Development and integration of oxygen generator for home air conditioner

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Abstract. An Oxygen Generator is developed to interface with Home Air Conditioner that
serves for Home Oxygen Therapy & it is controlled by a Microcontroller which is connected to
an IoT app through which users can monitor and control the whole system. Oxygen levels are
to be maintained as per OSHA cited acceptable levels. For generating oxygen we are using
Pressure Swing Adsorption Technique with two bed molecular sieve columns with Zeolite
filled inside in it which acts as a Filtering component of Nitrogen. When a Pressurized air is
passed through the Zeolite it filters out Nitrogen (due to its chemical nature Nitrogen molecules
gets trapped inside its pores) and allows rest of the Air components pass through it so that we
can get oxygen enriched air at the outlet and it is given to home.

1. Introduction
Air is a mixture of several gases. Out of which majority of the gas components in Air are Nitrogen of
78% and Oxygen of 20.9% and rest are some other gases like Carbon di oxide, Argon, Hydrogen and
many other. In recent days Air Pollution is increased due to increase in Industries which releases
harmful gases, heavy usage of Automobiles also leads to air pollution. Due to this Pollution particulate
matter increases in air and Oxygen levels may decrease and causes Respiratory problems. People with
Chronic Obstructive Pulmonary Disease (COPD) and people living in highly polluted cities like
Kanpur, Faridabad, Delhi faces problem in breathing that restricts Lungs to Oxygenate Blood. Due to
this they have severe effects on their health issues like Cardiopulmonary related, Hemodynamic,
Neuropsychological and soon. So, they are recommended to have Long Term Oxygen Therapy
(LTOT), People use Oxygen cylinders which restricts them from work and makes them dependable
and more expensive and needs to take care of it as there maybe chance of exploding or catching of fire.
So, here we are going develop and interfacing an air filtering unit for Home Air Conditioner. So that
we can filter out Nitrogen from Ambient Air and gets Oxygen enriched air inside the room. So that the
filtering unit serves as an artificial Lungs. The air inside the room is enriched with Oxygen which
serves for LTOT. And mostly this LTOT is achieved by monitoring Indoor Air Quality.

Nowadays people spent most of their time inside highly populated closed environments like offices,
schools, colleges, theatres, shopping malls which results in increase in pollutants like carbon dioxide
and carbon monoxide causes breathing problems and Cardio Pulmonary diseases. So we need a system
that manages the air inside the indoor environment. Such system should maintain the levels of the
gases at their normal or acceptable levels and it is called as Indoor Air Quality management system.
IAQ keeps on tracking the levels of the gases inside the environment either they are harmful gases
(CO, CO2, CH4) or life essential (Oxygen) and alerts people as per the levels of the gases
2. Literature Survey

The conditions of falling down of partial oxygen pressure (PaO$_2$) in arterial blood below 60mm of Hg and increasing of carbon di oxide in arterial blood at sea level are called Hypoxemic and hypercapnic respiratory failure which results in COPD. COPD prevalence is high about 7% of the population out of 1% is severe.

Gas cylinders have their own backdrops like frequent replacement, two days of maximum duration, should not be stored near heat or flame. Oxygen have drawbacks like noise, power consumption and maintenance. Due to temperature differences inside and outside of the tank Liquid oxygen cylinder gets empty after few days.

General criteria for LTOT, recommendations for patients receiving LTOT and National Guidelines for the countries are clearly explained in Reference Paper 1. A luggage bag sized rechargeable/removable battery operated portable oxygen concentrator with alerting system for medical purposes which uses ambient air with controllable flow rates is designed with two molecular sieve beds inside with synthetic zeolite filled to filter air by pressure swing adsorption, which will last for minimum 8hrs at normal flow rates. [2]. An electronic operated hand bag sized portable $O_2$ generator which last for minimum 30 minutes is designed with weight less than 10kg and with the oxygen levels 50-95%.[3]. Adsorption and desorption characteristics of air on different types of zeolites have been observed with simulation adsorption dynamics using Langmuir-Freundlich model. RPSA, VSA are the advancements in PSA. PSA process is applied on different forms of Zeolite like 5A, 10X, 13X, at different atmospheric pressures of 3, 4.5, 6 for and compared all the test results of each type and dawn comparative characterizes of equilibrium isotherms, time versus oxygen concentration, Feed flow rate versus Breakthrough time. [4]. Several Oxygen concentration techniques are available like Cryogenic technique, Membrane separation Distillation, Pressure Swing Adsorption, Temperature Swing Adsorption. Cryogenic distillation technique is leading and is used to serve for industrial needs but it consumes much power. PSA has the advantage of small scale productions with less energy consumption. Whereas membrane separation needs high pressure and selective permeable materials. So, PSA has more feasible characteristics for portable oxygen concentrator.

Electrostatic field between cationic zeolite and the quadruple nature of nitrogen is responsible for adsorbing nitrogen over oxygen, as the quadruple nature of nitrogen is 3X times than oxygen which results to selective nitrogen adsorption. The concentrator is tested with pressure between -.82 to 1.79 barg, with an output flow rate of 1.128L/min with an average oxygen concentration peak of 91.64%. They had observed that after 300cycles of usage the concentration had been fallen to 80%. Here they have studied two types of inflow inlets whereas a) central flow without inlet distributor; b) distributed flow with inlet distributor. They have observed that the 1) time for pressurization in central flow is 1.6s more than that of distributed flow. 2) Distributed inlet is inflow significant but pressurization time for the adsorption cycle gets decreases. [5]. Temperature swing adsorption (TSA) is more complicated because changes in temperature can take much time and most of the electronic devices are not able to tolerate much temperature and cycle time is more. In other hand PSA, the changes in pressure can be achieved more rapidly and cycle time is in minutes in TSA it takes hours.

Here they conducted the test with 5A compound in two columns. They have studied purity variations of oxygen versus time at different pressures from 1bar to 6 bar for 16minutes of operating time cycle of each pressure. They have found that they at 4bar pressure they got optimum level of oxygen of 76.9% after 4minutes of operation. They have estimated that the cost of the portable oxygen concentrator they have designed is $4200 with weight 75kg. [6]. Mathematical modelling has been developed for two step Pulsed PSA (PPSA) and the process performance was analysed in COMSOL Multiphysics software together with Matlab. Through the simulation results they found that depressurization time is more than pressurization in both 5A and Ag-Li-X zeolites. [7]. Skarstrom cycle was optimized with different equalization techniques, they have followed top-top equalization (TE), bottom-bottom equalization (BE), cross equalization (CE), with different adsorbents oxysiv5, oxysiv7 and MS S 624.
Out of which top top-to-top equalization is the best configuration and oxysiv7 is a best adsorbent with high flow rate. [9]. Pressure swing adsorption (PSA) for separation of air varies for different operational modes of adsorption, desorption and the complementary steps, filtering adsorbent utilized. Three commercial PSA processes for separation of air were reviewed and compared. Zeolite enriches oxygen only in the first process, and simultaneously produces both nitrogen and oxygen in the third process. Whereas in the second process carbon molecular sieve is used for nitrogen generation. The performance and separation efficiency of third process, called the “vacuum swing adsorption (VSA) process,” is reported to be efficient to the others. [10].

3. Methodology

3.1. Proposed work
A sensor circuit is used to monitor the gases in the indoor air. The microcontroller contains an ADC which converts the voltage output of the sensor circuit at appropriate time. Various gas sensors are interfaced to Arduino board to measure the level of pollutants present in indoor air and exhale the pollutants through exhaust outlet and to maintain oxygen at desired level. A particular output level for the gas is set in the controller. If the measured level of $O_2$ goes below the set value, this output is used to maintain the oxygen level and is pumped through electrolysis. Thus the oxygen from electrolysis produces required amount of oxygen in the building which the occupants can inhale. If the temperature goes above desired level ventilating system will ON.

A sensory circuit with a microcontroller is used for monitoring the air quality in indoor environment. Microcontroller reads the data from the sensors and if they are above the levels pollutants are purged out through the exhaust outlet. If the sensor reads the oxygen levels below the desired value it turns on the device to generate oxygen enriched air through Pressure Swing Adsorption.

3.2. Block Diagram of Smart IAQ Management
Basically it contains sensors module which consists of CO, CO2, CH4, O2, Temperature and Humidity to read the gas levels and keep Temperature levels inside the environment. A control module is having a preprogramed microcontroller which reads the data from the sensors and takes necessary action. Ventilation control system is there for intake of fresh air or purging out air inside. Oxygen generator generates the oxygen enriched air if the levels of oxygen falls down by the minimum values. A power module is there to provide necessary power for the working of ventilation control system and Oxygen generator.
Figure 1. Block Diagram of Smart IAQ Management.

Figure 2. Proposed Prototype Schematic Model.
3.3. Generation of Oxygen

For the generation of oxygen we are using Pressure Swing Adsorption Technique with two Zeolite filters which are semi continuously fed with pressurized air feed with help of 5 ports 2 way operated Direction Control Valve (5 ports::1 inlet, 2,3 outlets, 4,5 Vents). When pressurized air is passed through Zeolite due to its chemical nature and atomic structure Nitrogen gets attracted and trapped inside the micro pores of the Zeolite, only Oxygen and rest of the air constituents pass through it so that we can collect Oxygen enriched air collected at the outlet of the filtering device. While Filter1 filters the air, Filter2 purges out nitrogen through vent as we blocked its outlet with an On/Off DCV. Like this the system generates in vice versa until it generates the oxygen levels are reached to acceptable levels and after that it is turned off through pre-programmed micro controller with the help of sensor readings. Oxygen generation flow is as follows in two steps

Step1: Air feed → first inlet of 5/2 → first outlet of 5/2 → filter1 → CHV1
Step2: Air feed → second inlet of 5/2 → second outlet of 5/2 → filter2 → CHV2

Figure 3. Block Diagram of Oxygen Generation.
4. **Hardware implementation:**
Implementation of the Oxygen Generator is shown in the following figure. A 5/2 DCV, two normally closed pneumatic valves and an air compressor is connected to a 4 channel relay module for switching them on and off with micro controller which receives the percentage and PPM levels of the gases from sensors. All the five sensors are connected to micro controller so that the micro controller can read the data from sensors and takes necessary action.

**Working:**
When the control module is powered ON with a supply of 5V, all the sensors interfaced to Arduino board get turns ON and threshold values are defined for every gas. Whenever the CO, CO₂ and CH₄ reaches threshold value, the ventilator which is connected through a relay to arduino pin 13 gets turned ON. Similarly when the temperature reaches its threshold value the cooler connected through a relay to arduino pin 9 gets turned ON. When oxygen content is low, it can be pumped through the Oxygen Generator by the Pressure Swing Adsorption Process. The results can be displayed through serial Monitor in the Arduino IDE.

![Two bed Molecular Sieve Oxygen Generator](image)

**Figure 4.** Two bed Molecular Sieve Oxygen Generator.
Figure 5. Sensor’s Module.

Figure 6. Design of smart indoor air quality management system.
5. Results and Discussion

5.1.1 Bed Room

- **Result**: CO (421-480ppm), CH4 (482-510ppm), Temp (31°C), Hum (52%), CO2 (132-138ppm), O2 (15.92-16.09%)

- **Inference**: In this Bedroom test the CO and CH4 levels are in abnormal range, other parameters (Temp, Hum, O2, CO2) concentrations are in between normal range.

![Test Result in Bed Room.](image)

5.1.2 Classroom

- **Result**: CO (145-146ppm), CH4 (282-284ppm), Temp (34°C), Hum (43%), CO2 (87-88ppm), O2 (14.09%)

- **Inference**: In this Classroom test all the parameters (Temp, Hum, O2, CO2, CO, CH4) concentrations are in between normal range.
5.1.3 Java

- **Result**: CO (252-266ppm), CH4 (295-348ppm), Temp (34°C), Hum (46%), CO2 (84-86ppm), O2 (14.77%)

- **Inference**: In this Java test all the parameters (Temp, Hum, O2, CO2, CO, CH4) concentrations are in between normal range.

![COM10](image)

**Figure 8.** Test Result in Classroom.
5.1.4 Juice Shop

- **Result**: CO (178-180ppm), CH4 (280-282ppm), Temp (33°C), Hum (27%), CO2 (115-117ppm), O2 (15.75%)
- **Inference**: In this Juice Shop test all the parameters (Temp, Hum, O2, CO2, CO, CH4) concentrations are in between normal range.
5.1.5 **Play Ground:**
- **Result**: CO (219-222ppm), CH4 (277-280ppm), Temp (38°C), Hum (16%), CO2 (104-109ppm), O2 (15.82%)
- **Inference**: In this Play Ground test the Temperature is above normal range and Humidity is below the normal range, other parameters (CO, CH4, O2, CO2) concentrations are in between normal range.

![Figure 11. Test Result in Play Ground.](image)

5.1.6 **Market**
- **Result**: CO (192-220ppm), CH4 (276-301ppm), Temp (39°C), Hum (15%), CO2 (104-106ppm), O2 (15.95%)
- **Inference**: In this Market test the Temperature is above normal range and Humidity is below the normal range, other parameters (CO, CH4, O2, and CO2) concentrations are in between normal range.
6. Conclusion
Smart Indoor Air Quality (IAQ) management system is to maintain IAQ for commercial and residential building along with oxygen generator was developed. The system proposed could not only monitor the indoor air quality, but also auto-control if the quality is poor, which is a high performance indoor environment control system using Arduino UNO board. Major indoor air pollutants such as CO, CO₂, CH₄, temperature and O₂ level are monitored using discrete sensors MQ7, MG811, MQ4, DHT11 and ME2-O2 sensors respectively. Firmware is loaded in ATmega328p microcontroller, to monitor the air contamination level using signal from various sensor and generate control signal to the ventilation and oxygen flow control system. It is seen that the concentration of gases in air increases drastically even with a small amount of the pollutants in air. So considerations have to be taken to eliminate such pollutants so as to lead a healthy life.

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