S&T's Peer to Peer

Volume 1 | Issue 2 Article 9

May 2017

Assessment on Food and Water Collection on Mars vs. Human Survival

Michael Todd Herman Jr.

Recommended Citation

Herman, Michael Todd Jr. (2017) "Assessment on Food and Water Collection on Mars vs. Human Survival," *S&T's Peer to Peer*: Vol. 1 : Iss. 2 , Article 9.
Available at: http://scholarsmine.mst.edu/peer2peer/vol1/iss2/9

Michael Todd Herman Jr.
Aerospace Engineering at Missouri University of Science and Technology

ASSESSMENT ON FOOD AND WATER COLLECTION ON MARS vs. HUMAN SURVIVAL

Abstract

This research focuses on the possibility of farming and water collection on Mars to determine if enough food and water can be gathered to support sustained human life. The inspiration for this comes from the plans to put a human on Mars and create a sustained colony, such as Mars One. This colony can become the basis for a multi-planetary civilization that will substantially reduce future overcrowding problems (the population in 2050 is projected to be 11 billion and is expected to continue to grow exponentially) and promote additional research on space travel that can aid in the reduction of the space debris that will eventually cover the planet if its current growth rate is left untouched. The problems that arise in building a colony on another planet are food and water collection. On Mars specifically, the soil is dry compared to that of Earth and there are no nitrogen fixing bacteria that are necessary for plant growth, making it very hostile to crops. Additionally, liquid water is not existent the planet's surface, and the planet's existing water is difficult to access and is highly contaminated In order to properly assess sustained human survival on Mars, it must first be determined whether farming and the collection of pure water on Mars is possible under the given conditions. If food and pure water can be obtained on Mars, it is then necessary to determine if enough food and water can be acquired to support sustained human life. The research conducted for this paper consisted heavily on lab reports and write ups on studies about water collection methods, farming methods, water purification, and Martian soil composition with a few articles from National Aeronautics and Space Administration (NASA) on Martian ice and farming off of Earth.

Assessment on Food and Water Collection on Mars vs Human Survival

Ever since Aristotle and the ancient Greeks, humans have been fascinated by outer space and what lies within. They have worshiped suns and moons as gods and goddesses, studied planets and galaxies with curiosity and wonder, and have even set foot on another world. Now, the quest to conquer space continues as plans to put a man on Mars permanently begin to unfold. The urgency to colonize Mars stems greatly from the fear of becoming trapped on an Earth that's coated with a thick layer of space debris that increases its numbers with each rocket launch, eventually trapping humankind on an Earth that is rapidly warming and running out of space. If a Martian colony can be established and become sustainable, it will greatly aid in the issues of overcrowding while the promotion of space travel will bring spacecraft to the forefront of technological development and induce more research that will help reduce the number of space debris orbiting the Earth. The most basic issues of this Martian colonization mission is whether man can obtain the most basic necessities of survival, food and water, in the barren Martian environment. In order to properly assess sustained human survival on Mars, it must first be determined whether farming and the collection of pure water on Mars is possible. If this can indeed be done, it is then necessary to determine if enough food and water can be acquired to support human life.

There are limits to the project's scope. The most substantial limitation presented in this paper is that no human has ever been to Mars to test the methods of farming and water collection. These methods have only been tested under Martian like conditions (temperature, light intensity, and atmospheric pressure) and have yet to be exposed to the full score of the Martian environment. Furthermore, this paper operates on the pretense that the proper facilities consisting of current technology are provided, such as pressurized living quarters and a greenhouse. In the current plans to permanently send a person to Mars, these facilities are included (Mars One, 2017) and this paper is solely examining survival in terms of food and water.

The research for this paper consisted largely of keyword searches on Google Scholar and the Missouri S&T library databases. The keywords included hydroponics, Martian water, water purification, hydroponics under Martian conditions, hydroponics yield, Mars drilling, Martian soil composition, water collection Mars, and Mars water composition. Additionally, the Farmer's Almanac online and the Mars One website were used. The searches turned up scholarly essays and experiments on water collection methods, farming methods, Martian soil and water composition, and water purification. The information gathered was then used to determine the possibility of farming and water collection on Mars and then the yield of food and water to assess the potential of human survival.

Farming Methods

There are two prominent ideas on Martian farming methods. The first method is collecting opaline silica on Mars and combining it with Martian topsoil and bacteria brought from Earth inside a greenhouse. Opaline silica deposits are found in volcanic areas on the planet's surface. When silica from these deposits is combined with the topsoil, it creates a microenvironment similar to bacterial ecosystems found on Earth.This means that the nitrogen fixing bacteria that are vital for the survival of crops can live on Mars and can be used to create a thriving greenhouse ecosystem (Squyres, 2008). Although the notion of combining silica and topsoil seems like an easy and effective way to create a sustainable microenvironment, there are many roadblocks. First, a great amount of energy would have to be consumed to break down the andesitic rocks to harvest silica, which could deplete other important systems, like oxygen filtration. Next, the most prominent location of volcanic silica deposits is the northern plains. The northern plains present challenges to survival because there is not much water there. If a silica/topsoil farming method is chosen, the base site would undoubtedly be the northern plains, and dehydration would become a more substantial concern than it is elsewhere on the red planet (McLennan, 2003). Lastly, silica is a well known human health hazard and extended contact with crops could result in the uptake of silica through the roots and its spread throughout the entire plant. A silica uptake of even 0.01% would present a significant human health hazard and result in the decimation of all crops (Miloy and Williams, 2002). The silica/topsoil farming method presents too many health hazards and limitations, so it must be ruled out as a potential method of farming on Mars.

The other method of farming is hydroponic farming. Hydroponics is the process of growing plants by adding nutrients to water, instead of using soil (Dyck, 2016). This is how current astronauts grow plants in space and how crops will be grown during their journey to Mars (Dyck, 2016). Under hydroponic conditions, nitrogen fixing bacteria are able to attach to the roots of plants and survive to produce nitrogen to the plant on Earth. According to a study and paper published by O. J. Macintyre, hydroponic conditions in a Martian (low pressure) environment also support nitrogen fixing bacteria, but not as well as it does on Earth. In this study, the bacteria lost 22% of its population in the first few days but maintained constant numbers for the remainder of the study. In other words, as far as bacteria are concerned, hydroponic farming is sustainable on Mars (Macintyre, 2011). Gathering the nutrients such as potassium, nitrogen, calcium, and water that are required for hydroponics is another issue for this method of farming. NASA plant physiologist Dr. Ray Wheeler believes that all the resources necessary for hydroponic farming can be either recycled from those initially used on the journey to Mars, acquired on the surface of the planet, or made on site, a process known as in-situ resource utilization. A major source of recycled materials would be wastewater and urine collected and processed by the Environmental Control and Life Support System found aboard all spacecraft (Herridge, 2016). Other required nutrients, like iron, can be found in the soil and on the surface of Mars (Herridge, 2016). The briney ice water located in subsurface pockets also contain nutrients that can be harvested, like calcium (Fischer, 2014). Dr. Wheeler conducted a study using hydroponics and in-situ resource utilization on potatoes in 2014 which simulated deep space conditions. The potatoes harvested from the study were on par with those grown in normal Earth conditions in terms of nutrient content, taste, and size. The results of this study indicate that a hydroponic farm system will work with materials found and brought to Mars (Herridge, 2016). Thus, hydroponic farming is a feasible and sustainable way to effectively grow crops during the journey to and on the surface of Mars, making it method of choice to feed humans on Mars.

Water Collection and Purification

Water exists on Mars as both a liquid and a solid. However, it is both impure and located within the planet, meaning that the water's current state is useless. First, it is necessary to focus on the extraction of water from the planet by the two prominent methods. The first of which is to pull water directly out of the soil using a microwave radiation oven developed by a team of engineers from Colorado School of Mines. This device is powered by silicon solar cells on top of the device so that it needs no outside fuel. This microwave oven works by exposing soil placed inside of it to high levels of microwave radiation in order to vaporize ice crystals located within the soil. Once the ice is heated to a temperature greater than 200^{o}C it turns into water vapor. It is then collected in the water transport system where it is condensed into a liquid due to high pressure inside the chamber. The transport system can then be removed and the liquid water can be collected. This system is capable of producing 200g of water per hour and can operate on a 12 hour on/off cycle under Earth's temperature and atmospheric pressure (Wiens, 2001). It has yet to be tested under Martian conditions due to a lack of funding (Wiens, 2001). This lack of funding leads to the only downside to this device which is that a full prototype has yet to be built and the team has been limited to crude models and parts of a whole prototype, meaning that it is not practically able to collect water. However, the fact that it is theoretically able to collect water means that at some point it could become a way to obtain water on Mars.

While the microwave oven is theoretically an efficient way to collect water from Mars,the University of California at Berkeley has developed a drill bit that has been proven to effectively extract water from the Martian subsurface. The water in the Martian subsurface is located in shallow pockets that contain a briney ice water mixture. The area that contains subsurface water ranges from the polar regions to the midlatitudes of the planet at a depth of approximately 100 meters below the surface (Fischer, 2014), which is shallow enough for a drill to reach. Drilling under Martian temperatures and atmospheric pressures (-62.2^{o}C and .6 kPa) is very different from drilling on Earth. This is because typical methods used on Earth involve cleaning the drill bit with a pre-prepared gas or liquid flow (Zacny, 2004), but pre-compressed air is not readily available on Mars and liquid water is not stable under these conditions. In order to effectively clean the drill bit on Mars, the team created a drill that uses the surrounding air. The drill takes in 1 L of the surrounding air and uses a low power compressor to compress the air inside the machine. This compressed air is then stored in a reservoir also in the drill and is used to provide intermittent blasts to clean the drill bit (Zacny, 2004). When tested in a lab under Martian conditions, the results were "encouraging" (Zacny, 2004). When exposed to California limestone, the drill ejected the cuttings with "considerable speed...and [they] fell some distance away from the hole in a completely dry condition" and the drill's penetration rates were twice of the typical measured value on the same rock while using half the power at 100 W (Zacny, 2004). This proves that the compressed surrounding air is effective in cleaning the drill bit while it is in use. When the drill encountered ice, there was no melting and refreezing during the drilling process which demonstrates that the drill can effectively pass through/extract ice under the Martian surface without getting stuck (Zacny, 2004). This study shows, try to avoid using the word "prove" that water collection on Mars is possible using the technology demonstrated above.

In order for any of the water collected on Mars to be usable, it must be purified. The impurities of the water are predominantly perchlorates such as calcium perchlorate [$Ca(ClO_4)_2$] and sodium perchlorate [$NaClO_4$] (Fischer, 2014). The main methods for removing perchlorates on Earth is ion exchange and reverse osmosis (Hernandez, 2015). Ion exchange involves swapping the ions in the water, like perchlorates, with other ions of the same charge. Reverse osmosis uses pressure to push only water molecules through a selectively permeable membrane. Both of these methods will work on Mars (Hernandez, 2015), but ion exchange is the less practical method because it is relatively expensive on a world without easy access to the ions necessary for this method of purification. This means that it is possible to collect and purify the water located on Mars.

Food and Water Collection: Quantification

Since it has now been determined that food and water can be produced on Mars, it is now necessary to determine if enough can be collected to support human survival. In a study on the effects of a soilless environment on fruit quality, water consumption, and mineral composition of plants under greenhouse and hydroponic conditions, it was determined that hydroponic farming has a higher overall yield than conventional farming (Rouphael, 2004). This study's data showed that hydroponic plants exhibited a higher yield in fruit number and water efficiency than those planted in soil. The hydroponic plants also exhibited a slightly higher uptake in nitrogen (N), Magnesium (Mg), Sodium (Na), Iron (Fe), Copper (Cu), Manganese (Mn), and Zinc (Zn) than those grown in soil. After 73 days of solution recycling, N, Fe, Mn, Potassium, and Phosphorous were all depleted by 26, 92, 25, 16, and 40 percent respectively. In soilless plants, however, Calcium, Mg, Na, Cu, and Zn all increased by 6, 69, 113, 360, and 981 percent respectively (Rouphael, 2004). Finally, the hydroponic plants produced more carbohydrates and sugars than the soil bound ones while maintaining similar levels of protein (Rouphael, 2004). The results show that using hydroponic farming allows growers to improve control of water and nutrients as well as fruit yield and quality. Considering humans need an average of 1500 calories per day to survive and maintain health and the average potato (a crop easy to grow on Mars) contains 110 calories, it would be necessary to eat approximately 13.6 potatoes a day (Farmers Almanac, 2010). Potatoes have ten week harvest cycle meaning 952 potatoes must be grown per person per harvest, although less would be required with the hydroponic method due to the better quality of crops produced. As long as the proper facilities to produce 1500 calories or about 13.6 potatoes per day are provided, greenhouse hydroponics is a viable way to support human life on Mars.

A human needs 64 oz (1814.37 grams) of water per day to survive. There are two viable methods for obtaining water on Mars, but the methods vary in the amount collected per day. Assuming after full development and simulation under Martian conditions, the theoretical microwave oven maintains its extraction rate 200 grams of water per hour from Martian soil, it would extract 2400 grams of water per day (Wiens, 2001). At this rate, a single oven would be enough to support one person and have water left over to use in other tasks. While the hypothetical oven extraction method produces a consistent amount, pulling water from subsurface pockets is not so. Subsurface water can range from ice sheets the volume of Lake Superior ($3.1965*10^{15}$ gallons or $1.21*10^{16}$ L) (NASA Jet Propulsion Lab, 2016) to pockets the size of a puddle. This inconsistency leads to a lack of specific data on the volume of subsurface pockets. However, considering the Lake Superior sized ice sheet is more than large enough to support human life, the best drill for extraction is not nearly large enough to pull enough water to support a human, even though it is possible to pull water from the subsurface (Zacny, 2004). This means that in order to support human life on Mars, the technology for collecting water must be improved upon as in its current state, it cannot collect enough water to support a human life.

Conclusions and Need for Additional Research

At this moment, the data conclusively demonstrates that humans can not survive on Mars given the proper facilities of today's technology because it is not possible to collect enough water on the planet to support human life. In order to make survival possible, further research must be conducted on the microwave water extractor and drilling technology or other methods must be found/discovered/invented. Both of these methods should be improved upon and made readily available to use on Mars. More funding and time should be devoted to the microwave oven, which can be used as the main source of water collection for daily human consumption where research on increasing the drill's harvesting power would allow for more water to be collected for side tasks and emergency water. The evidence does suggest, however, that human survival on Mars is possible in the future. Considering that greenhouse hydroponic farming can feed humans on Mars and the Mars One plan has been building the proper facilities to host human life on Mars, all that needs to be finished is water collection tools.

References

Daniel, Dyck. (2016, April 8). *Development of Micro-Hydroponic Systems for Space Travel.* Retrieved from http://commons.erau.edu/pr-discovery-day/2016/posters-and-demonstrations-presentations/13/

Farmers Almanac. (2010). *Potatoes.* Retrieved From http://www.almanac.com/plant/potatoes

Fischer, E., Martinez, G., Elliot, H., Renno, N. (2014, July 7). *Experimental Evidence for the Formation of Liquid Saline Water on Mars*. Retrieved from http://onlinelibrary.wiley.com/doi/10.1002/2014GL060302/full

Hernandez, Daniela. (2015, October 2). *What it would take to drink the water on Mars*. Retrieved from http://fusion.net/story/205189/water-mars-future-human-habitats/

Herridge, Linda. (2016, February 17). *NASA Plant Researchers Explore Question of Deep-Space Food Crops*. Retrieved from https://www.nasa.gov/feature/nasa-plant-researchers-explore-question-of-deep-space-food-crops

MacIntyre, O. J., Trevors, J. T., Dixon, M. A., Cottenie, K. (2011) *Application of Plant Growth Promoting Rhizobacteria in a Hydroponics System for Advanced Life Support in Space.* Retrieved from http://agris.fao.org/agris-search/search.do?recordID=US201400112037

Mars One. (2017). *Permanent Settlement.* Retrieved from http://www.mars-one.com/mission/technical-feasibility

McLennan, Scott M. (2003, April). *Sedimentary Silica on Mars.* Retrieved from file:///C:/Users/Michael%20Herman/Downloads/315.full.pdf

Meloy, T.P., and Williams, M.C. (2002) *The moon then Mars: Minerals Engineering.* (v. 15, p. 115–121).

NASA Jet Propulsion Laboratory (NASA JPL). (2016, November 22). *Mars Ice Deposit Holds as Much Water as Lake Superior.* Retrieved from https://www.jpl.nasa.gov/news/news.php?feature=6680

Rouphael, Y. Colla, G. Battistelli, A. Moscatello, S. Proietti, S. & Rei, E. (2004, July 29) *Yield, water requirement, nutrient uptake and fruit quality of zucchini squash grown in soil and closed soilless culture.* Retrieved from http://www.tandfonline.com/doi/abs/10.1080/14620316.2004.11511784

Squyres, S. W., Arvidson, R. E., Ruff, S., Gellert, R., Morris, R. V., Ming, D. W., Crumpler, L., Farmer, J. D., Des Marais, D. J., Yen, A., McLennan, S. M., Calvin, W., Bell III, J. F., Clark, B. C., Wang, A., McCoy, T. J., Schmidt, M. E., de Souza Jr. P. A. (2008, May 23). *Detection of Silica-Rich Deposits on Mars.* Retrieved from http://science.sciencemag.org/content/320/5879/1063

Weins, J., Bommarito, F., Blumenstein, E., Ellsworth, M. Cisar, T. (2001, January) *Water Extraction from Martian Soil.* Retrieved from http://www.lpi.usra.edu/publications/reports/CB-1106/csm01.pdf

Zacny, K. A., Quayle, M. C., Cooper, G. A., (2004, July 22). *Laboratory Drilling Under Martian Conditions Yields Unexpected Results.* Retrieved from http://onlinelibrary.wiley.com/doi/10.1029/2003JE002203/abstract