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Ecuador, Oil spills

Bioremediation in Ecuador's Napo river: An environmental breakthrough

As an elementary school kid, I remember we would learn very little about the environment; we were taught about flowers, plants, the water cycle, and animals in our country, but we should have learned about the present concerns rather than hiding all the environmental crises, such as oil spills.

Whenever there's an oil spill, the principal concern revolves around the waste of the product and money, including the recovery of pipes, but most people still don't take into account how much harm to the environment these disasters cause, when this aspect should be the principal concern. Furthermore, the communities that live closest to the polluted water bodies must be a part of the principal concern and they must be provided with enough food and water until the river is cleaned and medical attention post-spill; for example, Quechuas/Naporunas in Napo river, located in Ecuador and other South American countries (BDPI, 2013).

The Quechua or Quechuas are found in most of the countries in South America, but the ones in Ecuador make up 20 000 indigenous people in total – which is 12% of Ecuador's total population –. Counting with 842 882 farms in the entire country; a small number compared to the 2.02 million farms in the U. S.. Their population profits mostly from agriculture, growing many types of fruits, vegetables and seeds like coffee, bananas, strawberries, cacao, potatoes and asparagus due to the advantages of the climate of the latitude the country is located in, which we can infer by the name of the country: right on the Equator's latitude (Flynn et al., 2020).

Ecuador has several variations in altitude, which also causes variations in climate. Lowlands are generally hot and damp that go from 65°F to 90°F, the temperatures in the Sierra are cool going from 35°F to 75°F, which in direct sunlight can reach up to 85°F during the noon, whereas in the evenings the temperature decreases. The mountains always have snow, it hails sometimes but it never snows on inhabited altitudes. Ecuador's total area covers 109 483 square miles, the land area 106 888 square miles, the water area 2 595 square miles and the coastline covers 1.390 miles. The geographic coordinates are 2' 00 S, 77' 30 W and the highest point is 20 561 feet tall (Hernández et al., 2022).

These communities require bigger housing and more resources than an average family in the U. S., which consists of 3.14 members per family, whereas the average size of a Quechua family has 6 members. Their housing dwellings have tall, arrow-shaped ceilings that keep the heat on the top, covered on the outside with palm tree fiber put together that represent plants and jaguars, capped with thick leaves and the houses' entrances are built with animals' bones embedded on the floor as charms to protect from the rain, sunlight and strong winds as well as mischievous spirits roaming within the jungle. The windows face the dawn, the jungle and the river – all life-giving bodies. Other houses are built with adobe mostly with ceilings nowadays built with tiles instead of thatch (Greenfield et al., 2020).

Some Quechuas help build other community members' houses, grow vegetables and fruits, trade, do pottery, textiles and accessories for a living. The average wage per hour in the Napo province, where many Quechuas live is 2.36 - 2.48 USD; shown in the image below (Stephenson et al., 2012).

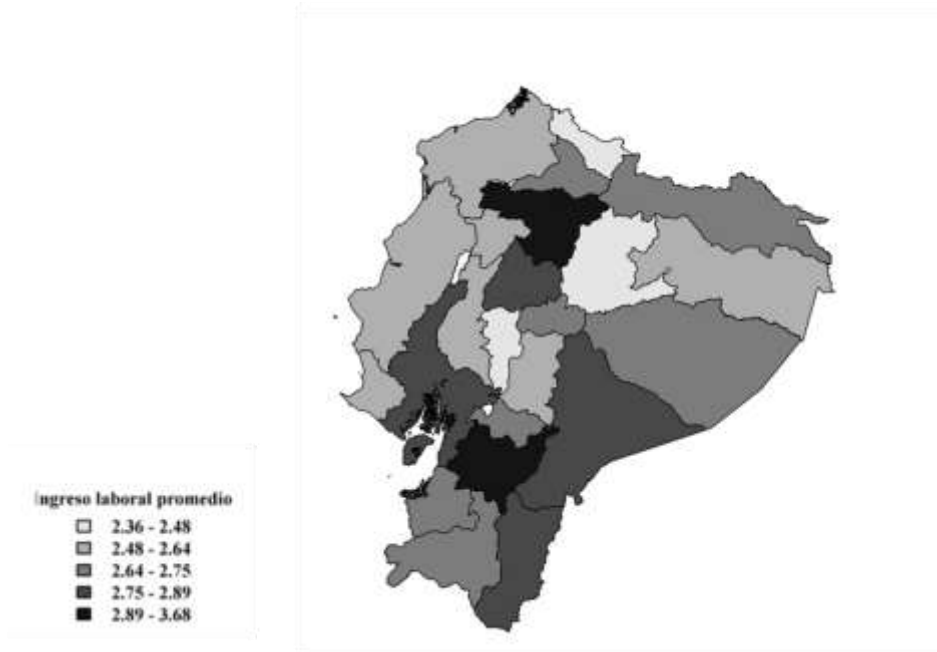


Figure 1
Average wage per hour in Ecuador's provinces in 2020 (Ontaneda, 2020).

Even though Quechua/Naporuna communities make up 12% of Ecuador's total population, health care and education are not always provided to them. 88% of indigenous households live in poverty conditions; this is reflected in the maternal and infant mortality rates, 1 in 10 children dies before their first year born. One of the causes of impoverishment is the lack of education, since women receive up to 2 and a half years of education and men receive up to 4, when the national average is 7.1 years. In solidarity, an Ecuadorian NGO started a health care center for indigenous people, called Jambi Huasi, combining standard medicine with local medicinal plants (Stephenson et al., 2012).

The demand for drinking water is exhausting the water sources for Quechuas due to climate changes, according to experts. Water is needed not only for human consumption but for livestock consumption, e.g. llamas and alpacas and for agriculture. Most rural homes lack clean water access, while the big cities in the region have access to it and have developed roads (Fraser, 2009).

Nowadays more than 60% of the people living in the Amazon, which Quechuas are close to, own a television, a radio and refrigerator (Sellers et al., 2017).

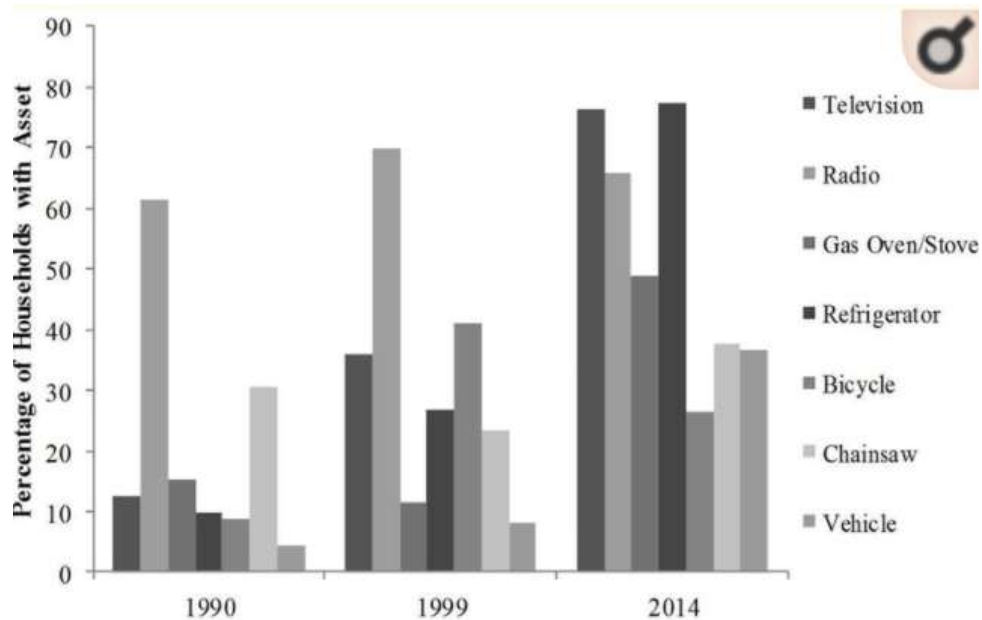


Figure 2
Comparison of surveyed appliances in the Ecuadorian Amazon households in 1990, 1999 and 2014 (Sellers et al., 2017).

Ecuador’s main rivers are Napo and Pastaza, located in the Northeast across Peru and Colombia. Their main exporting partners are the United States, Italy, Panama and Peru. Oil is also one of the products that is exported more abundantly to these countries (Flynn et al., 2020).

Oil spills are major crises to a country because they affect it in three aspects: human’s health, ecosystem’s well-being and economy. First of all, the aspect with most importance is the harm caused to the ecosystem, because it includes plants, animals, water bodies, air and microorganisms on which humans depend for hunting, fishing, harvesting. All in all, we depend on ecosystems to survive. Humans’ health is affected because if oil gets in direct contact with the skin, it may lead to severe irritation, also in the eyes, dryness, cracks, burns and dermatitis, moreover the access to water and food for humans and non-human animals is restricted, since their sources are contaminated and blocked by the oil’s damage until the areas are clean and recovered to be safely handled again (Tapia et al., 2021).

The oil enterprises’ economy is also greatly affected, due to the great amount of money that traditional procedures to clean up oil spills require, for example using oil booms, skimmers, burning the oil, etc. To add more, the average volume of medium size oil spills is 700 metric tons (Sönnichsen, 2022).

A recent oil spill in Napo that took place in April, 2021 affected just about 2000 indigenous families and around 15 thousand gallons of oil were spilled. These events are very common in the Ecuadorian Amazon and Napo, but according to ‘Our World in Data’ their frequency has increased (Tapia et al., 2021).

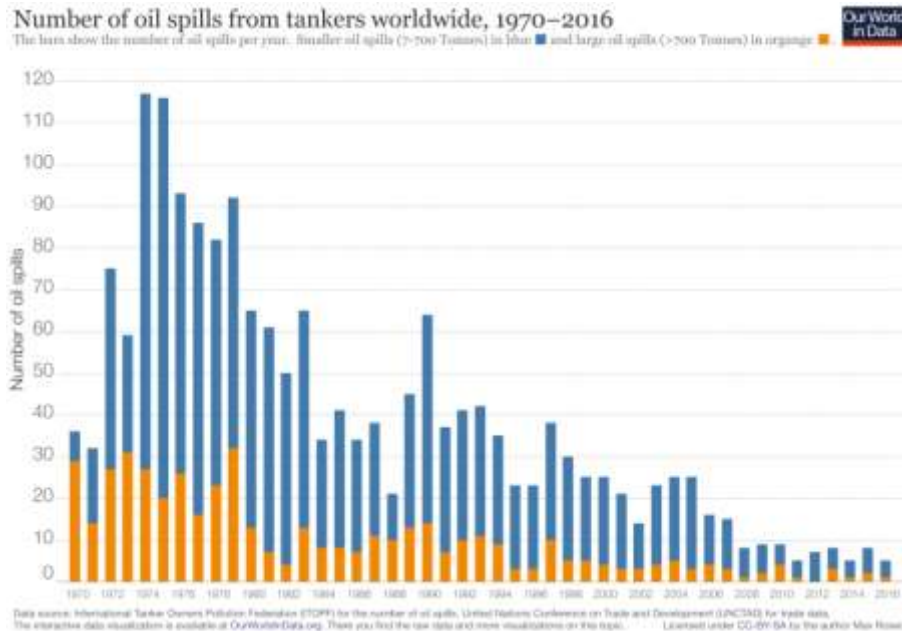


Figure 3
Number of oil spills vs. Year, 1970-2016 (World Bank, 2016).

Most oil spills are caused accidentally by barges, pipelines, refineries and storage facilities when equipment is broken, natural disasters or wars take place in a closeby area or acts of vandalism or illegal dumping are committed. Some parts of the spilled substance sink and others become thinner the more they spend on the surface of water, thus, fish, sea turtles, marine mammals and birds might suffer irritations on their skin and system after touching it or swallowing it, and eventually die from poisoning or their growth and reproduction rates lower(API, 2022).

Oil on land prevents the absorption ability on soil and can kill plant life in some communities. In urban environments, the priority after oil spills is human health and the restoration of the site for it to be used again normally as soon as possible. The oil can reach groundwater, sewers and rivers. Erosion occurs on the land and water bodies, thus their primary source of food which is fishing, is cut off. Children are affected differently from elders and adults, because they go fishing and are the ones that suffer from the skin diseases (Tapia et al., 2021).

The average amount of tons spilled by barges and refineries has lowered since the 1970s from 340 000 to 21 000 since the beginning of the 2000s to even 100 tons a year in 2009, but even so, this problem has become greater after the beginning of the pandemic, because not only do they need to be confined in their communities, but they also have to find ways to get food when the crops and rivers are polluted, so they have to risk getting infected by looking for food in the nearest towns. In 2021, a year after the beginning of the pandemic, indigenous communities still faced food and water insecurity (Tapia, 2021).

Furthermore, the marine spills caused by leaks and broken pipelines have increased from 47 spills per year in the late 1960s to 278 spills per year since the 1980s. These kinds of spills are caused because of the pipelines' abundance and pumping stations' aging (Jernelöv, 2010).

In the island of Scilly of Cornwall in Torrey Canyon in 1967 a wide oil spill happened, which was handled in the least environmentally clean way: The oil was bombed and burnt with napalm and not

much oil was eliminated because the oil and water particles were already united. 10 000 tons of dispersants were sprayed on land and water and instead of helping the wildlife, it worsened the situation because it made the oil even more toxic (Jernelöv, 2010).

The most toxic and persistent amounts of oil are the ones stranded on coasts and wetlands, however, oil spreads out in a thin layer on the surface of water and thanks to natural mitigation, it can evaporate or dissolve. The waves help break up the oil molecules by turning them into smaller droplets (this is why water becomes brown), helping it follow its natural degrading process more easily; UV rays can also contribute to it (Jernelöv et al., 2010).

There are already several methods that help clean oil spills, but the most used techniques aren't necessarily the most effective ones. For example, oil booms and skimmers contain the spill and remove the oil but are extremely expensive (Oil Skimmers, Inc., 2022). A 42 inch long oil boom costs 75 USD, and an average oil spill may take up approximately 3280 square feet, which would require more than 100 oil booms of the mentioned size. A single skimmer costs around 600 USD and can be easily clogged (ULINE, 2022). Then, the cost for covering the perimeter of an average oil spill would be at least 7500 USD depending on how many techniques would be used.

Another solution would be using dispersants, sorbents and burning the oil, but as I mentioned previously, burning isn't the cleanest way to remove oil and it may not be the most effective method in some cases. Sorbents and dispersants can harm the ecosystem's marine life (especially corals) and they may make the oil sink; although, they are able to disintegrate oil molecules and absorb liquids (SkyTruth et al., 2021).

Bacteria have been used to degrade waste products in ecosystems because of their low cost and eco friendly characteristics. This method for cleaning oil spills is called Bioremediation, for which living beings help. These need carbon and the energy in it to grow and reproduce. Just as bacteria eat the remaining sugar inside our mouth, the bacteria in this proposal consume oil's components by degrading them using enzymes and oxygen in their system and end the process by producing carbon dioxide, for example, like plants produce oxygen (Biello, 2010).

The principal bacteria that contribute to the removing of oil are: *Colwellia*, that feeds off of ethanol, *Cycloclasticus*, which consumes aromatic hydrocarbons, *Oceanospirillales*, that degrades alkanes, and *Alcanovirax*, which consumes oil (Beillo, 2015).

Almost none can degrade an entire fraction of oil, most can degrade specific components which makes them more sensitive to big masses of oil. So multiple species are needed to clean as much oil off as possible and it becomes a long process. Some of these bacteria may be found in marine trenches and other types such as *Alcanivorax borkumensis* can be found naturally on the surface of the ocean and as soon as they find oil, they degrade it and produce carbon dioxide and water. When fertilized with Nitrogen or Phosphorus, they grow in size, number and appetite; although the amount of fertilizer should not exceed a limit because otherwise they could take up oxygen and create dead zones (Little, Sheppard, & Hulme, 2021).

This proposal would take action immediately after stopping the leakage of oil from the corresponding source by the stimuli of said bacteria using a Nitrogen (10 mg/L, maximum) or Phosphorus (0.25 mg/L, maximum) seachem, which is environmentally friendly, because it is used in aquariums to help the

living being be nourished with this element. After that, all that's left is to wait for the oil to dissolve in a few weeks, depending on the polluted surface (Gatiboni et al., 2019).

Hydrocarbon degrading bacteria already exist in their own ecosystems, but they can be stimulated through the use of non-toxic dispersants, oxygen, fertilizers such as iron, nitrogen, and phosphorus – as used in the Exxon-Valdez spill in Alaska –, and by water currents to turn oil into nutrients for themselves (Biello et al., 2010). The dispersants divide the oil into smaller droplets, making it easier for the bacteria to degrade them. This method has an effectiveness of 95 to 100% over the course of three weeks in a single application and the price for cleaning a gallon of spilled oil is approximately 2.67 USD. Bacteria can also be added to water bodies to increase the effectiveness of this method (Editorial La República, 2015).

For bacterial culturing, the totality of the chosen bacteria have to be contained in a gel called 'medium' with the right temperature conditions and preventing the entrance of contaminants. They can also be cultured in plates by colonies (Hartsock, 2022). To transport them, antimicrobial agents may be added, the specimens have to be labeled, they need to be at room temperature and be collected and delivered at a specific time in leak-proof containers (Becton, Dickinson & Company, n.d.).

Another example of an oil spill that was cleaned mainly by these cosmopolitan bacteria through bioremediation was the Deepwater Horizon spill in the Gulf of Mexico (Biello et al., 2010).

Over time, hydrocarbons oxidate, become less toxic, and lose their pollutant properties according to Ricardo Aguilar, Director of Investigations of Oceana Europe. Whereas the Responsible for Greenpeace Pollution Campaign, Sara Del Río, argues that not cleaning oil spills causes a catastrophe, for which it must be removed in the most sustainable ways, avoiding the use of chemicals. For example, regular dispersants, such as Corexit 9527A, contain 2-butoxyethanol, a carcinogenic solvent to humans and non-human animals and other dispersants can end up killing the needed bacteria, fungi, and enzymes.

The Ecuadorian government already has a program for the prevention of oil, fuel and toxic chemicals spills, which is planned to be carried out through the correct disposal of said waste for individuals and official deposits, but doesn't promote reducing the use of fossil fuels in the country (,), so that is an aspect the country can work on and also opening volunteering opportunities for people to learn about the effects of oil spills and how they can help to prevent and remediate once they happen.

The traditional methods for removing oil from polluted water bodies tend to have a very high price, not a very high effectivity and cause great damage to ecosystems all around the world rather than helping them, for example when the oil is burnt and explosions are caused, great masses of greenhouse gasses are emitted and that can be avoided. These spills are another reason why fossil fuels should stop being used so frequently and renewable energies have to be more accessible and affordable to every country.

This method is proof that sometimes, humans don't need to try to intervene in order to "make things better". We can help as humans, to stimulate the environment bacterias are in to degrade hydrocarbons so that it becomes easier for them to remove as much oil as possible, but in fact, the bacteria themselves complete this process naturally in order to survive.

This method is an active way companies and environmental sponsors or NGO's can participate to mitigate climate change and improve the access to water and food for indigenous communities like Quechuas in Ecuador. Even gasoil companies can benefit from it, because since they could help become

a more sustainable organization, more people that follow also sustainable principles may pay attention to them.

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