Human Moon Base

SD2905 Human Spaceflight

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Abstract

In order to maintain a function lunar base, a functioning life support system is necessary to allow a crew to use it for extended periods of time. This paper combines research and practice from today's open-loop systems such as the ISS, and conceptualizes possible long-term solutions to close the loop. This makes it possible to recycle materials in the base and eventually lets the base self-sustain.

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Introduction

Almost half a decade after Armstrong walked on the Moon, mankind looks towards Mars as the next celestial body in our solar system to explore. Partly due to the lack of knowledge concerning extra-terrestrial human settlements, the International Space Station has served for research concerning human spaceflight since late 1998. However, with the station retiring in 2024, the main focus of human space exploration will move to the Moon. This is both for scientific research but also in preparation for a similar colonization of Mars in the future.

Knowing the composition of the harsh Lunar and Martian environments, a lot of work needs to be invested in human life support, guaranteeing the safety and well-being of an on-site crew.

This paper investigates and describes how the basic requirements of the human physiology can be met, and attempts to identify the psychological effects of remaining in a small enclosed base 400,000 kilometres from Earth. It will also analyse how an initially open-loop system can be closed in order to make the establishment self-sustaining and also to reduce resupplying costs.

1. Atmospheric System

In order to have a viable base on the moon we had to look after the different gas which will be produced by the crew and to make sure that the concentrations remain constant during the mission. That why we tried to find some suitable systems to look after oxygen, carbon dioxide and methane. In addition we thought about systems for long term mission.

1.1 Oxygen Production

For every space mission the basic requirement is to make sure that the astronauts will be able to breath during the whole mission. However for this kind of mission, it can be shown that a six member crew will consume between 6 and 8 kg (with a temperature of 25°C and a pressure of 1 atmosphere) of oxygen every day for the basic activities and some sport which is necessary for the health of the crew. This oxygen, cannot be bring from the Earth for safety reasons, there is a high hazard of fire with high pressurised oxygen. In addition it will be very costly.

See Appendix for calculation details.

1.2 Electrolysis

Looking to what is done in submarines and on the *ISS* we thought of using electrolysis to produce oxygen from water. In order to produce 8kg of oxygen we will need about 9kg of water every day. In addition this water must be a pure water because minerals will damaged the electrodes on a long term. For this pure water, distillation is not acceptable because it will consume too much power. Filtration by osmosis is a good way to produce a water pure enough. Nevertheless, electrolysis will need at least a power of 1371 W to work. Looking at the *Elektron* system on the *ISS*, it may be possible to have a complete system for a weigh of 200kg [1].

See Appendix for calculation details.

1.3 Recycling electrolyzed water

The main problem of electrolysis is that we produce hydrogen and that we don't really need it because the concentration of hydrogen in the air is not affected by breathing. But instead of just dispose of this hydrogen we thought of a way to recycle it to produce water. In fact there is a chemical reaction which make it possible by using hydrogen and carbon dioxide to produce water and methane. The Sabatier's reaction is possible at high temperature, moreover as it is an exothermic reaction, it will produce its own heat to keep the reaction going. So in fact we will just have to launch the system which need a power of 120W, this is acceptable for the space mission.

The carbon dioxide will be the one produce by breathing and other human activities. Then when we will have an efficient waste management system we could have carbon dioxide from it.

This reaction make it possible to recycle half of the water consume by the electrolyser, so instead of 8 kg per day we just need 4 kg of water. [2]

1.4 Long term system

For the long term mission, to be more sustainable we though to build a greenhouse. With the plants we also think to grow microalgae in order to produce oxygen without having to bring water from Earth. The use of photosynthesis from algae like *Thermosynechococcus Elongatus* will produce enough oxygen from water and carbon dioxide. Algae are advantageous because they have a better efficiency than plant for the release of oxygen. And with the artificial lighting of the green house we will be able to have photosynthesis at every moment.

To have an idea of the quantity of algae we need, experience shown that 1.5 m^3 produce on Earth enough oxygen for one person. The point is that we don't know in which way the limited gravity of the Moon (0,16 g) will affect the production of oxygen. We might take into account that we may need a bigger space for them. In fact experience as to be made on the base before having a working system

At the end we want to have a production big enough to use electrolysis as a backup system if there is a problem with algae or the greenhouse. [3]

1.5 CO_2

The CO_2 produce by human activities will mainly be use in order to achieve the Sabatier's reaction. Nevertheless, in we need to filter more CO_2 from the base a solution can be to use the same technology we use for methane. Activated carbon filter make it possible to remove CO_2 from air. [3]

1.6 Disposal of Methane

For the methane that will be produced by human activities and the Sabatier's reaction there is no perfect solution. The best option is to store it thanks to activated carbon cartridge.

It can be used as a fuel when we will have to burn the wastes of the base. As it will consume oxygen to have a combustion. To do it without any hazard for the crew member by using their oxygen, we can use the electrolyser which is no more useful with the algae production and have an extra production of oxygen to burn methane.

One other solution is also the pyrolysis of methane to create hydrogen which will be use to improve the production of the Sabatier's reaction and make it possible to recycle the whole water used by electrolysis assuming we have enough carbon dioxide. The backlash is that we need very high temperature to do the pyrolysis, between 1000 and 1200 °C. The other point is that it the carbon produced will react with carbon dioxide to produce carbon monoxide which is toxic. Without a very safe system to dispose of the carbon produced we cannot use pyrolysis for the base.

At the end we can also just release the methane outside the base without using it. [4]

2. Automated systems

2.1 Emergency systems

In case of need we also have to think about another system to produce oxygen if electrolyser was out of service temporarily. That what we may use chemicals way to produce oxygen in case of emergency. Even if the heat produce by this kind of systems can be dangerous, it's a good way to change quickly the oxygen production system. With this system, one litter of lithium perchlorate can produce enough oxygen for one crew member for one day.

2.2 Warning System

One of the main problem of the air system is to make sure that the air remains safe for the crew. That's why we have to have an electrolyser which is able to produce more in case of need, actually with 7.5 kg of oxygen everyday it will be sufficient because it's a strong assumption of the crew consumption. In addition when the bioreactor will be operational there won't be any problem of safety.

The fact is that we have to make sure that the other gas remain at a normal level. That why we have to measure their concentration (especially for CO_2, Methane, CO and of course O_2). In case of need we have to be able to isolate a part of the base if the air is detected as dangerous.

3. Water production

There are three methods to meet the water requirement – producing, transporting, and recycling. Actually, we can set producing and recycling in same category, but as we wanted to research the recycling method more specifically, we divided them. Also, the meaning of water production is mining the moon ice and produce water from it using recently researched technology.

3.1 Requirement, recycling and production

Table 1: Water requirements on Earth and in space. [5]

Item	In Space
	kg per person per day
Drinking water	1.62
Water for food	0.80

Table 1 shows the water requirement in space. As we assumed that the water requirement on the moon is as same as in space, we calculated the amount of water requirement for 6 people and categorized it into 2 situations: a 3-month period between launches, and another 3-month emergency storage. We need to transport the water that can sustain life at the very first time for emergency, in 3 months. After 3 months, we can produce water without water transported from Earth.

3.1.1 Emergency storage

Table 2: Water requirements on the Moon for 3 months. [6]

Purpose	Amount of Requirement (kg per 3 months)
Drink	875
For food (Rehydrate)	432

Table 2 shows the water requirement on moon for 3 months, or the amount of water to be transported from Earth to the moon.

3.1.2 Long-term water situation

Table 3: Water requirements on the Moon including a recycling process.

Purpose	Amount of Need (kg per year)	Recycle [7]
Drink	3548	.
For food (Rehydrate)	1752	.
Electrolysis (produce oxygen)	1460	.
Shower	10800	83% -> 8964
Sum	**16100**	**8964**

Table 3 shows that water requirement in the moon after 3 months from arrival, and the amount of recycling that we can. We assumed that the crew will use water on the moon to drink, rehydrate food, produce oxygen, and shower.

Using the simple calculation, it indicates that we must mine approximately 7136 kg of water per year, or **20 kg per day**. Therefore, we calculated the amount of ice on the moon to know if there is plenty of water there.

3.2 Amount of water on the Moon

There was an article about the quantity of water ice on the moon.

"NASA's Mini-SAR instrument, which flew aboard India's Chandrayaan-1 spacecraft, found more than 40 small craters with water ice. The craters range in size from 1 to 9 miles (2 to 15 km) in diameter. Although the

total amount of ice depends on its thickness in each crater, it's estimated there could be at least 600 million metric tons of water ice." [8]

According to this article, we estimated the quantity of the water ice.

Amount of ice in a crater

$$\frac{6 \times 10^{11} kg}{40} = 1.5 \times 10^{10} kg$$

Assume the average diameter to 8km, then the average area of the crater is $2 \times 10^8 m^2$

So, we can get the amount of ice per area in a crater which is,

$$\frac{1.5 \times 10^{10} kg}{2 \times 10^8 m^2} = \mathbf{75 kg/m^2}$$

Therefore, comparing to the water requirement (**20 kg per day**), there is plenty of water on the Moon.

3.3 Water recycling

There is some system that operates now at ISS or other.

- The Russian SRV-K system.

- ESA core water recycling system.

We can recycle grey water by these methods:

- Evaporation and condensation.
- Filtration.
- Reverse osmosis.
- Bioreactor. Microbiological organisms used to purify water.

3.4 Water production

We can produce water by several methods such as Sabatier reaction, using fuel cells, digging the ice, but we can't bring all the device for water production. Therefore, we choose the most efficient method, the microwave extraction process. First, the scientists found that there is water on the polar region of the moon, and that is the reason we chose our moon base at polar region. As we calculated, there are plenty of water at the moon.

First, using microwave, because its resonance frequency is as same as resonance frequency of water, we can obtain water in the form of gas. It means that we can convert the frozen water into gas, or vaporize it. The efficiency of this method is approximately 98%.

Second, it is possible to capture the water in the form of gas. The efficiency of this method is approximately 99%. [9] [10]

Using this method, it is much easier to provide water at the moon base. However, it is also important to prepare for the emergency.

4. Food

The lack of edible material on the Moon will mean that large food transports from Earth will initially be required to sustain the crew. This segment will examine how energy expenditures can be compensated for, and also how food variety can increase crew efficiency as well as maintain morale while still keeping in mind the requirement of various nutrients. Finally, the conceptualization of a greenhouse will provide a long-term solution to the base's food demand as well as aid in the revitalization of the atmosphere and water purification.

4.1 Food requirements

Table 4: Recommended Daily Nutrient Intake of Cosmonauts and Astronauts. [11]

Nutrients	Cosmonauts	Astronauts
Energy [kJ]	13400	9600-12950
Protein [*]	1,5	0,8
Fat [*]	1,4	1,3
Carbohydrates [*]	4,5	4,8

* grams per kilogram of bodyweight.

Table 4 shows the main nutrients required for the human metabolism, as well as the recommended daily amounts for Russian cosmonauts as well as western astronauts according to Gitelson and Litovsky. The deviations are relatively large at times, indicating a lack of international norm on this subject.

Carbohydrates (found in potatoes, crop, rice ...) generally cover approximately half of the daily energy need. Lipids and fatty acids (found in various oils or butter for example) will commonly cover approximately a third of the daily need, while proteins cover the rest. The meal standard on Earth would be unattainable in interplanetary travel where simply providing the nutrients proves a challenge. Required vitamins or things such as condiments would have to be provided from Earth.

To guarantee sufficient quantity as well as variety, NASA estimates in the *First Lunar Outpost Study* that a crewmember would consume 3.82 kg per day, including approximately 1.6 kg of solid food and 2.2 kg of water in the food as well as water used to prepare the freeze-dried food. [12]

The base would need to store food for normal consumption between resupplying launches from Earth, as well as a cautious emergency storage should a launch be delayed for some reason. If the expedition can expect a launch every three months, storage of approximately four tonnes of food would need to be maintained.

4.2 Greenhousing as a long-term solution

With the elevation of one kilogramme of payload into Earth's orbit costing approximately $20,000 [13], a constant resupply of consumables to the Moon would require considerable amounts of funding. As the base is meant to operate for at least ten years, this proves an unsustainable and very inefficient solution. A greenhouse on the Moon would provide a method of on-site food production and would also prove useful in the handling of waste products such as carbon dioxide or grey water.

4.2.1 Advantages and drawbacks of lunar greenhousing

Since the lunar atmosphere is essentially a hard vacuum, all activity will obviously be performed indoors in pressurized modules. Unlike on Earth, the presence of micrometeoroid impacts on the surface pose a problem not only to a hypothetical greenhouse, but to all human activity. In fact, a surface of 150 m^2 is hit by a meteoroid larger than 0.5 mm per year. With velocities around 13 kilometres per second, the impacts could potentially cause significant damage. [14]

This particular issue can be circumvented by an underground greenhouse, where lighting can be provided artificially via solar energy and where the atmosphere can be regulated and controlled to achieve maximum efficiency. The advantages of such a method of lunar greenhousing are that there are no weather irregularities to take into account. It is also easier to manage it in an enclosed environment, crops can be stacked on shelves to minimize required surface area, and light, water and atmospheric levels can be controlled to a higher extent.

4.2.2 Efficiency and possible output of a greenhouse

Before implementing a greenhouse in a human spatial biosphere, a lot of research has been made and will continue in order to analyse all factors affecting its efficiency, as well as identify all inputs and outputs of such a system, and how these can be optimally tuned.

This has not been extensively tested, however research has been done on the matter. The Plane Science Department at the Lunar and Planetary Institute state that 24 m^2 of growing area of wheat would be enough to feed an adult. Using high pressure sodium lamps along with high efficiency reflectors, a square meter of growing area could in theory produce 140 grams of dry mass per day. [15] A bare minimum of 144 m^2 would then be required to self-sustain. However, to achieve variety, and also for redundancy's sake as a safety measure, this figure should be higher to be able to produce more wheat, and also experiment with various other crops. The European Space Agency ESA are currently experimenting with other plants such as potatoes, tomatoes and various algae, and further experiments could be done on these plants in a lunar greenhouse. Other possible crops targeted by NASA are lettuce, cucumber and strawberries would be prime targets for further research to achieve maximum efficiency both production-, cost- and nutrient-wise. [16] Considering the relatively low efficiency of high pressure sodium lamps, a power supply of 600 W per square meter to reach the appropriate light levels is required, which would mean that a large establishment of approximately 200 m^2 would require 120 kW to function properly. Seeing as the International Space Station generates 110 kW from 8 large solar arrays, such a large power demand would prove difficult to achieve. [17] However, due to the existence of fully illuminated areas in proximity to the suggested base location, the amount of solar power will be abundant. Furthermore, the use of nuclear power production in the future might facilitate the power generation further.

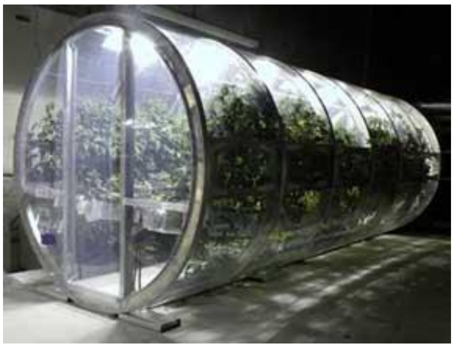

Figure 1: Possible greenhouse configuration permitting atmospheric control independent of other modules. [16]

The lunar base would require resupplying for many years following its establishment, however with the on-site production in the greenhouse, the amount required would progressively decrease, thus freeing up more possible payload for scientific purposes.

5. Waste management

Consumption of oxygen, water and nutrients inevitably leads to the expulsion of waste materials, such as carbon dioxide and sewage. Atmospheric revitalization and water purification are covered respectively in parts 1 and 3, whereas this chapter covers unrecoverable biomass.

The ISS is essentially an open loop system where a majority of the inputs are resupplied from Earth, and where waste products until recently were stored in the Automated Transfer Vehicle ATV that were deorbited once full. [18] This would obviously be impossible on the Moon, and launching it from the lunar surface into orbit would be an extremely inefficient solution.

5.1 Problems of waste accumulation

Storing of waste on-site would prove an expensive way of storing unusable material that could otherwise have been spent on valuable payload in form of either scientific equipment or life support.

An alternative would be storing the waste or debris in remote locations of the lunar region of the base. The transportation could eventually be performed using rovers and remote tech, but unfortunately this would not be a long-term solution should the base look to expand.

Ideally, a method of integrating the waste management into the closed loop system and recycle as much as possible.

5.2 Possible methods of efficient waste handling

A device currently in development is the Vortical Oxidative Reactor Technology, or VORTEX. [19] It is essentially a burner over which waste materials are swirling in an airflow. The products of incinerating waste are:

- Water that can be used by the crew for various purposes, such as drinking or oxygen production.
- Carbon dioxide, generally an unwanted by-product. It can however prove useful for a greenhouse and research concerning augmented carbon dioxide levels in the atmosphere.
- Ash that can serve as fertilizer for the greenhouse.

In fact, if plants are provided with water, an atmosphere and fertilizer, they would be able to grow in the abundant lunar soil regolith.

Furthermore, incineration is a slower process in a lower gravity, which is why the airflow is necessary to expose the waste to the flame. In order to accelerate the process, methane can be used as a fuel. Methane would be produced as a by-product in the Sabatier reaction mentioned in section 1. As methane currently has very few uses, this reaction would prove a useful method of depleting both the amount of waste and methane.

6. Medical life support

6.1 Health maintenance

The main medical focus has been laid on illness prevention. Due to the logistic issues, restrictions in medical personnel and equipment that can be brought, along with the knowledge gaps remaining in space medicine it is clear that there are limitations on which ailments can be treated effectively. Also, the risk factors and, the disease and injury spectrum differs greatly from earth and can be further affected by the choice and preparation of the astronauts.

Healthy individuals have to be chosen to avoid complications of pre-existing conditions. Screening of the candidates should exclude those affected by any relevant diseases or restrictions, such as diabetes, cancer, claustrophobia, organ problems and cardiovascular diseases, along with drug problem and limited functionality. For practical reasons it is also necessary that the candidates are able to work under high pressure. Short term quarantine after a final medical check-up minimizes, but doesn't eliminate the risk of common cold, the flu, and other often occurring, and on earth uncomplicated ailments [20].

Leading up to the flight, medical and practical preparations need to be included in the astronaut training. These include, but are not limited to, survival skills in the wild, ability to swim, first aid and further basic medical training. Actions to keep the health the best possible condition, via exercise and diet are also necessary.

During the flight, several risk factors arise. The decrease of gravitational load on the body leads to degradation of the bones and increasing levels of calcium in the bloodstream affecting the cardiovascular system in a negative way. The bone osteoporosis usually does not present a problem during the space travel, but means an increased risk of bone fractures when coming back down to Earth. It is mitigated by calcium, vitamin D and vitamin K intake [21], along with regular exercise, meaning that these supplements need to be included in the food or brought in the form of pills, along with exercise equipment. Necessary tools include a treadmill, exercise bike and resistance equipment, such as rubber bands and resistive exercise devices. Present research indicates that gravity spins could introduce a full gravitational loading equal to lying down on earth for an hour a day in the future, though still presenting some problem with nausea. Due to the necessary protection from radiation, all UV-light from the sun is also shut out, requiring D-vitamin supplements, as the body no longer can produce it. Another expected problem is sleep, partly due to lack of a normal earth light cycle. The location of the pole will create some disorder due to constant light. To prevent any disorder into the crew a good point to use different light, which will reproduce a normal daylight. A solution is found in submarines [22], which control the colour composition of light to mimic the sunlight changes on earth. This requires that the sleeping patterns of the astronauts are the same. Sleep inducing drugs are an alternative when needed, but has to be chosen as a compromise between effectiveness and alertness in case of an earlier sudden wake up alarm due to some emergency. It is not viable if astronauts have a decreased alertness and reaction time when they wake up. Finally, hygiene must be maintained. Although the moon has some gravity, it is still too small for showers to be realistic in the first missions. The limited water supply also presents a problem there. Instead washing cloths will be used as on the ISS, and changed regularly. Also, toothbrushes and soap will be needed.

Further, the problem of lunar dust cannot be ignored. As its effects on the human body are still relatively unknown, but thought to be more harmful than mineral dust on earth, total isolation from it is necessary. [23]

After the flight, medical check-ups are necessary to study the changes in health, both for future research and to find suitable medical interventions and rehabilitation.

6.2 Health interventions

Although a large effort is put into preventing diseases and injuries, they cannot be avoided completely, and thus possibilities of treating a compromised person are necessary. Medical training for at least two of the crew at each time is necessary, but as the space medicine differs from ordinary medical training on many points it is more important that the correct training is provided than to find traditional doctors.

To be able to treat an ailment, it is first necessary to be able to diagnose it. Thus equipment for this, and a connection down to specialists in diagnostics and emergency treatment in the expected fields are necessary. Fields include, but are not limited to cardiovascular disease, bone fractures. X-rays and other radiation based examination equipment are not viable on a moon mission; instead a laptop-sized ultrasound can be used for a large array of conditions. Due to the delay of moon to Earth communication, the crew need to know how to interpret the most acute conditions, while less pressing conditions and images they cannot interpret properly can be sent to specialists on earth. Beside the investigations off a suspected condition, routine health check-ups are necessary partly to find developing conditions early on and to provide data for future research.

Basic medical equipment is necessary to treat the conditions found. This include, among else, bandages, drugs, sedatives and special tools for simpler surgery in low gravity conditions.

6.3 Psychology

While candidates are chosen to avoid irrational fears and predispositions to mental illness and conditions, it is reasonable to think that the mission will provide a certain strain on the psyche. The smaller possible implications of this strain need to be dealt with to minimize the risk of them developing into bigger concerns. Such are extreme fear, depression and high stress, which can be mitigated early on by communication with a suitable specialist down on earth and prevented by repeated situation simulations and psychology check-ups before the flight. For acute cases some kind of calming medicine need to be accessible. Further ways to prevent the development of these problems during the mission are considering the group dynamics, as discussed under 6.4 social factors, allowing time and possibility to call loved ones at home, access to solitude and keeping room in the schedule for fun.

In addition the crew shouldn't have too much free time, we thought that one hour per day is the limit. Every activity have to be scheduled, even lunch or sleeping time in order to avoid boredom.

Although improbable, the extreme cases of real panic attacks need to be addressed as they would pose a real danger both for the one in panic and for the rest of the crew. Again, calming medicine is necessary to deal with it instantly, while communication to a specialist down on earth can determine a suitable course of action on a case to case basis.

6.4 Social factors

For this mission, it's necessary to take into account the reaction of the crew about the living condition. As cosmonaut Valery Ryumin famously wrote in his journal during a difficult time on the Salyut-6: "All the conditions necessary for a murder are met if you shut two men in a cabin measuring 18 feet by 20 and leave them together for two months". Though the amount of people and accessible area would be bigger on the moon base, this is a jokingly but eerie reminder of potential problems isolating a small group of people and the importance of good group dynamics. In order to facilitate the crew life, here are few points that have been considerate for the mission. First and foremost, socially able and well-adjusted people are a requirement, but team building and examinations of the group dynamics of the top candidates for a mission need to be taken into consideration. Further, cultural disputes need to be taken into consideration as national disputes can materialize in individual conflicts, which research strengthens the anecdotal evidence for [24]. In addition, even if they are trained and they know the other team member, it will be difficult to remain with the same people for more than a year. So due to the cost of sending people on the moon, the crew should remain on the month between 6 and 12 month. But for that they may miss their family. So they should be able to use the communication systems to contact them sometimes.

The astronauts will live in a very small space due to technical and cost constrains. In order to facilitate the life to gather it can be advantageous to have a private room for everybody. It can be done easily without losing too much space.

6.5 Emergency situations

Historically, space travel has run into unexpected and pressing problems, accidents have killed whole crews, but fortunately it has been mostly liberated from non-fatal but acute and life threatening diseases and injuries and sudden deaths of single individuals on the stations. However, it must be realised that this is an existing risk, and something that need a planned management process so that it can be treated immediately. While accidents like these come in many forms and need to be treated on case to case basis, the necessary people to take these decisions must be reached as fast as possible.

Sudden death is a worst-case scenario, since the body needs to be disposed of quickly for sanitary reasons. This could either be done by sending the body back, alone or with remaining crew members or by burying it on location. A decision that need to consider the wishes of the family of the diseased, but also the logistics. It also needs to be done in an honourable manner out of respect, and to avoid media breakouts. An on location burial will require that the death can be proved medically, for which the right medical training and the ultra sound can be used, and possibilities for extravehicular activities and tools that can be used for the purpose, while sending the body back would need to consider if there are any options for going back remaining. If not, the crew should suitably be sent down. In either case, psychological support would be necessary for the remaining crew.

In case of acute illnesses and injuries that cannot be treated on location a vehicle back would be the best option, why it is necessary to keep possibilities for this open.

Conclusion and Discussion

Life support system is vital, and must be always considered at first. First, air system must be set. Especially, we must produce oxygen. By electrolysis and Sabatier reaction, we can produce oxygen. Also, there should be the warning system that measure the concentration of each gases. Second, we have to produce and recycle water. Fortunately, there is plenty of water ice on the moon, so we can mine it by microwave extraction process. Also, recycling occupies lots of proportion in making water on the moon base. Third, food system is also important to sustain life on the moon base. As a long term solution, we chose the greenhousing. In addition, we need to consider the psychological aspect because the crew must spend long time in a small space, and consider the way resisting the illness. By considering those aspects, we will successfully sustain life support system in the moon base.

Appendix I – Oxygen Requirement

Into the base the pressure is supposed to be of 1atm and the temperature 298 K

Calculation of the mass of dioxygen needed:

One people breathe about 6 to 8 litter of air per minute and about 70 L when doing sport. We assume that there won't be more than one people in the base doing sport at every moment.

So the average consumption is:

$\frac{5 \times 8+70}{6} = 18\, L.min^{-1}$ for one crew member.

But the air we breathe contains 21% of O_2, 78% of N_2 and 1% of other gas. When we breathe out it contains 17% of O_2 78% of N_2, 4% of CO_2 and 1% of other gas.

It gives a consumption of 0, 72 L.min^{-1} of oxygen.

The volume of oxygen needed for the 6 members every day is 1037L

It give a mass of 7.38kg

For safety reasons we will take 8kg.

Appendix II – Electrolysis

The electrodes equation are:

$$2H_2O(l) = O_2(g) + 4H^+(aq) + 4e^- \qquad E^o = 1,23V$$

$$2H^+(aq) + 2e^- = H_2(g) \qquad E^o = 0V$$

The reaction equation is:

$$2\,H_2O(\ell) \rightarrow 2\,H_2(g) + O_2(g)$$

For 8 kg of O_2 it means 250 mol. So we need 500 mol of pure water which weighs 9 kg.

Then we use 2 electrons for each water molecule, it gives 1000 mol.

$$Q = 1000 * N_A * e^-$$

Where N_A is Avogadro's number and e^- the elementary charge.

Then $I = \frac{Q}{T} = 1115$ A

The minimal power needed is 1371 W

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