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Guatemala: Phycoremediation in Rural Areas

Guatemala is a vibrant country that lies just south of Mexico. It is a hotspot for biodiversity as its wide range of climates and landscapes provide a wide variety of habitats. It is full of hardworking, family-oriented citizens who unfortunately lack access to clean, safe drinking water due to the unregulated pollution of surface waters rather than any physical lack of water. By adapting and integrating modern fish farming techniques with sustainable farming practices and algal based-bioremediation, Guatemala can combat water pollution while contributing to sustainable energy, fighting malnutrition, and addressing other challenges that citizens face.

Guatemala's wide variety of landscapes includes volcanoes, rainforests, fields, and mountains. Unfortunately, some of these landscapes face threats such as deforestation. Guatemala's tree cover has decreased by 20% over the past two decades. The main reason for deforestation in Guatemala is to clear land to grow crops or livestock (Ecosphere+, 2021). Guatemala has no issue with physical water scarcity, although water availability varies with season and location. Aquifers are spread throughout the country, giving citizens access to groundwater (Howell, n.d.). Guatemalans are known to be hospitable people, and members of small towns will often exchange greetings as they pass each other on the street. Guatemalan culture comes from the combination of Spanish and Mayan cultures, with Spanish being the country's official language and families making traditional Mayan meals. This culture is also present in the country's social and gender roles. Men are the heads of the households and are expected to earn the family income. Women use their domestic skills to hold the family together from their homes. Marriage is highly valued in Guatemala, as it determines a woman's social status. Guatemalan families are close-knit, with it being common for extended family members to live with or near their relatives (AFS-USA, 2022). About half of these families live in smaller homes with unstable infrastructure (Guatemala Housing Agency, 2019).

Guatemala was under authoritarian rule before it endured a thirty-six-year civil war that ended in 1974. It is now a republic that has one legislative house. It currently has one of the largest economies in Central America due to past growth. However, this growth has come to a standstill, and efforts from the government to revamp it have failed. This standstill has left many citizens living below the poverty line (Griffith, 2021). Guatemala's rich soil and various climates make it a great place to practice agriculture, with cash crops such as coffee, bananas, and cotton being grown (Nations Encyclopedia, n.d.). It also has good fishing resources in the Pacific ocean and has adopted Asian shrimp farming techniques to practice inland (Lutz, 2021).

Ninety-five percent of Guatemala's surface water is polluted and dangerous for human consumption (Lopez, 2020). This pollution is mainly due to a lack of government funding to regulate and protect its waters. Some of the government's limited funding goes to providing water services in urban areas, leaving the citizens in rural areas with no public investment in water services. One-third of rural Guatemalans do not have access to water sanitation (Lopez, 2020). Ingestion of polluted water can lead to health issues. Oftentimes, these waters contain harmful bacteria and parasites that can lead to potentially fatal conditions such as diarrhea and cholera (Rudrick, 2019). Ninety-four percent of Guatemalans have access to an improved water source close to their homes, but only 46% of the population have a source of clean

water in their homes. Of the 6% that do not have access to an improved water source, a whole 2% drink directly from polluted surface waters (UNICEF, 2020).

Roughly 15,712,000 people live in Guatemala, and 48.16% of them live in rural areas (Food and Agricultural Organisation, 2014). These rural citizens are disproportionately affected by poverty, malnutrition, under-education, and a lack of access to safe drinking water, with rural Guatemalans of Mayan descent being the most affected. Ninety-one percent of Guatemalans in rural areas live below the poverty line on an income equivalent to four or less United States dollars per day, with 75% of those households living off of the equivalent of two United States dollars per day, with the added income from child labor. Up to 20% of Guatemalan children work jobs to add to their family's income and are often taken advantage of and put in hazardous situations (Humanium, n.d.). These income levels may be due in part to the low wages of agricultural workers, which is usually the equivalent of three or four United States dollars a day. There is also a significant issue with education in rural areas, as only 25% of people living in rural Guatemala are literate, and 90% of rural schools do not have books (Guatemala Housing Alliance, 2019). Another major issue in Guatemala is malnutrition, having one of the highest malnutrition rates worldwide, with 48.9% of the children under the age of five being chronically malnourished. Almost 80% of Indigenous children in Guatemalan suffer from malnutrition (ALDEA, 2022). One significant sign of malnutrition is stunted growth, which affects 43% of children under the age of two in Guatemala (UNICEF, 2020). Malnutrition has a devastating effect on a person's physical and cognitive development, especially during early childhood. It can reduce the development of brain structure by up to 40%, cause mental delays, and impede physical growth (World Health Organization, 2006).

An algal-based bioremediation system may help both the environment and rural Guatemalans. Farmers could grow algae using a system of ram pumps and barrage ponds to conduct phycoremediation, provide a less-polluted water source to a nearby village, and utilize mountainous areas where they cannot grow crops. This system would use a ram pump to pull surface water up to the first barrage pond. This pond would be an open pond bioreactor where algae could be grown, harvested, and sold as biofuel. After a time in the open pond bioreactor system, the water would flow into a barrage pond where algae would be grown as fish feed. A screen would keep the algae in this pond to prevent buildup in the tilapia pond and to monitor the amounts of food produced. The algae in this pond would be given directly to the fish without processing. After this pond, the water would fall from a tube into another barrage pond containing tilapia. The fall would aerate the water so that the fish could breathe. By this point in the system, algae would have absorbed the dangerous pollutants from the water, leaving it clean enough to be used in aquaculture. After the third pond, the water would flow into the next barrage pond where algae would be grown as a human health supplement. This pond would need to be manually stirred to prevent algae from settling at the bottom and dying from a lack of sunlight. When the algae is not being stirred, a pothelene sheet would be stretched over the pond to prevent insects from feeding on or breeding in the pond without blocking sunlight. To harvest the algae, farmers would pour buckets of water from the pond into a fine cloth over the pond to drain the water back into the system. Farmers can then press the cloth to remove excess water before being left in the sun to dry. Dried algae would be stored in airtight containers (Government of India, Department of Science and Technology, 2019). Cloth sheets would filter the algae as water flows out of the spirulina pond and flows into a final pond. The last pond would be long and thin with a series of filters to prevent any algae from being introduced to surface waters. These filters would be made by stretching fine cloth over frames that can be put in and out of the pond for regular cleaning or replacement. After flowing through this final barrage pond, the water could either be reintroduced into the surface water or used as a cleaner water source for a nearby village. This system uses gravity and water flow alone to cycle water and farms self-replenishing algae and fish. Due to this, the system would be

entirely free to run once installed, aside from maintenance and the potential need to replace the fish or algae should they die.

The algae grown in the first barrage pond would benefit the environment because it would absorb pollutants from the water, reduce carbon dioxide in the atmosphere, and contribute to a future of clean, renewable energy. The microalgae strain called *Pseudochlorella pringsheimii* would be ideal for this pond because of its high tolerance for pollution as well as its high lipid content, which makes it a good source of biofuel (Kumar, 2021). The algae in the second barrage pond would give farmers a sustainable and easily managed source of fish food that they can give directly to the tilapia. A type of filamentous algae called Pithophora would be ideal for this pond because it will be easy to collect. The third pond would help contribute to Guatemala's aquaculture industry and give rural citizens the choice to sell the fish for profit or use it as a food source in their community. Tilapia would be ideal for this pond because of their tolerance for pollution, ability to survive on a diet of algae, fast growth, and year-round reproduction (Popma and Masser, 1999). The final pond would grow Spirulina algae to provide nutritional supplementation to the rural population in order to lower malnutrition rates. Just one tablespoon of spirulina contains four grams of protein and one gram of Omega-3 and Omega-6 fatty acids. The effects of consuming spirulina include a boosted immune system, reduced inflammation, improved digestive health, and improved muscle strength (Government of India, Department of Science and Technology, 2019). It provides all essential amino acids, is an excellent source of vitamin A, supplies both minerals and antioxidants, and is easy for farmers to grow, process, and sell on a small scale (Tang, G., & Suter, P. M., 2011). Spirulina has a mild, ocean-like flavor that can be disguised by incorporating it into Guatemala's traditional Mayan foods in its powdered form.

This system would benefit Guatemala and the environment. It would lower malnutrition rates in Guatemala, meaning that children would live longer, be less likely to develop illnesses, and that their brain structure development would not be impeded during essential periods of growth. Due to the reduction of malnutrition's harmful effects on mental and physical development, the human capital of rural Guatemala would increase without increasing education or training. Supplementation can also benefit children who already have stunted growth. Despite not catching up with the development of non-stunted peers, supplementation can cause a significant increase in development when taken for two years (World Health Organization, 2006). This system would help the environment by combating air and water pollution while contributing to a sustainable future using renewable energy. Algae absorbs greenhouse gasses such as carbon dioxide, nitrogen dioxide, and sulfur dioxide from the atmosphere (Bagh, S. S., 2015). It then photosynthesizes more efficiently than terrestrial plants due to its cellular structure. Algae naturally filters water, absorbing heavy metal pollutants and fertilizer runoff. It also reduces the number of harmful microorganisms in polluted water (Emparan, Q., Harun, R., & Danquah, M. K., 2019). Some may worry about algae's extraordinary ability to grow in polluted conditions, which has led to eutrophication issues in many countries' surface waters. This system would avoid eutrophication by harvesting the algae regularly to prevent decomposition, keeping the water safe for aquatic life later on.

The people of rural Guatemala need safe drinking water. This sustainable system would achieve that by using renewable resources with the help of something as simple as gravity. It will help farmers decrease the significant issues surrounding them and change the lives of future generations. No child deserves to go uneducated, no parent deserves to be underpaid, and no family deserves to lack the necessary resources they need to live a happy, healthy life. This system, while simple, could change lives in Guatemala while positively impacting the environment.

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