Investigating the Effect of Low-Frequency Sound in Enhancing the Efficiency of Water Generation in Thermoelectric Atmospheric Water Generators (TEAWGs)

PROBLEM & SCALE

Over **4.5 billion people, more than half of the global population, lack access to safe water**. This has led to over 1.4 million deaths in the past year from dehydration alone. Including indirect deaths from lack of sanitation and increased disease outbreaks, that number exceeds **4.5 million annual deaths**.

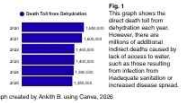


Fig. 1
This graph shows the direct death toll from dehydration each year. However, there are millions of additional indirect deaths caused by lack of access to water, such as those resulting from infection from inadequate sanitation or increased disease spread.

Graph created by Ankith B. using Canva, 2026

CURRENT SOLUTIONS

P&G Water Purifier

Pros:
- Removes bacteria, viruses, parasites, and heavy metals

Cons:
- Single-use
- Doesn't remove fuel contamination, salt, or chemicals

LifeStraw

Pros:
- Removes bacteria and parasites
- Lightweight and portable

Cons:
- Doesn't remove viruses, fuel contamination, salt chemicals, heavy metals, sal

Atmospheric Water Generators

Pros:
- Creates **clean water with no bacteria, viruses, parasites, fuel contamination, salt, chemicals, or heavy metals**
- **Doesn't require an existing water source** to produce clean, drinkable water
- Continuous, **renewable supply**
- Works in **any humidity**

Cons:
- Varies based on type of AWG (Detailed in Background Research)

BACKGROUND RESEARCH

Atmospheric Water Generators

AWGs (Atmospheric Water Generators) are devices that act as long-term infrastructure that can extract moisture from the atmosphere to generate safe, clean water.

There are two main types of AWGs: Desiccant-Based AWGs and Thermoelectric Atmospheric Water Generators (TEAWGs)

Desiccant-Based AWGs

A moisture-absorbing material (desiccant) captures water vapor in the air. Then, the soaked desiccant is heated to release water vapor, which is cooled to form water.

Pros:
- Works well in low humidity (<50% RH)

Cons:
- While the desiccant is being heated, it cannot absorb water, leading to a lower water collection rate
- Faster degradation of the machine compared to other AWGs

Thermoelectric AWGs (TEAWGs)

A machine that cools a heat-conductive metal below the dew point of water such that when air touches the plate, the water vapor condenses into liquid water.

Pros:
- Works well in high humidities (>50% RH)

Cons:
- Current TEAWGs lack the water output rate needed to scale efficiently
  - This is because water occupies more space on the condensation plate as droplets, leaving less area available for water generation. After the water is generated, during collection, some of it is lost due to the surface tension that prevents water from being fully collected.

I decided to focus my project on TEAWGs instead of Desiccant-Based AWGs because **~71% of the population that lacks access to safely managed water lives in humid or semi-humid areas** with a humidity above 50%.
While desiccant-based AWGs are far superior to TEAWGs in dry climates, **TEAWGs are far better than Desiccant-based AWGs in humid areas when comparing water outputs**. Also, TEAWGs can condense water continuously without requiring a regeneration cycle like Desiccant-Based AWGs.

ENGINEERING GOAL

The goal is **to design a custom modification for a self-built TEAWG that utilizes low-frequency sound to increase water generation efficiency** by a minimum of 15% compared to a no-sound baseline.

Design Criteria for the Modification:
- Uses Low-Frequency Sound
- Increases Water Output by more than 15%
- Reduces Energy Consumption compared to a Motor by a minimum of 50%
- The acoustics system uses less than 5% of the TEAWG's total energy consumption

DESIGN & METHODOLOGY

Design Process

DESIGN

After conducting extensive research on how TEAWGs work, I used this knowledge to **create a 3D design of the actual prototype.**

The design combines the base of a TEAWG with extra components that allow it to run with or without low-frequency sound of varying wave shapes.

HEAT TRANSFER

$q_x = -kA\,(dT/dx)$
q_x is the Rate of Heat Transfer
A is the Conductor's Cross-Section Area
k is the Thermal Conductivity Coefficient
(dT/dx) is the Temperature Gradient

I was able to use this formula to calculate the optimal size of the TEAWG based on the cooling system and metal used for the condensation plate.

BUILD & ITERATE

I used my design to build the prototype.

However, **during the build, I ran sample tests and found multiple design issues that I fixed to make the prototype run more efficiently.** For example, I removed the cooling system's fan, added insulation to the heat sink, and removed the inward fan from its original cutout.

After multiple iterations and sample tests, the prototype was ready for official trials.

TEST & ANALYSIS

To test efficiency relative to the baseline, I ran 15 four-hour tests.

- **Five of these tests had low-frequency sine waves of 60Hz and 60 dB.**
- **Five of these tests had low-frequency triangle waves of 60Hz and 60 dB.**
- **Five of these tests had no sound.**

During these tests, factors like location, relative-humidity, temperature, etc. were kept constant.

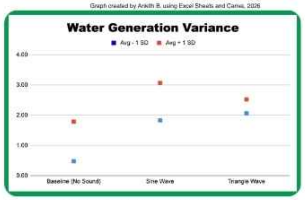
DATA & ANALYSIS

Table created by Ankith B. using Google Sheets and Canva, 2026

	Water Generated in grams (four-hour trials)		
	Baseline (No Sound)	**Sine Wave** (60 Hz, 60 dB)	**Triangle Wave** (60 Hz, 60 dB)
Trial 1	1.10	1.91	2.56
Trial 2	1.21	3.43	2.38
Trial 3	2.16	2.14	2.09
Trial 4	0.81	2.67	2.42
Trial 5	0.39	2.09	2.02
Average	**1.13**	**2.45**	**2.29**
Std Dev	0.66	0.62	0.23
Avg + 1 SD	1.79	3.07	2.52
Avg - 1 SD	0.48	1.83	2.06
		p-value of 0.0115 over Baseline	**p-value of 0.0137 over Baseline**

Constants: Location, Trial Duration, Temperature, Humidity, Setup

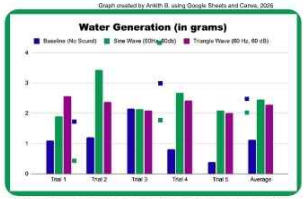
Graph created by Ankith B. using Excel Sheets and Canva, 2026



This graph shows that the average minus one standard deviation for the TEAWG enhanced with sine or triangle waves is greater than the average plus one standard deviation for the baseline TEAWG.

This confirms that the use of low-frequency sound consistently produces significantly higher water yields than a no-sound baseline even after factoring in data distribution.

Graph created by Ankith B. using Google Sheets and Canva, 2026



This graph shows a consistent overperformance of sine in comparison to triangle and triangle in comparison to the baseline.

RESULTS

The results surpassed the engineering goal

+ 117%
Sine Wave
Image created by Ankith B. using Canva, 2026

+ 103%
Triangle Wave
Image created by Ankith B. using Canva, 2026

77.3% Energy Reduction
Against an Equivalent Motor
Image created by Ankith B. using Canva, 2026

0.0115
p-value: Sine/ Baseline
Image created by Ankith B. using Canva, 2026

Sine Waves led to a Higher Average

The use of 60 Hz 60 dB sine waves in the TEAWG resulted in a 117% increase in water production with a p-value of 0.0115.

Image created by Ankith B. using Canva, 2026

0.0137
p-value: Triangle/ Baseline
Image created by Ankith B. using Canva, 2026

Triangle Waves led to Increased Consistency

The use of 60 Hz 60 dB triangle waves in the TEAWG resulted in a 103% increase in water production, with a p-value of 0.0137.

Image created by Ankith B. using Canva, 2026

Electrical Efficiency

Speaker Energy Consumption: The energy consumption of the speaker used was calculated to be **around 2-3W for a four-hour trial.**

Equivalent Motor Energy Consumption: The energy consumption of an equivalent motor was calculated to be **around 10-12W for a four-hour trial.**

Compared to an equivalent motor, the speaker consumed 77.3% less energy.

Baseline Energy Consumption: The energy consumption for the entire TEAWG with no sound was calculated to be **around 150W for a four-hour trial.**

In comparison to the baseline, the use of low-frequency sound was also extremely electrically efficient as it generated 117% more water while only consuming 1.6% additional electricity.

CONCLUSION

Real-World Scalability

Because the **sound energy in a TEAWG scales with the volume of the TEAWG** and not the condensation plate's area, an increased volume would lead to a percent increase in water generation much greater than that of a smaller model.

In addition, **low-frequency sound waves would allow for increased conductive heat transfer**, further increasing sound's impact

Speaker Waste Heat: Every speaker produces waste heat, which I could not account for. However, while this wasn't accounted for, large-scale TEAWGs could separate the waste heat from the low-frequency waves, enabling a lower temperature and more condensation, thereby increasing the 117% and 103% percent increases.

Speaker Frequency Variation: Small-scale speakers cannot perfectly reproduce low frequencies, so when scaled up or applied in the real world with a higher-quality speaker, the percent increases of 117% and 103% would actually increase even more.

For these reasons, **when scaled up, the percent increase in water generation in comparison to the baseline would far exceed 117%.**

Real-World Applications

Off-Grid Homes
650+ Million People
Image created by Ankith B. using Canva, 2026

Low-Income Areas
3.7+ Billion People
Image created by Ankith B. using Canva, 2026

Disaster Relief
830+ Thousand People
Image created by Ankith B. using Canva, 2026

Military Operations
4.3+ Million People
Image created by Ankith B. using Canva, 2026

Millions of lives annually could possibly be saved, along with helping over half of the global population.

While these are some of the more prominent ones, these aren't the only ones.

Future Work

For future research, I would like to use my TEAWG prototype to:

1. Conduct research on different wave shapes and **determine the optimal shape** for maximizing water generation. (Sawtooth, Square, etc.)
2. **Direct sound waves more efficiently at the condensation plates by incorporating parabolic reflectors.**
3. Test whether deploying **multiple sound sources can cause positive interference** and improve water generation efficiency.

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