Water Filtration, Before and After

A Converging Emergency in Water, Food, and Public Health — and a 2,200-Year Precedent

Working paper · Azul Nanotec, LLC · 2026 Luis Arturo Aguirre, Founder Austin | Hawai‘i | Guatemala | Belize

Filtrar lo que sale. No sólo lo que entra.

A note on this paper

This is a working paper, not a finished study. It is written by an engineer, not an epidemiologist or archaeologist. Some of what follows is well established and cited. Some of it is inference drawn from separate bodies of evidence that have not yet been formally connected. What it asks is whether the convergence of data that already exists — on water, on food, on cancer, and on coral — is sufficient to act. The author believes it is.

Corrections, disagreements, and better data are welcome and actively sought. This paper improves by being challenged.

I. The Emergency Is Now

Guatemala has among the highest liver cancer incidence and mortality rates in the Americas (GLOBOCAN 2022; Kihn-Alarcón et al.). This is not a historical observation. It is a current public health emergency with measurable causes converging in the same population, right now.

The food side

Aflatoxin is present in Guatemalan maize today. A 2022 cross-sectional study of 141 tortilla makers in five Guatemalan departments found widespread aflatoxin contamination in traditionally processed maize. Smith et al. (PLOS One / Johns Hopkins, 2017) found that virtually all sampled Guatemalan adults carry measurable aflatoxin biomarkers, with levels among the highest reported globally. Aflatoxin B1 is classified by IARC as a Group 1 carcinogen — it causes hepatocellular carcinoma. In high-exposure populations it presents at 35–45 years of age, not the 60+ typical of low-exposure countries.

The water side

Cyanobacterial blooms occur in Lake Atitlán and Lake Amatitlán and in waterways across the country. UNEP and national reporting indicate that the large majority of surface waters carry fecal contamination. The cyanobacteria produce microcystins — hepatotoxins that are not destroyed by boiling. Mrdjen et al. (Toxins, 2022) have directly linked cyanotoxin ingestion to liver cancer development.

The convergence

Both toxins — aflatoxin from stored maize and microcystin from contaminated water — target the liver. Both interact with the same cytochrome P450 metabolic machinery. The honest summary is that co-exposure to these two hepatotoxins is common in this region, that the mechanistic grounds for synergy are serious, and that no published work has directly tested the interaction in a Guatemalan population.

This is not a mystery to be solved before acting. The individual pathways are each sufficient cause for intervention. If they synergize, the urgency is greater. If they don't, every separate intervention is still justified by its own evidence.

The reef

Downstream, the Río Motagua carries untreated discharge across 450 km to the Gulf of Honduras. Eighty thousand cesspools in the watershed each contribute. The Mesoamerican Barrier Reef — the second largest in the world — receives it. In Hawaiʻi, the same pattern: 80,000 cesspools on the Big Island alone, discharging into coastal waters where coral is already stressed.

As Cindi Punihaole, Director of The Kahaluʻu Bay Education Center, Hawaiʻi, said: "And no one is working on a solution."

II. Three Geographies, Three Problems, One Principle

It is worth being precise about terrain, because the engineering answer depends on it.

Guatemala City barrancos (~1,500 m)

Tens of thousands of households on unstable slopes without any toilet. No sewer extension possible — the terrain is too steep, tenure informal, cost prohibitive. No safe pit — a soakaway saturates the slope, and Guatemala's worst disasters (Mitch, Stan, Eta, Iota) killed through landslides triggered by saturated hillsides, not wind.

Volcanic highlands (1,500–1,900 m)

Communities on slopes above waterways with limited or no sanitation infrastructure. Greywater from pilas and kitchens discharges directly to the surface. Volcanic soil is deep and porous — a natural advantage for contaminant attenuation between daily rain events, but only if discharge is managed at the source.

Petén lowlands (~200 m)

Porous karst limestone. Water moves through fractures. Surface reservoirs in a hot, humid climate produce ideal conditions for both cyanobacteria growth and aflatoxin development in stored maize. This is the environment where the problem is most acute and most ancient.

The principle

In all three geographies, the same conclusion: where collection networks are impractical or impossible, each household must contain its own outflow. **Filter what comes out. Not only what goes in.**

III. What We Are Doing About It

The Waterlily Jaguar distributed sanitation system treats every household outflow at its source:

- **Greywater tower** with graded media and a 20 × 40 nm nanoporous membrane (Jaguar cartridge) — removes bacteria, parasites, microplastics, and the particle-bound fraction of pharmaceuticals. Gravity-fed, no electricity.
- **Double-vault dry toilet** — urine-diverting, alkaline desiccation, no water consumed, no discharge to the water table. Built for squatting, not sitting, because that is how people here use a toilet.
- **Passive rain-hold valve** — holds treated effluent during the daily rain event so it doesn't mix with runoff.
- **Nutrient return** — urine diluted 1:5 to corn, coffee, avocado. Cured vault solids to tree crops and patio soil.

Built from locally appropriate materials. The design is open (CC BY-SA 4.0). The membrane is proprietary, sold at cost in countries that cannot afford the commercial price until R&D is recovered.

Each unit is a containment node. At 80,000 units across the Motagua basin, the watershed cleans itself.

The system is named for the Water Lily Jaguar of Classic Maya iconography — the guardian of clean water, cenotes, and underground streams. If the system works, waterlilies grow in the output stream. The biological indicator and the cultural symbol are the same thing. The Jaguar earns its waterlily.

IV. The 2,200-Year Precedent

This is not the first time this region has faced this problem. It is a repeat.

The first filtration engineers

In the Popol Vuh, the creation narrative of the K'iche' Maya, the gods formed the first successful human beings from maize. The civilization that defined itself by corn also became the first in the Western Hemisphere to engineer a water filtration system — and the earliest known example of zeolite filtration on Earth.

At the Corriental reservoir at Tikal, archaeologists found zeolite (clinoptilolite and mordenite) with coarse crystalline quartz sand, in sediment layers dated to approximately 2185–965 years before present. Neither mineral occurs naturally at the site. Both were transported roughly 30 km from the Bajo de Azúcar area, where the water was locally known to be clean (Tankersley et al., Scientific Reports, 2020).

The Corriental system predates Sir Francis Bacon's documented sand filtration experiments (1627 CE) by nearly two millennia and anticipates the materials now standard in modern water treatment.

When filtration was not enough

Despite their engineering, the Maya of Tikal could not outrun the consequences of their own growth. A 2020 study (Lentz et al., Scientific Reports) analyzed sediments from four major reservoirs and found:

- Mercury contamination in the Palace and Temple reservoirs — traced to cinnabar pigment washing off the buildings
- Cyanobacteria (Planktothrix and Microcystis) producing boiling-resistant microcystins
- Peak contamination coinciding with peak population, just before abandonment

The Corriental reservoir, with its zeolite filtration, stayed clean. It was the only excavated reservoir at Tikal with a filtration system, and the only one that remained uncontaminated.

The maize intensification trap

Stable isotope analysis of 50 burials at Cahal Pech, Belize (Ebert et al., Current Anthropology, 2019) shows that during the Late Classic, elite diet shifted from diverse (mixed forest foods, game, fish, and maize) to hyperspecialized maize monoculture — a "rigidity trap." The commoners actually diversified during drought while the elites doubled down on corn.

More maize meant more nixtamalization (lime treatment), which meant more lime kilns, more deforestation for fuel, and more calcium-rich wastewater into the reservoirs — driving the nutrient loading that fed the cyanobacteria. The same substance that made corn safe to eat helped make the water toxic.

The honest confound

Corriental's catchment was also farther from the mercury sources. Perdido, likewise distant, was cleaner without filtration. So Corriental's cleanliness is attributable to both filtration and a favorable catchment.

This does not weaken the argument. It sharpens it. **Catchment determines water quality. Treatment at the intake only operates on what the catchment has already delivered.** That is why the modern intervention must work on the output, not the input.

V. What Has Changed in 2,200 Years

Two capabilities exist today that the Maya did not have.

The first is engineered nanoscale manufacturing. The Maya filtered at the molecular level using the natural pore structure of zeolite. We can now manufacture precise pore geometries at 20 nm — smaller than any virus, smaller than any bacterium, smaller than any parasite.

The second, and arguably more important, is measurement. The Maya could not quantify microcystin concentrations, aflatoxin biomarkers, or nutrient loading rates. We can. And measurement is what turns a plausible story into knowledge. Colleagues at the Universidad del Valle de Guatemala have already characterized the Río La Campana micro-watershed — its morphometry, its water quality parameters, its contamination profile — and published that baseline (Revista UVG No. 38, 2019). That is precisely the kind of *before* picture that makes it possible to measure whether an intervention works. What is missing is the study that connects the pieces — and the intervention that gives the *after*.

VI. What We Are Asking For

Not funding, at this stage. Three things:

Correction. Where the data, the reasoning, or the priorities above are wrong — before resources are committed.

Data. Field monitoring records from existing sanitation installations, water quality baselines, and honest accounting of what has been tried and what failed. The most valuable data may be the simplest: which toilets were abandoned, and why.

Partnership. With Guatemalan universities, municipalities, engineering firms, and community organizations. And with researchers willing to co-author, challenge, and extend this work.

VII. This Is Not Archaeology

The Classic Maya political order did not survive the convergence of water contamination, food risk, and climate stress. Guatemala today faces the same convergence — with additional modern contaminants the Maya never had. The data is not a mystery to be investigated. It is a pattern repeating in real time, in the same place, to the same people.

The author's interest is currently in helping build a solution to mitigate ocean water contamination that currently exists in Hawaiʻi. It turns out that the research data that we have seen in Guatemala points out that it will also help Mesoamerica.

The hombres de maíz are still here. The volcanic materials are still here. The engineering tradition that produced the world's first zeolite water filter is still here, in the same country, in the hands of its descendants.

That is not destiny. It is a starting point.

My experience in life has many times showed me that you cannot solve a problem until they are ready for a solution. As Cindi Punihaole, Director of The Kahaluʻu Bay Education Center, Hawaiʻi, said in our last meeting: "And no one is working on a solution."

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