

## OXYGEN ENRICHMENT BOOSTS MINERS' PRODUCTIVITY

Mountaineers, miners, pilots, and astronomers; People in these professions attest to the irrefutable fact that high altitude affects people's physical and mental performances and quality of sleep. For those who work under these conditions, the result is impaired performance and productivity. One cost-effective measure to combat high-altitude conditions is oxygen enrichment of working and sleeping quarters via oxygen concentrators.

As barometric pressure falls with increasing altitude, the partial pressure of oxygen ( $P_{O_2}$ )<sup>1</sup> in the air drops. Known as high-altitude hypoxia, this condition similarly influences the  $P_{O_2}$  in the body. At 3000 meters, the average height of ski resorts, barometric pressure and inspired  $P_{O_2}$  drops to approximately 70 percent of that at sea level. Many Andean mines are located at about 4000 m, where inspired  $P_{O_2}$  falls to approximately 60 percent of its sea-level value. With decreased  $P_{O_2}$  in the lungs (alveoli  $P_{O_2}$ ), the  $P_{O_2}$  level in the blood (arterial  $P_{O_2}$ ) also drops, and therefore less oxygen is absorbed into the tissues, a condition known as hypoxemia, or oxygen deprivation.

The effects of oxygen deprivation are well documented. Widespread problems include deteriorated physical and mental performance and the lack of quality sleep. Studies at 4000 m have shown fatigue and a drop in arithmetic ability, decreased attention span, and visual impairment, as well as frequent wakefulness and periodic breathing at night.<sup>2</sup> These changes have a sizable impact on worker productivity, be they miners, astronomers, or workers on the new Goldmud-Lhasa railroad in Tibet. Other, more serious conditions include sub-acute and chronic mountain sickness and retinal hemorrhage, as well as potentially fatal conditions such as high-altitude pulmonary edema, high-altitude cerebral edema, and acute mountain sickness.

To counter the effects of high-altitude diseases, the body must return arterial  $P_{O_2}$  toward normal. Acclimatization, the means by which the body adapts to higher altitudes, only partially restores  $P_{O_2}$  to standard levels. Hyperventilation, the body's most common response to high-altitude conditions, increases alveolar  $P_{O_2}$  by raising the depth and rate of breathing. However, while  $P_{O_2}$  does improve with hyperventilation, it does not return to normal. Indeed, while studies of miners and astronomers working at 3000 meters and above show improved alveolar  $P_{O_2}$  with full acclimatization, the  $P_{O_2}$  level stubbornly remains equal to or even below the threshold for continuous oxygen therapy for patients with chronic obstructive pulmonary disease (COPD).<sup>3</sup> In addition, there are complications involved with acclimatization. Polycythemia, in which the body increases the number of red blood cells in circulation, thickens the blood, raising the danger that the heart can't pump it.

The only way to counteract the effects of high-altitude diseases is oxygen enrichment. By increasing the concentration of oxygen in the air, the effects of lower barometric pressure are countered, and the level of **arterial**  $P_{O_2}$  (oxygen in the blood that actually reaches the tissues) is restored toward normal capacity. Even a small amount of supplemental oxygen reduces the equivalent altitude in climate-controlled rooms. At 4000 m, raising the oxygen concentration level by merely 5 percent via an oxygen concentrator and an existing ventilation system provides an altitude of 3000 m, which is much more tolerable for the increasing number of low-landers who work in high altitude.<sup>4</sup>

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<sup>1</sup>  $P_{O_2}$  is the percentage of oxygen in the air multiplied by the barometric pressure. At sea level,  $P_{O_2}$  is .2093 X 760 mm Hg, or 159 mm Hg.

<sup>2</sup> West, John B., "The Physiologic Basis of High-Altitude Diseases," *Annals of Internal Medicine*, 2004, 141(10): 791.

<sup>3</sup> *Ibid.*

<sup>4</sup> West, John B., "Oxygen Enrichment of Room Air to Relieve the Hypoxia of High Altitude," *Respiration Physiology*, 1995: 99(2): 230.

Providing additional oxygen to employees would increase productivity, and hence profits, for companies working at high altitude. In a study of astronomers working in Chile at 5050 m, oxygen concentrators increased the level of oxygen concentration by 6 percent (that is, from 21 percent to 27 percent). The result was increased worker productivity, less fatigue, and improved sleep.<sup>5</sup> Oxygen enrichment at high altitude is a “simple but highly effective way of improving sleep quality, mental performance, work efficiency, and general well-being.”<sup>6</sup>

Oxygen generators are uniquely suited for this purpose. They require little maintenance and electricity, provide a constant source of oxygen, and eliminate the expensive, and often dangerous, task of transporting oxygen cylinders to high, remote areas. Hyperbaric air chambers, which are used in hospitals to treat cases of carbon-monoxide poisoning and to enhance wound healing, can counteract the effects of high altitude, but they are expensive. The key to oxygen concentrators is their cost and their practicality. Offices and housing already have climate-controlled rooms, in which temperature and humidity are at a constant level of comfortableness. Oxygen can be added to this system easily and relatively cheaply. Indeed, growing use of oxygen concentrators has “greatly increased the feasibility of oxygen enrichment of room air.”<sup>7</sup> In a remote Himalayan hospital, situated at 3,900 m, the staff found that oxygen concentrators as a source of supplemental oxygen yielded cost savings of over 75 percent versus cylinders.<sup>8</sup>

Simply put, high-altitude complications arise from oxygen deprivation, and oxygen deprivation leads to inferior performance. “The best way to alleviate the problem [of low inspired  $P_{O_2}$ ] is to increase the inspired  $P_{O_2}$  using supplemental oxygen.”<sup>9</sup> Therefore, an initial investment in oxygen concentrators would pay substantial dividends in terms of overall improved worker performance and productivity.

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<sup>5</sup> West, “The Physiologic Basis of High-Altitude Diseases,” p. 793.

<sup>6</sup> West, John B., “Commuting to High Altitude: Value of Oxygen Enrichment of Room Air,” *High Altitude Medicine and Biology*, 2002; 3(2): 223.

<sup>7</sup> West, “The Physiologic Basis of High-Altitude Diseases,” p. 793.

<sup>8</sup> Litch, JA and Bishop, RA, “Oxygen Concentrators for the Delivery of Supplemental Oxygen in Remote High-Altitude Areas,” *Wilderness Environ Med*, 2000 Fall; 11(3): 189.

<sup>9</sup> West, “The Physiologic Basis of High-Altitude Diseases,” p. 793.

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