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AN INTELLIGENT SYSTEM FOR INDOOR AIR QUALITY MANAGEMENT AND OPTIMIZATION OF AIR CONDITIONING IN BUILDINGS

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ABSTRACT

Maintaining the Indoor Air Quality in air conditioned spaces, has always been a challenging task. In a usual design approach, the fresh air is often added to the air conditioned space from the outside environment so as to dilute the concentration of carbon dioxide which otherwise may increase beyond permissible limits. The proposed concept in this paper, however, differs from this usual design approach for HVAC. In this approach, we need not take the outside air (which is generally either hotter or cooler than the inside air) but we make use of an intelligent Indoor Air Quality Management System recently invented by BUNKERMAN [1,2] to achieve this purpose. With a result, a considerable reduction in Peak Heat Load (20 to 30% approximately) is achieved as illustrated in the calculations presented in this study. The proposed approach also helps in electrical load balancing and electricity saving in a city. It also mitigates the harmful effects of the split air conditioners which lack the provisions of ensuring the desired levels of CO_2 and Oxygen in their air conditioned space. The proposed system helps in cleaning the indoor and outdoor air and in mitigation of Global Warming and Climate Change.

Keywords: Indoor Air Quality, Button Up Mode, CO_2 Removal, Oxygen Replenishment, Positive Pressure, TVOC.

I. INTRODUCTION

A. The Present Day Challenge

The world is facing a big challenge today to find a practical and efficient solution to cope up with the ill effects of rising air pollution in big cities, increase in carbon emission, global warming and climate change. Getting feared of the outside pollution in the environment, most people are preferring to stay indoors without realising that it is the indoor air which becomes more toxic than the outside environment if proper Indoor Air Quality is not maintained by proper ventilation and other arrangements. In the quest for healthier indoor environments and efficient energy consumption, the convergence of Artificial Intelligence (AI) and HVAC (Heating, Ventilation, and Air Conditioning) systems presents a promising solution. By leveraging AI algorithms, building managers can not only monitor and manage indoor air quality (IAQ) effectively but also can optimize air conditioning load, leading to significant energy savings and improved occupant comfort. This article explores the integration of AI in indoor air quality management and the optimization of air conditioning load in buildings.

In a usual design approach, the fresh air is often added to the air conditioned space from the outside environment so as to dilute the concentration of carbon dioxide which otherwise may increase beyond permissible limits. The proposed concept in this paper, however, differs from this usual design approach for HVAC. In this approach, we need not take the outside air (which is generally either hotter or cooler than the inside air) but we make use of an intelligent Indoor Air Quality Management System recently invented by BUNKERMAN [1,2] to achieve this purpose.

II. PROPOSED SYSTEM

A. The Concept

Traditionally, IAQ management relied on static rules and scheduled maintenance routines. However, these methods are often inefficient and may not address dynamic changes in air quality. This is where AI comes into play, offering real-time monitoring, analysis, and adaptive control strategies. However, the system proposed in this paper employs the following important features of AI in IAQ Management and Optimization of Air Conditioning in buildings:-

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1. **Real Time Monitoring**: AI-powered sensors have been used in the Facility Management System (FMS) designed by BUNKERMAN, which continuously monitor various IAQ parameters such as temperature, humidity, CO_2 levels, volatile organic compounds (VOCs), and particulate matter. These sensors provide a wealth of data that AI algorithms can analyze to assess IAQ conditions accurately
2. **Data Analysis and Pattern Recognition**: AI algorithms analyze the data collected from sensors to identify patterns and trends indicative of IAQ issues. The algorithm can detect anomalies in air quality, predict potential problems and take corrective actions before such problems escalate.
3. **Dynamic Control System**: AI-enabled HVAC systems can dynamically adjust ventilation rates, temperature, and humidity levels based on real-time IAQ data. By optimizing airflow and filtration, AI ensures that indoor spaces maintain optimal air quality while minimizing energy consumption.
4. **Fault Detection and Diagnostics**: AI algorithms can detect faults or inefficiencies in HVAC systems, such as malfunctioning sensors, clogged filters, or duct leaks. Early detection allows for timely maintenance and prevents IAQ degradation.

B. Air Quality Index (AQI)

The National Air Quality Index (IAQ) adopted in India and most of the other countries takes care of only 8 types of pollutants in air i.e. PM2.5, PM10, Nitrogen Dioxide (NO_2), Carbon Monoxide (CO), Sulfur Dioxide (SO_2), Ground Level Ozone (O_3), Ammonia (NH_3) and Lead (Pb). It does not measure and accounts for the contents of CO_2 and other harmful gases like Methane, Formaldehyde, foul or undesirable odour from human perspiration, toilets, kitchens and other sources etc. These are generally described in a single factor termed as Total Volatile Organic Compounds (TVOC). AQI also does not give any indication whether the desired level of oxygen is present in the air or not. Therefore, it becomes necessary to monitor various air pollutants and toxic gases in a building by installing AI based sensors and monitoring systems to ensure the desired levels of AQI for human health, safety and comfortable living conditions inside the buildings.

C. Normal and Button Up Modes

Also in actual practice, the situations may arise where it may not be possible to use the air from outside environment for maintaining the Indoor Air Quality and as a supplement of oxygen and controlling the levels of CO_2 and other harmful gases in the indoor environment. Such situations are mainly faced in Spacecrafts, Submarines, Nuclear Bunkers, Emergency Shelters and other such facilities which are required to operate in Button Up or Filtration Modes. In such situations, in addition to the AQI, it becomes necessary to monitor the levels of CO_2, Oxygen, TVOC and other toxic and harmful contents including Nuclear, Biological and Chemical (NBC) Warfare Agents suspected to be present in the air. The approach presented in this study facilitates and provides an efficient and practical solution under such circumstances. The BUNKERMAN system proposed such facilities comprises of following sub systems:-

(a) CO_2 Removal System.

(b) Odour/TVOC Removal System

(c) Oxygen Replenishment System.

(d) NBC Filtration System.

(e) Compressed Air System

(f) Facility Management System.

The proposed HVAC System for buildings for civil population may be used in the following two modes of operation i.e. Normal Mode and Button Up Mode.

Normal Mode

This mode is used under normal conditions when the outside air is having only normal type of air pollution and it is not contaminated by any Biological, Chemical or Radiological contaminant. In this mode of operation only CO_2 Removal System should suffice to be integrated with the HVAC System for most of the buildings. However, TVOC Removal System and Oxygen Replenishment System may also be added for integration, wherever felt necessary in such buildings. The method of integration are illustrated in Figures 1and 2 below.

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Button Up Mode

A Button Up Mode or Period is defined as a period in a habitat during which no outdoor air is permitted to be used for human inhalation (being contaminated). In such a situation, the occupants of the habitat, have to survive only on the available indoor air with some additional provisions for Indoor Air Quality Management which becomes necessary for the safe survival of the occupants. Such situations may arise even for civil population in times of any pandemic like corona or in case of any threat of Biological, Chemical or Nuclear attack.

Under Button Up Conditions, the following six sub systems which are duly integrated with one another, may be necessary for the civil population:-

(a) CO_2 Removal System.

(b) Odour/TVOC Removal System

(c) Oxygen Replenishment System.

(d) Compressed Air System

(e) Facility Management System.

D. AI Based Facility Management System (FMS)

All the above five systems are required to operate not independently but in coordination with one another so as to always maintain the desired CO_2, TVOC, Oxygen and Pressure levels in the facility for human inhalation and not to allow any inward leakage of contaminated air from outside environment by maintaining a positive pressure inside the facility. This is achieved by installing AI based sensors and algorithms to record and analyse the indoor air environment and to take necessary actions automatically by the systems to ensure the desired levels of safety, survival and healthy life. The typical arrangements under such conditions are shown in Figures 1 and 2 below.

Figure 1: AI Based Facility Management System (FMS) by BUNKERMAN

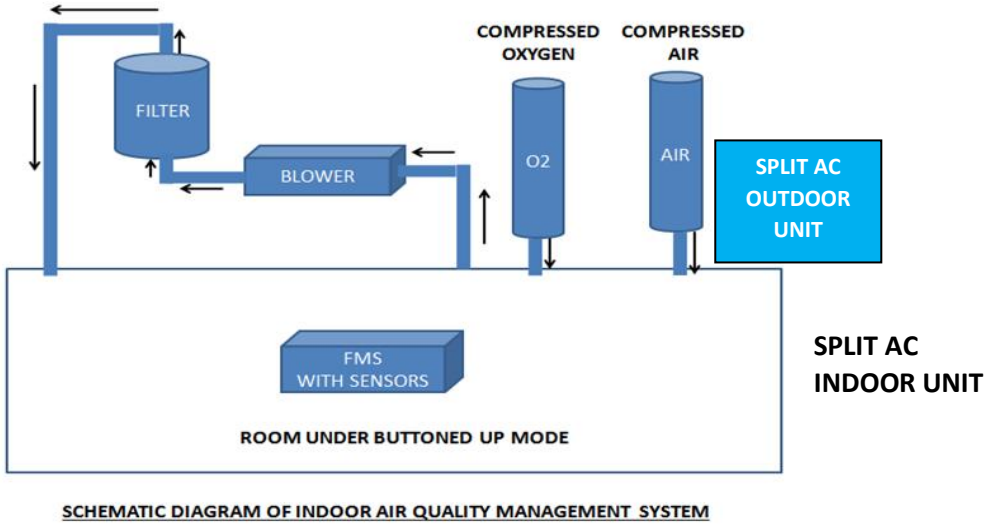

Figure 2: Typical Arrangements of AI Based CO_2 Removal System Integrated with HVAC System in Button Up Mode

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E. Mitigation of Pollution, Climate Change & Global Warming

In addition to providing the clean and healthy air to our citizens with this indigenous technology, we can also eradicate the problem of rising pollution, climate change and global warming permanently from the entire world. The Bunkerman filters manufactured with this technology absorb/adsorb the CO_2, toxic gases and other pollutants from the air and once saturated, the waste material of these filters is used to manufacture Minerals Rich Organic Manure (MROM).which provides nutrients to our crops, trees and plants [13, 14, 15]. Thus the proposed system works as a sustainable ecological system in conjunction with nature where the trees and plants provide us food and oxygen and whatever CO_2 and other pollution we (human beings, live stocks and industries) create in the environment, it is converted into MROM and returns back to our crops, trees and plants as their nutrients. The proposed system, therefore, ensures a sustainable coexistence of human beings, live stocks, trees and plants in the nature on the planet earth. The process diagram of the system is explained in Figure 3 below. The two models of the system which can be used in houses and offices are shown in Figs 4 and 5 below.

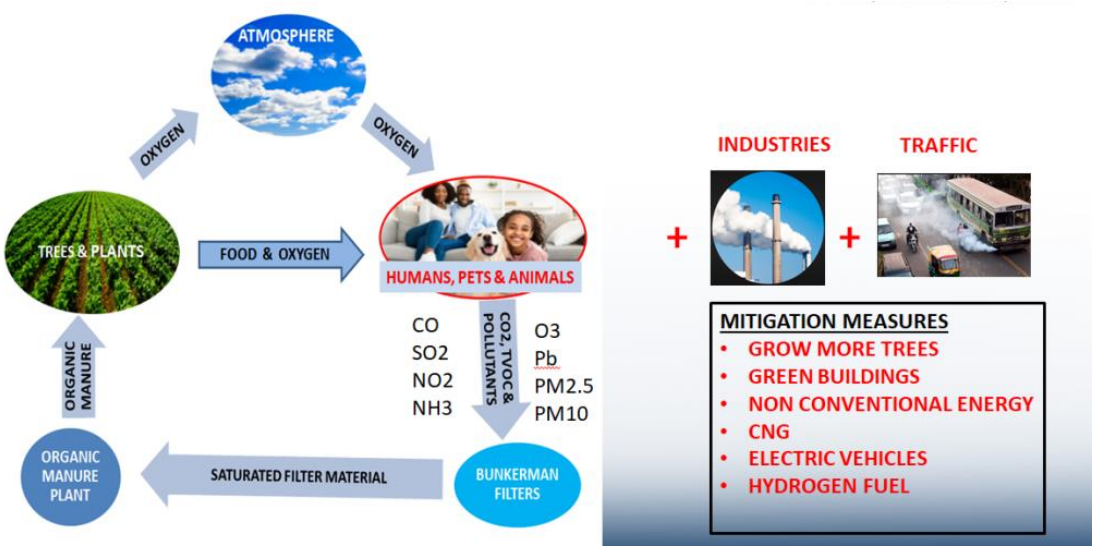

Figure 3: Sustainable Eco System Adopted by BUNKERMAN

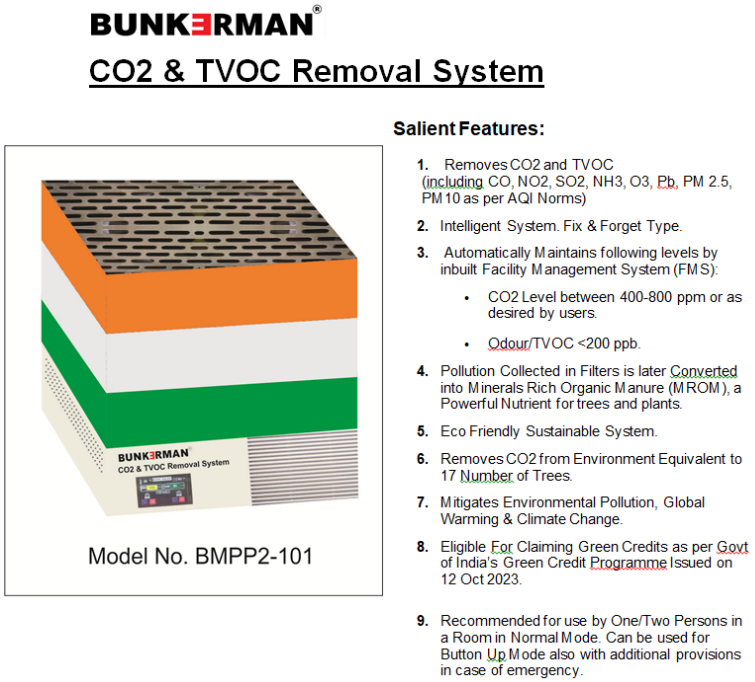

Figure 4: AI Based CO_2 & TVOC Removal System by BUNKERMAN (Model No BMPP2-101)

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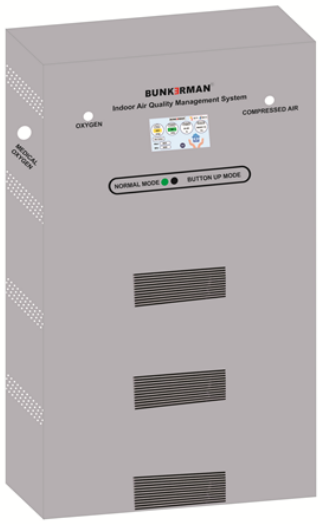
BUNKERMAN®

Indoor Air Quality Management System



Model No. BMPP2-102

Salient Features:

1. Removes CO2 and TVOC (including CO, NO2, SO2, NH3, O3, Pb, PM 2.5, PM 10 as per AQI Norms).
2. Provides Oxygen Replenishment.
3. Maintains Positive Pressure in the room.
4. Can be used in Normal Mode or Button Up Mode as desired by Users.
5. Intelligent System. Fix & Forget Type.
6. Automatically Maintains following Levels by inbuilt Facility Management System (FMS):
   - CO2 Level between 400-800 ppm or as desired by users.
   - Odour/TVOC <200 ppb.
   - Oxygen Level between 17-21% or as desired by users.
   - Positive Pressure Level as desired by users.
7. Provides Medical Oxygen to Patients in case of Emergency.
8. Pollution Collected in Filters is later Converted into Minerals Rich Organic Manure (MROM), a Powerful Nutrient for trees and plants.
9. Eco Friendly Sustainable System.
10. Removes CO2 from Environment Equivalent to 51 Number of Trees.
11. Mitigates Environmental Pollution, Global Warming & Climate Change.
12. Eligible For Claiming Green Credits as per Govt of India's Green Credit Programme Issued on 12 Oct 2023.
13. Recommended for Use by 2 to 4 Persons in Normal Mode and 2 Persons in Button Up Mode in a Room.

Figure 5: AI Based Indoor Air Quality Management System by BUNKERMAN (Model No BMPP2-102)

III. RESULTS AND DISCUSSION

A. The Integrated System

The integrated system in which the above five sub systems are integrated with HVAC system, will have the following advantages:-

(a) The outdoor air is not required to be taken into the ventilation system on continuous basis, without compromising the ASHRAE and ISHRAE mandates.

(b) The inbuilt Facility Management System (FMS) automatically controls the indoor climate by ensuring the desired levels of oxygen, CO_2, Positive Pressure and TVOC as per laid down standards and required by the users; and eliminating other harmful gases, if so required.

(c) It also reduces the heat load of HVAC building substantially to save capital cost, power and space of the building.

(d) This technology is specially useful in buildings like Emergency Isolation Rooms and other rooms in the hospital, Apartments, Institutes, PUBs, Restaurant, Hotel, Bunker, Tunnel, Submarine, Mines, Cinema hall/Theatre, Community halls etc.

(e) In case of any virus suspected in air like Corona or in case of any Nuclear, Biological or Chemical (NBC) environment suspected or encountered outside, the building or facility can immediately be switched on to the Button Up Mode to safeguard the life of the people inside.

(f) Monitor the Dry Bulb Temperature and Relative Humidity inside the room.

B. Reduction Achieved in HVAC Load of the Building

The calculations of heat loads in a typical building (ICU of a Hospital) under the two conditions (one with normal design with fresh air change and another with CO_2 Removal System without using any air change) for three different stations, are compared in Table 1 below. It may be concluded from this comparison that an saving of approx 20 to 30 % in Peak Heat Load can be achieved for air conditioning if we combine the proposed CO_2 Removal System with the air conditioning plant and dispense away the current design concept of adding

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fresh air of a higher or lower temperature into the air-conditioned space. the expenditure of electricity consumed by the small fan unit of the CO_2 Removal system is almost negligible as compared to the electricity consumption of the air conditioning plant. Therefore, following important conclusion can be made by this comparison:-

(a) The current procedure of air changes requiring addition of the fresh air from outside environment may be totally dispensed away. The outside air is generally either at a higher or a lower temperature than inside air and it is also generally more contaminated than the inside air; and it therefore, unnecessarily adds to the extra heat load and the contamination to the inside environment.

(a) A saving of approx 20 % to 30 % can be achieved in Peak Heat Load for the HVAC system by integrating or combining the above proposed CO_2 Removal System and other sub systems with the air conditioning system in a building.

Table 1: Comparison of Estimated Heat Load

ESTIMATED HEAT LOAD COMPARISION												
SL NO	LOCATION	ODU TEMP	ODU TEMP	Area-ICU room	ESTIMATED HEAT LOAD WITH FRESH AIR AS PER STANADRD		ESTIMATED HEAT LOAD WITH CO2-REMOVAL SYSTEM		HEAT LOAD DIFFERENCE WITH CO2-REMOVAL SYSTEM		%REDUCTION IN PEAK HEAT LOAD WITH CO2-REMOVAL SYSTEM.	
		SUMMER	MONSOON		SUMMER	MONSOON	SUMMER	MONSOON	SUMMER	MONSOON	SUMMER	MONSOON
		DEG C/% RH	DEG C/% RH		TR	TR	TR	TR	TR	TR		Peak Heat Load
						Peak Ht Load		Peak Ht Load		Peak Ht load reduction		% Peak Ht load reduction
1	DELHI	43.3/20%	35/60%	1400sqft,ht 3.5m height with underdeck Insulation-15 Patients.	8.56	9.47	7.51	7.51	1.05	1.96	12.3%	20.7%
2	MUMBAI	35/60%	29.4/88%		7.25	7.3	5.39	5.39	1.86	1.91	25.7%	26.2%
3	GUWAHATI	34.6/51.2%	31.3/81.7%		6.73	7.31	5.31	5.31	1.42	2.00	21.1%	27.4%
4	Peak Heat Load reduction range											20-30%

IV. CONCLUSION

A. Peak Load Reduction

The calculations of heat loads in the examples explained above, clearly explains that a saving of approx 20 to 30 % in Peak Heat Load can be achieved for air conditioning if we combine the proposed CO_2 Removal System with the air conditioning plant and dispense away the current design concept of adding fresh air of a higher or lower temperature into the air-conditioned space. The expenditure of electricity consumed by the small fan unit of the CO_2 Removal system is almost negligible as compared to the electricity consumption of the air conditioning plant.

B. Electric Load Balancing

A great advantage of the above heat load reduction concept is that this can be used in balancing the peak load and the normal load in a day. The climatic conditions in India are such that the average air conditioning load in a day is generally low during morning and evening hours and it generally peaks up in the afternoon hours say approximately around 3 pm to 5 pm, particularly so during summer and monsoon seasons. With a result, in many cities particularly industrial cities, the electricity department has to resort to a compulsory shut down in some areas during such peak hours. It is at such peak hours that the use of CO_2 Removal System can be made compulsory during such peak hours to reduce the AC load and balance of the time CO_2 Removal System may be switched off and outdoor may be taken into the HVAC System to compensate for the reduced levels of oxygen and increased CO_2 concentration inside the rooms. Thus the CO_2 Removal System and Oxygen Replacement Systems can be used to effectively achieve such type of load balancing during the day.

C. Split Air Conditioners: The Silent Killers

The Split Air Conditioners generally used in India and other countries, only cool and circulate the air inside the rooms without having any provisions of supplying fresh air to the room. With a result, in most of the cases, the CO_2 levels in such rooms goes down below the permissible limits of 800 ppm and the oxygen level may also decrease below permissible value of 17 %. Such situations are very dangerous and these are certainly a health hazard for the occupants. It has a sort of slow poisoning effect on the occupants of the room. Therefore, it is recommended that it should be made compulsory to provide a suitable CO_2 Removal System and Oxygen Replenishment System if Split Air Conditioners are used in a building or a room. In addition to issuing suitable

guideline by ISHRAE and ASHRAE in this respect, the concerned Govt authorities should be approached to make a law by legislation in this respect in the interest of safety and health of its general public.

D. Mitigation of Global Warming and Climate Change

In addition to the advantage of ensuring clean and healthy indoor environment inside the buildings, the proposed system in this study also helps in cleaning the outdoor environment and thus helps in mitigation of Global Warming and Climate Change. The system is therefore, recommended to be implemented throughout the world based on the Indian philosophy of "Vasudhaiv Kutumbakam" so that the problem of Global Warming and Climate Change may be eliminated from the entire world.

E. Integration of AI

The integration of AI in indoor air quality management and air conditioning optimization represents a paradigm shift in building automation. By harnessing the power of AI algorithms, building managers can create healthier indoor environments, minimize energy consumption, and reduce operating costs.

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