Review paper:

Reduced oxygen partial pressure in air: critical to diabetes and other health problems

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Abstract

Any fuel combustion for transportations, industries etc. needs huge amount of oxygen which is taken from air and besides this also generates other by product pollutant gases which contribute to decrease the partial pressure of oxygen in air. When the consumer of oxygen increases many fold than the oxygen produced by the producer, he suffers from lowering partial pressure of oxygen in the atmosphere. Crowded cities with scanty plantations, traffic jam places etc. will be affected by low partial pressure of oxygen in air.

Continuous combustion processes, combustion by-product pollutants and low partial pressure of oxygen are of great concern to health. The lower partial pressure of oxygen certainly will have impact on diabetes and other health problems.

Key words: Fuel combustions, pollutant gases, low partial pressure of O_2, impact on diabetes, health problems.

Introduction

Air is very essential to human beings, animals and living bodies. Air with requisite quantity of oxygen in it is most essential to all lives for their activities. Oxygen is required to produce energy in the body for all living bodies for their activities such as movements, respirations, heart beats, working maintenance and other activities. Nature has created air with different compositions of gases in it in order to maintain environmental and ecological balance. Nature's clean air contains around 20.9% oxygen. All animals consume requisite quantity of oxygen to produce energy for their sustenance and give out CO_2 and H_2O whereas plants and vegetation consume CO_2 and H_2O to produce starch for them giving out O_2. So, there is a symbiosis between plants and animals.

Plants are the producer of O_2 and animals are the consumers. These producers and consumers of O_2 are maintaining the ecological balance. Besides these there are other activities going on continuously such as transportations, production of steel, plastics, textiles, brazing, welding, cutting metals, rocket propellants, oxygen therapy, life support in air crafts, submarines etc. But what will happen if the consumers are more than the producers? This will result in an imbalance in consumers and producers of O_2 resulting in lowering the oxygen partial pressure in air. Human activities are increasing day by day such as transportations running on fossil fuels, industrial combustion processes, defence combustion activities, other combustion processes etc. Many of these activities consume huge amount of oxygen from air and also generate unwanted gases in the atmosphere.

The burning processes to sustain require O_2 from air also generate pollutant gases. For example, transportation which runs on fossil fuels every day, consumes large quantity of atmospheric oxygen during combustion processes and it is estimated that around 2.4 kg of O_2 is required per litre of petrol combustion in automobiles[12]. Everyday millions of litres of petrol and diesel are used in transportation consuming enormous amount of oxygen from air and produce pollutant gases such as CO, CO_2, NO_x, unburned hydrocarbons etc.

The extensive literature is available on heat release rate by oxygen consumption in the atmosphere[1,5,8,9,14]. Producer of oxygen has remained same whereas consumers have increased many folds as a result there is a drop of partial pressure of O_2 in air. Besides this, the generation of other pollutants gases will fuel further reduction of O_2 partial pressure in air[3,7]. According to WHO, the number of people with diabetes rose from 108 million in 1980 to 422 million in 2014. The global prevalence of diabetes among adults over 18 years of age rose from 4.7% in 1980 to 8.5% in 2014. In 2016, an estimated 1.6 million deaths were directly caused by diabetes and it was estimated that diabetes was the seventh leading cause of death in 2016 and a major risk factor for other life threatening conditions[4,6,10].

Role of oxygen

As we know that O_2 is metabolised in the body, it has to reversibly take up from air and transport to O_2 requiring tissues and organs, where it is used. The role of Fe in haemoglobin (Hb) for carrier of O_2 is very important. About 65% of Fe in human body is used for O_2 transport in the form of oxy-haemoglobin and nearly 6% of Fe is present in the form of myoglobin. Haemoglobin binds O_2 at lungs and then arteries carry blood to different parts of the body where O_2 is required. Then O_2 is transferred to myoglobin (Mb) molecule where it is stored until it is required for biological process. After O_2 removal from Hb, its position is occupied by H_2O molecule and then absorbs H^+ ions. This helps in removal of CO_2 from tissues.

During cellular respiration, sugar is broken down to CO_2 and H_2O and in the process ATP is made that can be used for cellular work as energy shown below in equation (1):

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \sim 38\, ATP\ (energy) \qquad (1)$$

Sugar ($C_6H_{12}O_6$) is oxidised to CO_2 and H_2O releasing energy (ATP) in the process. All activities of the body require energy in the form of ATP. Quite a bit of O_2 is required for this process. The sugar and O_2 are delivered to cells through blood stream. This process takes place partially in the cytoplasm and partially in mitochondria.

Impact of human activities: Human activities have increased exponentially like various combustion processes, industrial combustions, transportations, space research etc. which consume tremendous amount of oxygen from atmospheric air, also giving out other pollutant gases, as a result decreasing partial pressure of O_2 from air.

According to Dalton's theory of partial pressure, the total atmospheric pressure involved by a mixture of gases present is equal to the sum of the partial pressures of the individual gases in the mixture. Humans have fixed breathing rate and in that volume of air, oxygen partial pressure is low, obviously the supply of O_2 to blood will be low or insufficient O_2 for complete oxidation of sugar in the blood.

The O_2 intake in the respiration process achieves lesser amount and this has an impact in sugar oxidation in the blood. The un-oxidised sugar builds up in the blood and excess sugar may be extracted out through urinary process. The number of diabetes is increasing day by day besides hereditary causes. The environmental factors play a deteriorated role in diabetes.

Another impact is the generation of pollutant gases such as NO and CO which are present in transportation exhausts environments running on fossil fuels. Crowded cities with scanty plantations and traffic jam places are bound to show lower partial pressure of oxygen in air. Besides nature's requirements such as respiration processes in lives, high dissolution of O_2 in sea, rivers to sustain aquatic lives and bio-degradation processes etc. many other activities of men are consuming O_2 highly from air.

Reduced oxygen partial pressure

In low partial pressure with lower concentration of O_2, a partial break down of sugar takes place that results in merely sufficient of energy enough to keep the cells working, but not as efficiently. In the body cells, anaerobic respiration results in the production of lactic acid. The lactic acid and H^+ ions released cause the muscle to become more acidic, sometimes cause pain. The binding of oxygen to haemoglobin is shown as a function of partial pressure of O_2 versus the relative Hb-O_2 saturation. The resulting graph as O_2 dissociation curve is somewhat sigmoidal[2]. Increase in partial pressure of O_2 increases the saturation of O_2 on haemoglobin.

Figure 1 shows oxygen binding curve and it indicates that as the partial pressure of O_2 increases, more is the saturation of O_2 binding to Hb. However, the affinity of haemoglobin for O_2 may shift to right depending on concentration of CO_2, blood pH, body temperature, diseases, environmental factors such as pollutant gases and lower partial pressure of O_2. The O_2 carrying ability of Hb determines how much oxygen is carried in the blood.

Also, it depends on other environmental factors such as partial pressure of O_2 in air; pollutants and other malfunctioning can affect O_2 carrying capacity. This is also true for CO_2 levels, blood pH and body temperature. When CO_2 is in the blood, it forms bicarbonate (HCO_3^-) with H_2O and H^+ ions. As the level of CO_2 in the blood is more, H^+ ions also increase, pH of the blood decreases and subsequently decreases the affinity of Hb for O_2. The oxygen binding curve as in fig. 1 shifts towards to right showing lower affinity for O_2. CO_2 molecules are removed from blood by the following three methods: i) dissolution directly into the blood, ii) binding to Hb and iii) carried as a bicarbonate ion.

University of Southampton in 2014 investigated the effect of low O_2 level on insulin resistance. It seems apparent that the more O_2 we get, the better insulin sensitivity is observed. An insufficient supply of O_2 in cells triggers inflammations and insulin resistance.

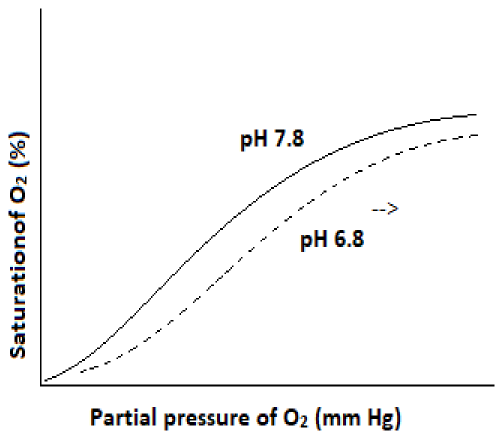

Fig. 1: Oxygen binding isotherm.

The diabetics show decreased ability of the circulating blood to release O_2 to the tissues. Oxygen is essential to life, also a key factor in insulin resistance and type 2-diabetics. Some research studies have shown that restricting O_2 intake does indeed result in increased insulin resistance. It is apparent that the more is O_2 supply, the better is insulin sensitivity[11]. Insulin resistance syndrome includes a group of problems such as high blood pressure, type 2-diabetes etc.

Other example to cite is the functioning of White Blood Cells (WBC) which is the body's internal defence force. This defence force will function efficiently when O_2 supply is adequate to blood to produce sufficient energy (ATP) for the proper functioning of WBC. If the supply of O_2 is insufficient, the defence functioning will be hampered similar to a situation like WBC low counts in the blood and will fall prey to the body infections easily. Insufficient supply of O_2 to blood will weaken the defence system of the body surrendering the infections including Covid-19.

Impact of other pollutants: Low partial pressure of O_2 in air due to various combustion processes and transportations also produces quite a bit of pollutant gases, further reducing the partial pressure of O_2 in the blood. CO and NO have greater affinity for Hb than O_2. The carbon monoxide which is discharged in air due to combustion processes is odourless and colourless. When CO is present in air, it preferentially binds with Hb than O_2, as a result O_2 cannot bind to Hb. Hb has more preference to CO than O_2 forming carboxy-heamoglobin which is irreversible and takes long time for the release of CO molecules[13].

The public health impact of CO has increased due to its environmental poison. CO toxicity causes reduced O_2 delivery to different parts of the body including important organs such as brain, heart, lungs etc. Deprived of sufficient supply of O_2 to important organs and insufficient oxidation of blood sugar will result in certain complications of the humans' health such as creating diabetes in men.

Conclusion

Natural partial pressure of O_2 in air is very essential for human and animal health. Reduced partial pressure of O_2 will cause insufficient supply of O_2 to different parts of the body leaving incomplete oxidation of blood glucose. Continuous various combustions processes consume huge amount of O_2 from air and giving out numerous gaseous pollutants initiating lowering the O_2 partial pressure in air.

According to Dalton's theory, various pollutant gases contribute lowering the partial pressure of O_2 in the atmosphere. Besides this, some gases like CO and NO combine with Hb, thus depriving adequate supply of O_2 to different parts of the body. This will help in reduction in oxidation of glucose in the blood. These will certainly have some impacts on diabetes and other health problems on humans and animals.

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