose, eye irritations, cough, chest tightness, fatigue, and headache. SBS has become a common issue in Malaysia in recent years due to the construction of energy-efficient buildings with air conditioning system but poor maintenance and services of heating, ventilation and air conditioning system have resulted in increased indoor air pollutants levels.[4] Prevalence of SBS in buildings with air-conditioning system has increased from 30% to 200% when compared with natural ventilation systems. It is fair to say that indoor environment problems still exist in many air-conditioned and mechanically ventilated buildings, even though existing standards may be met.[5] Human respiratory passages are covered with a mucus layer which both moisturises the air inhaled and simultaneously traps germs and particles. The dust-laden mucus is constantly driven towards the mouth by a carpet of fine hairs. These hairs flick the mucus upwards at a speed of approximately 5 mm/min. If the mucus loses moisture it will become more viscous and would be expected to move more slowly and in extreme cases dry up completely. This dryness is noticeable in the nose and throat at low humidity and leads to discomfort. Subjects have reported dry noses when the indoor relative humidity falls to 25% RH.[6] The human airway must provide gas at core temperature and 100% RH at the alveolar surface in order to optimise gas exchange and protect lung tissue. In the early '70s about 60% of buildings failed to achieve the standard of indoor dust concentration, but this proportion has declined rapidly since late '70s. However, no improvement during the last three decades has been observed for standard RH in buildings, mainly because of the high proportion of buildings experiencing a very dry air environment during the cold winter time. In winter, air-conditioning maintenance of an adequate RH is even more difficult to attain, and as a consequence, the RH of indoor air is less than 40% in large buildings. In addition to the general problems associated with the dry air environment in buildings, specialised industries such as high-tech device manufacturers require less than 5% RH. Workers exposed to non-physiological extreme

ultra-dry environments may develop various related signs and symptoms.[7] Children spend most of their time in schools; it is the indoor environment where they spend most of their time besides in their home. It is therefore important that schools have a good indoor Air. Classroom ventilation was already recognised as an important determinant of IAQ in the beginning of the 20th century; however, even recent studies showed that classroom ventilation rates do not meet building standards. Two studies performed in the Netherlands in 2007 showed that more than 80% of the schools exceeded CO_2 levels of 1,200 ppm during classroom occupation.[8] Relative humidity affects the rate of evaporation in the air and affects the energy balance in the body and it is dependent to human thermal comfort. Relative humidity affects human thermal comfort and health.[1]

Iran is located in the north hemisphere and Zanjan province is located in north-west of Iran near the Caspian Sea and it is 320 Km away from Tehran. Zanjan city lies on a valley of the Zagros Mountains, with a present day population of 400,000. The mean statistics information in relation to different meteorological parameters of Zanjan city from 1969 until 2012 were obtained from Zanjan Meteorology Site.[9] Zanjan temperature in winter drops below -20 °C during night. Major determinants of indoor thermal environment are air temperature, relative humidity, air movements and radian temperature. Correction of humidity during cold seasons in dry area is important as temperature control. Therefore, heating devices have a pivotal role in maintaining the indoor thermal environment in cold seasons.

The objective of this study was to evaluate the effect of a simple portable humidifier by using a container on the gas heater and radiators and compare the efficacy of each on indoor relative humidity.

MATERIAL AND METHODS

Different models of heater and central heating system were used in order to provide desirable indoor environment in the building. The gas heater used in this experiment was Keyvan gas heater model KN16 with minimum heat power of 3,000 kcal/h and maximum heat power of 9,350 kcal/h. The surface plane of the heater dimension is 840 mm long and 305 mm wide. It was decided to invent a simple humidifier by using a container on the gas heater and radiator, and the efficacy of each system was evaluated. A container with dimensions matching the surface of the gas heater or radiator and 15 Cm height was built from stainless steel. The space in which this study was conducted had a ground floor and a 1st floor, and each floor area was about 120 m^2. The home had the central heating system and radiator, the temperature of ground floor was regulated by the central heating system. The sleeping rooms were on the 1st floor and in addition to the central heating system and radiators, gas heaters were used to regulate room temperature in the sleeping room.

The relative humidity (ϕ) of an air-water mixture was defined as the ratio of the partial pressure of water vapour (H_2O) (p_w) in the mixture to the saturated vapour pressure of water (p_{ws}) at a given temperature. Relative humidity is normally expressed as a percentage and was calculated by using the following equation:

$$\phi = \frac{p_w}{p_{ws}} \times 100\%$$

Climate control refers to the control of temperature and relative humidity for human comfort, health, and safety; for the technical requirements of machines and processes; and in buildings, vehicles, and other enclosed spaces.[3]

Initially, the relative humidity was measured by a hygrometer product of TFA (Germany) without using containers on the gas heater and radiator during cold season, and subsequently these containers were put on the gas heater or radiator and the relative humidity was measured again and the role of each humidifier in increasing humidity was evaluated and the efficacy of two models of humidifier in correction of indoor relative humidity were compared. We conducted this study for a long period of time (10 years) and the efficacy of these two models of humidifier was compared.

RESULTS

Various parameters of weather information in relation Zanjan meterological parameter from 1969 until 2012 are shown in Table-1 and 2. The mean relative humidity was from 1969 until 2012, the mean temperature was from 1969 until 2012, the rate of mean daily rainfall was from 1969 until 2012, the mean sunny hour/day was from 1994 until 2012, the mean number of freeze day/year was from 1969 until 2012, the mean sunny hours/day was from 1994 until 2012, the mean speed of wind was related to from 1996 until 2012.

The mean temperature during the autumn and winter from 1969 until 2012 in Zanjan were 23.5, 20.2, 14.7, 8.3, 2.2, and -1.8 °C and the absolute minimum temperature during these months were 6.6, 0, -4, -15.2, -21.6 and -25.6 °C. The mean daily rainfall during the autumn and winter months from 1969 until 2012 was 4.7, 3.6, 14.7, 32.1, 27.1, and 26.6 mm. The mean relative humidity during the autumn and winter months from 1969 until 2012 in were 42, 42, 46, 57, 65 and 68% respectively.

The temperature of central heating system in this building was adjusted between 60–75 °C. When a container with 15 Cm height and 110 Cm length and 20 Cm width was on the radiator, the rate of water evaporation was about 5–10 L/day. Without using container on the radiator the mean relative humidity was

about 15–25% in winter. After putting water container on the radiators, the mean relative humidity was rose to 25–35%. By putting the flat on the radiators, and using this model of humidifier in the ground floor, the indoor relative humidity increased by 10%. Figure-1 shows the flat on the radiator, radiator's heating energy could be used for water evaporation.

Table-1: Various parameters of weather information from 1969 until 2012 from Zanjan's meteorological stations during Jan-Jun

Parameter	Jan	Feb	Mar	Apr	May	Jun
Relative humidity (Average Max, %)	86	82	79	78	69	65
Relative humidity (Average Min, %)	52	41	32	30	23	23
Relative humidity (Average, %)	69	61	55	54	46	44
Temperature (Average Max, °C)	3.1	8.2	15.2	20.5	26.9	31.3
Temperature (Average Min, °C)	-7.1	-2.6	2.4	6.6	10.1	14
Temperature (Absolute Max, °C)	17.4	25.8	27.3	30	37	40
Temperature (Absolute Min, °C)	-28.6	-21.8	-9.8	-5	0.8	2.4
Temperature (Average, °C)	-2	2.7	8.8	13.6	18.5	22.7
Daily Rainfall (Max, mm)	40	38.7	44.2	45.6	28.4	20
Daily Rainfall (Average, mm)	29.3	36.2	47.5	52.5	16.2	7
Sunny Hours (Average, Hours)	160.9	185.2	214.9	256.2	343	355.7
Snow freeze Days (Average, Day)	26.8	21.6	9.1	0.7	0	0
Wind Speed (Max, m/S)	21	27	26	20	20	27
Vaporization (Average, mm)	---	---	---	169.8	253.7	286.9

Table-2: Various parameters of weather information from 1969 until 2012 from Zanjan's meteorological stations during Jul-Dec

Parameter	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Relative humidity (Average Max, %)	62	62	67	78	83	86	75
Relative humidity (Average Min, %)	22	22	25	37	46	52	34
Relative humidity (Average, %)	42	42	46	57	65	68	54
Temperature (Average Max, °C)	32.1	29.1	22.7	14.4	7.3	3.1	17.8
Temperature (Average Min, °C)	14.9	11.3	6.6	2.2	-2.8	-6.7	4.1
Temperature (Absolute Max, °C)	40	37	31.2	25	21.4	16.8	40
Temperature (Absolute Min, °C)	6.6	0	-4	-15.2	-21.6	-25.6	-28.6
Temperature (Average, °C)	23.5	20.2	14.7	8.3	2.2	-1.8	10.9
Daily Rainfall (Max, mm)	17.2	12.8	28.8	39	32	18.5	45.6
Daily Rainfall (Average, mm)	4.7	3.6	14.7	32.1	27.1	26.6	297.5
Sunny Hours(Average, Hours)	350.1	327.8	263.8	182.8	146.9	140.9	2928.3
Snow freeze Days (Average, Day)	0	0	1	9.3	21.7	26.8	117
Wind Speed (Max. m/S)	20	19	20	20	16	24	27
Vaporization (Average, mm)	310.1	244.9	152.2	---	---	---	1417.6

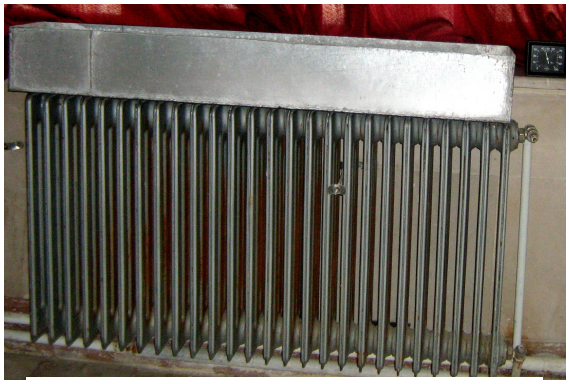

Figure-1: Container on the radiator is used for water evaporation and maintaining the desirable relative humidity

Figure-2: Container could be used for water evaporation on gas heater

DISCUSSION

Heating energy could increase or even regulate indoor relative humidity. Using gas heaters or central heating system is associated with a reduction of indoor relative humidity in winter. Without using container on the radiator, the relative humidity was about 15–25% and the relative humidity was increased to 25–35% by putting containers on the radiators. Without using the

flat on the gas heater, the relative humidity was about 10–20% and the relative humidity in the sleeping room without gas heater was 20–30%, and after using container on the gas heater, the relative humidity in the sleeping room was about 35–45% and the relative humidity in the sleeping room without was 45–55% in winter. Putting a water container on the radiator could increase the indoor relative humidity, however indoor relative humidity could not be corrected by maintaining normal level ranges in every temperature. In comparison with putting a container on the gas heater, the rate of indoor relative humidity could be corrected by maintaining normal level ranges. The vapour pressure of water depends entirely on the temperature of the water. The greater the temperature, the greater the kinetic activity of the molecules and, therefore, the greater the likelihood that the water molecules will escape from the surface of the water into the gas phase. For instance, the water vapor pressure at 0°C is 4–5 mm Hg, and at 100 °C it is 760 mm Hg. However the most important value to remember is the vapour pressure at body temperature, 47 mm Hg.[10] Attention to indoor humidity was drawn in last century. During winter without using humidifier, indoor humidity could not be regulated by maintaining indoor levels at 40–60%. In most of the Iranian houses during cold seasons no instrument regulates indoor relative humidity, in comparison during summer water cooler regulates indoor temperature and relative humidity. Different body systems have the best performance in a limited temperature and humidity. The majority of adverse health effects caused by relative humidity would be minimised by maintaining indoor levels at 40–60%. This would require humidification during winter in areas with cold winter climates. Humidification should preferably use evaporative or steam humidifiers, as cool mist humidifiers can disseminate aerosols contaminated with allergens.[11]

Here are a few features/requirements that are most important in this humidifier:

1. Auto shut-off
2. Quiet operation
3. Easy controls
4. Well-designed for easy filling
5. Permanent or cheap, accessible filters
6. Warranty (JbpReviews.com)

This two simple humidifiers are energy saving. In this simple model, heating system was used for water evaporation and correction of indoor relative humidity and there are the mentioned a few features/requirements necessary for good humidifier in our models. Humidification/dehumidification (HDH) technology is a promising process for decentralised small-scale water production applications, but it needs additional research and development to enhance the system efficacy and economy.[12]

Nasal complaints affect many visitors to high altitude. Complaints occur when sea-level residents ascend to high altitude. The human airway has an important role in heating and humidifying inspired gas, and recovering heat and moisture from expired gas.

The amount of water vapour in a gas mixture can be measured as absolute humidity (AH) or relative humidity (RH) in relation to the temperature. AH is the total water present in the gas (mg H_2O/L) and RH is the amount of water present expressed as the percentage of maximum carrying capacity at a given temperature. Nasal complaints include nasal obstruction, nasal bleeding, headache etc. It has been attributed to low atmospheric pressure, hypoxia, dry and cold weather which characterises the high altitude environment. Patients with nasal complaints often have a reduced quality of life, not only due to the symptoms, but also because of nasal disorders which can reduce sleep quality and decrease productivity at work.

Environmental humidity relieves the clinical symptoms of respiratory tract diseases. Various types of home humidifiers are available on the market. Time, energy and money spent on humidification mechanisms may be better spent on proven therapies such as steroid sprays and topical decongestants.[5] The obtained results in this study coincide with similar findings released by other researchers. In agreement with some earlier studies our study revealed that different heating systems were used for regulating indoor temperature in winter. This means the whole of water vapour in air-water mixture is reduced by increasing indoor temperature in winter. Previous work has established that indoor moisture levels are dependent on outdoor moisture loads, indoor moisture sources and ventilation rates. Studies conducted in Finland, Canada and Wisconsin have shown that heating season indoor RH levels are low, ranging between 15 and 45% with mean levels of approximately 35% .[13]

CONCLUSION

Indoor humidity should be corrected when air-conditioning. The two humidifier models are very simple and energy saving. Designing water containers for gas heater will help control humidity in the room.

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