Vayu Jal

Air Water

Atmospheric Water Generator

Extracting water from the air

to provide

Safe Drinking Water

to

Water-starved Communities

by

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A Dream

Addressing Water Scarcity and Water Crisis Situations to Bring Immediate Relief

The ability of the human mind, to detach from the known framework of reality and ordinary, allows it to conjure images of what possibilities lie beyond the known. This ability lies at the heart of humanity's ability to create, invent and engineer. Devices and machines that enable every activity today, such as aircraft, drugs and pharmaceuticals, even the internet, are all results of a dream battling the common framework of the society at the time. It was the end of the battle that brought out their tangible manifestation.

The remote, isolated pockets of human settlement spread across India, detached from quality lifestyle and civilisation lacking fully-functional connectivity for even essential utilities, is home to numerous dreams with exceptional untapped potential. One such area hosted the India Nationals Interschool Soccer Tournament where lodging and infrastructure arrangements were a stark contrast to the facilities available at metropolitan cities such as New Delhi. The absence of basic necessities gave impetus for new ideas and inventions to emerge.

Three hundred fifty female students had participated in the tournament, and each team accompanied by a teacher in charges as well as sports coaches. The classrooms of the run-down school converted into makeshift rooms, housed 14 students per room. The biggest challenge, however, was the availability of just one restroom between almost 100 young female students.

A power outage on the first day of practice brought the inevitable fiasco with the water supply running out. The electric motors that fed the water supply line had not run through the day and by the evening, players were left with no water to drink after a hectic practice. In what seemed like a theatrical diversion from the core issue, everyone experimented with an ancient Yogic technique that sages used in the Himalayan mountains when they were thirsty but could not break their meditation. This technique got the students to sit still and calm themselves by focusing on their breath. Once relaxed, they needed to dampen their lips and then take in some air, very slowly. The moisture on the lips coupled with the cold winter air created a cooling effect in the throat and mouth, reducing their need for water. The diversion laid the foundation for the concept of the atmospheric water generator – Vayu Jal.

What was left was to explore a way to recreate the same phenomena mechanically. If the human body could harness water from the air, would it not be plausible for a device to control airflow and temperature, to collect water from it. The scope of such a device to aid water scarcity and water distress situations, particularly in communities with marginal resources, would be limitless.

This compilation is a detailed account of how the dream of constructing a mechanism to extract water from the air came to fruition. The valuable support and contribution of the management and teams at Perfect Air Conditioning Trading Company, DeltaPure Water India Limited and Cool Breeze Aircon Pvt. Ltd. made the project a success.

A Mission: The Aim

United Nation's Sustainable Development Goal Number 6: Clean Water and Sanitation [1]

- To create clean water provisions in remote areas where the main water supply line is unavailable or inefficient
- To generate at least 20 litres of water a day an average quantity, enough for a family of 4 for drinking and cooking
- To engineer a durable and cost-effective mechanism that draws air and generates water

One piece successfully installed at Naya Prayas Pahal School at GB Road, the red-light district in New Delhi, in February of 2020 encouraged initiating mass production. Initially scheduled to begin in April 2020, a nationwide lockdown imposed to restrict the spread of COVID19 March 2020 onwards, obstructed the community deployment phase of the Vayu Jal. The deployment will resume in Spring 2021 tentatively.

Summary of stages of development:

Figure 1: Stages of Development

ABSTRACT

An atmospheric water generator (AWG) [2] is a device that extracts water from humid atmospheric air based on dehumidification / condensing technology. Extracted water undergoes a filtration and purification process, making it safe for human consumption. In the AWG, atmospheric air cools down with the help of a refrigerant which decreases the air temperature below its dew point, causing water vapour in the air to condense. It passes through a filtration system, and pure drinking water gets collected in a storage tank.

The objective of this project is to supply pure drinking water to those areas where potable water scarcity is leading to immense human suffering. Since potable water, a bare necessity of life is severely scarce in many areas; people often line up to collect their share of water allocated to them. The small quantity and extended duration of the water allocations reflect the scarcity in such areas. Fistfights, bulling and even setting of mafia gangs who control and monitor water in such areas is a common practice in India as well as other countries.

Figure 2: People in Rural India Queuing to Collect their Water Supply

INTRODUCTION

The atmospheric air contains water in the form of water vapour or moisture. Approximately 30 – 35% of water available in atmospheric air is of no use. The remaining 65 – 70% if extracted using an atmospheric water generator – a device designed to create usable drinking water from the moisture present in atmospheric air – can resolve water scarcity in various communities. The device uses the principle of latent heat to convert the water molecules present in the air into water droplets. When cooling air down, the temperature at which it gets saturated with water vapour is called the dew point. There are many zones across the world located in rain forests, flood plains, grasslands and temperate region where atmospheric humidity is high; however, sources of potable water may be insufficient. These areas offer the best locations for exploring the scope of utilisation of this device that uses air condensation to generate water.

With a population of over 1.37 Billion, India has the second-highest population in the world, after China. [3] The global water stress ranking places India at the 13th spot highlighting the rapid degeneration of the country's water resource. [4] Furthermore, the Composite Water Management Index by NITI Aayog places India at the 120 ranks among 122 countries for its water quality. [5]

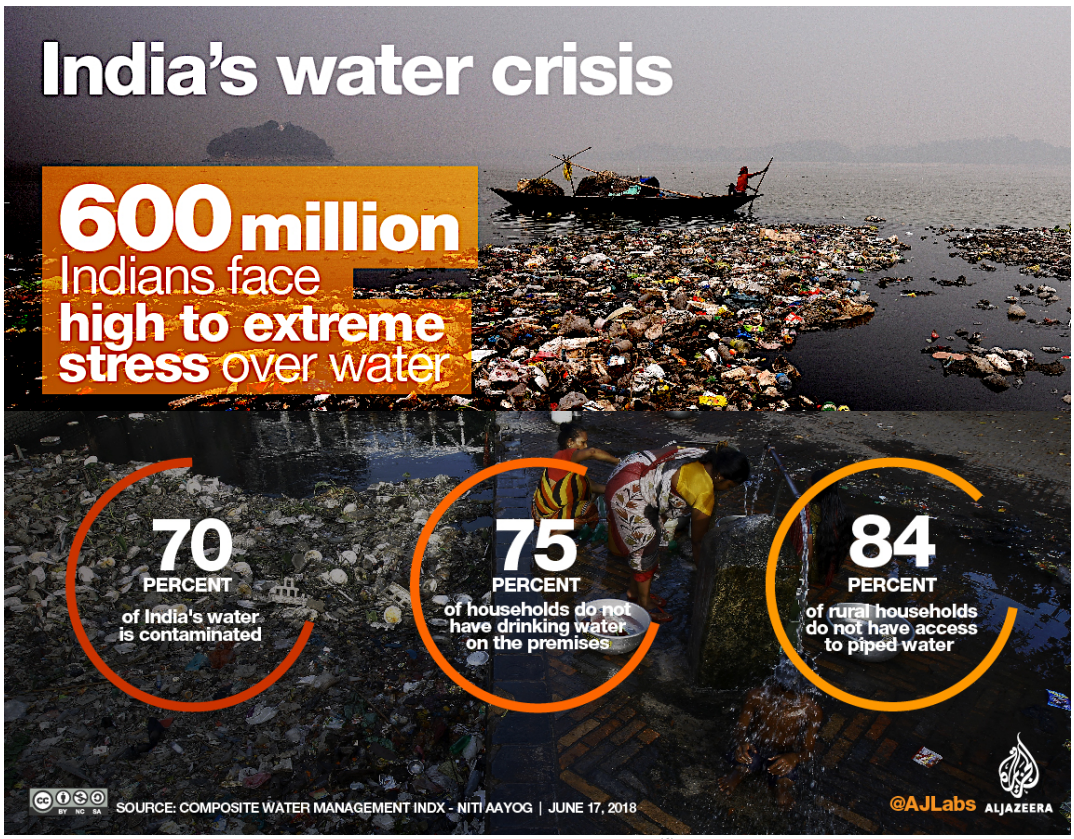


Figure 3: India's Water Crisis [6]

An estimated 600 million people in India suffer from high to extreme water stress, resulting in 200,000 deaths annually. [6]

The country relies strongly on the use of groundwater to meet its growing demands. However, this has left the water source severely depleted. NASA tracked this overuse using satellite data and alerted the national and global authorities of its finding. The expectation to initiate a change in the dynamics of the water usage and distribution system; remains a farsighted vision as actions to address or resolve the crisis remain insufficient.

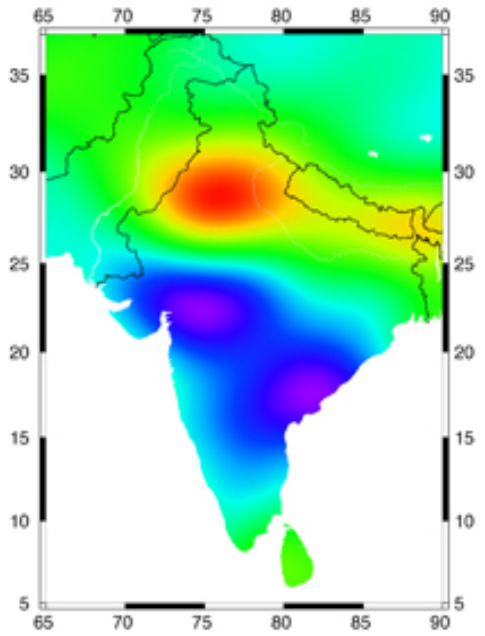


Figure 4: NASA Satellite Images of India's Water Crisis [9]

It is in dire circumstances such as the water crisis in India that the need for an atmospheric water generator comes to light. The successful development and implementation of an AWG can not only reduce the overexploitation of groundwater but also ensure that communities do not continue in a water-starved existence.

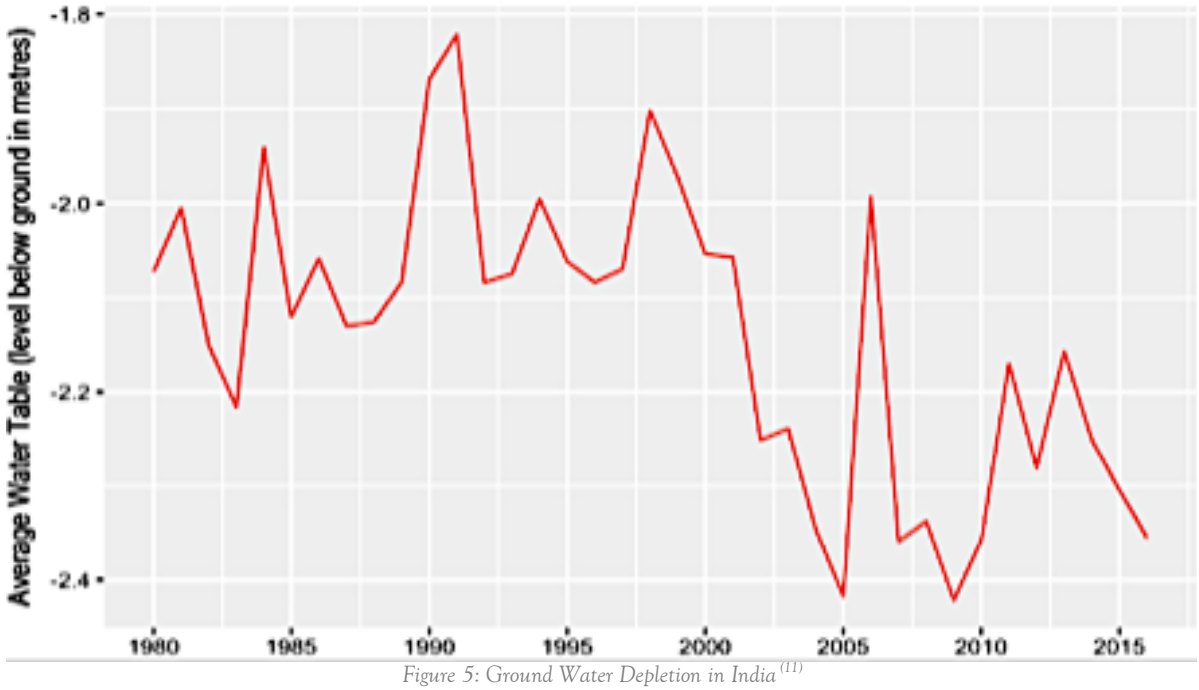


Figure 5: Ground Water Depletion in India [11]

Definition

- *Refrigeration:* The process of removing heat from a substance under controlled conditions and bringing down its temperature is called refrigeration.

- *Vapour Compression Cycle:* Vapour compression cycle is an improved method of air refrigeration cycle in which a suitable working substance, termed as refrigerant, is used. The refrigerants most widely used in this process are ammonia (NH_3), carbon dioxide (CO_2) and sulphur dioxide (SO_2).

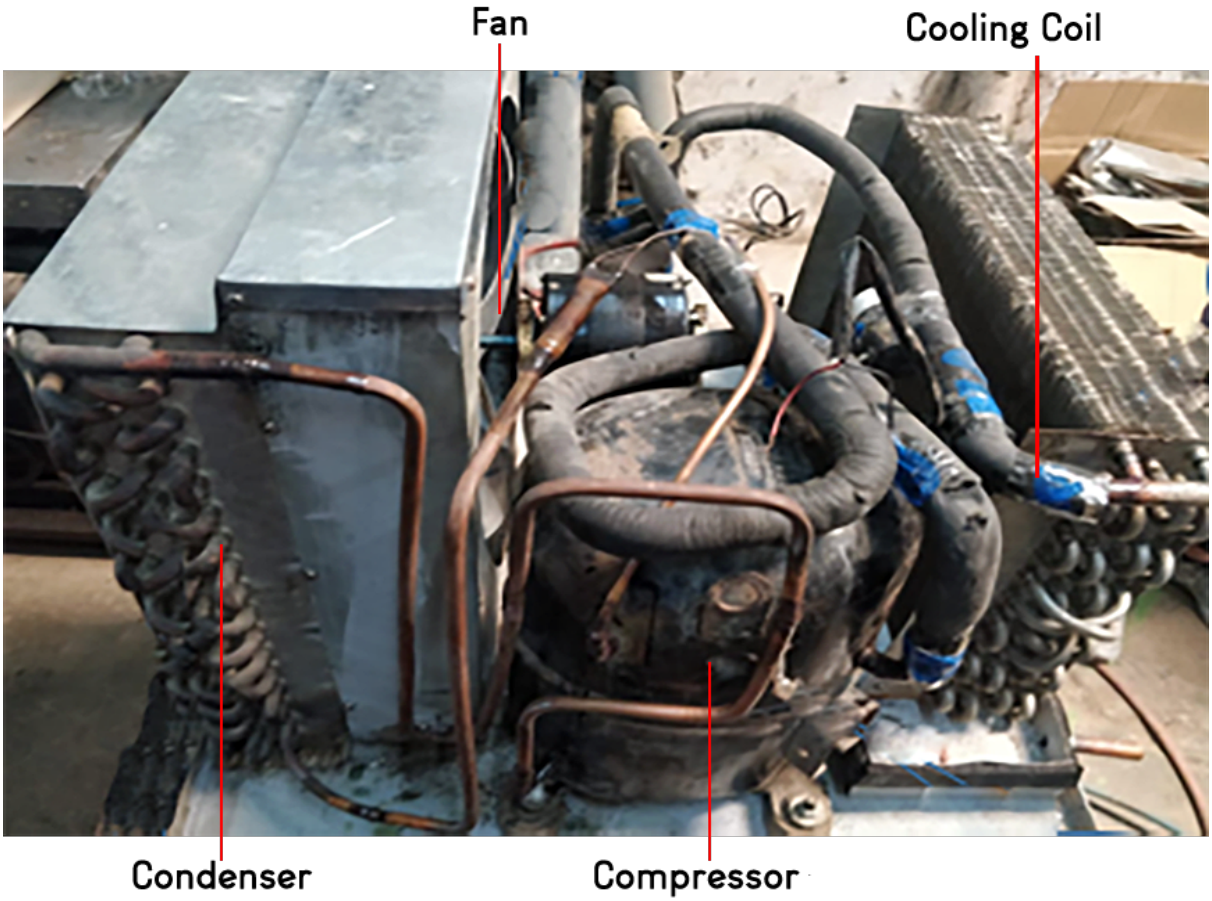


Figure 6: My 1st Prototype made from Scrap and Spare parts

Machine Components

- *Air Filter:* Air Filter is a device used for filtration of air to remove pollutants like dust, pollen, bacteria, and other particles. It does so with the help of an absorbent, usually carbon.

- *Cooling Coil:* Cooling Coil is a device which absorbs the heat from incoming air with the help of refrigerant.

- *Refrigerant:* Refrigerant is a mixture which used to absorb and remove heat from air or liquid by undergoing transitions from gas to a liquid state.

- *Condenser:* A condenser liquefies refrigerant from the hot gas to liquid and rejects heat through a coil and a condenser fan. [7]

- *Compressor:* A compressor compresses the refrigerant from a lower evaporating pressure to a higher condensing pressure [7], i.e. lowers the volume of refrigerant to increase its pressure. Here it is used to increase the pressure of refrigerant subsequently also increasing its temperature to enable it to reach a state known as superheated vapour. It is ready for condensation at this stage.

- *Electric Motor:* An electric motor is a device that converts electrical energy into mechanical energy. In the atmospheric water generator prototype, the electric motor moves the condensed water through the water filter, towards the storage tank after filtration.

- *Fan:* A fan is a device that expels the warm air inside the AWG outwards.

- *Capacitor:* A capacitor is a device that stores electrical energy in an electric field.

- *PLC:* A programmable logic controller or programmable controller is an industrial digital computer which has been ruggedised and adapted for the control of manufacturing processes, such as assembly lines, or robotic devices, or any activity that requires high reliability, ease of programming and process fault diagnosis.

- *Water Filter:* A water filter removes impurities from the water that passes through it. It can remove sediments, pathogens, chemicals and other impurities. The purification function of the water filter depends on the materials used to build it.

- *Water Storage Container:* A water storage container is a collection tank where filtered water from the AWG is collected, ready for use when needed.

- *Other Components:*

i. **Sensor:** An AWG uses a sensor to detect the humidity and temperature conditions of a region. The collected information allows the control panel to adjust the functioning of the device.

ii. **Control Panel:** The control panel processes the information received by the sensor. It employs a pre-fixed condition of temperature and humidity modifications to ensure the device operates at peak efficiency.

iii. Electric Wiring
iv. Condenser Pipe
v. Water Pipe
vi. Tap
vii. Nut bolts and fasteners
viii. Electrical Plug and wiring
ix. Labels
x. Grease and oil
xi. Packing box
xii. Work instruction leaflet

Assembly Process

1st Trial Prototype: Concept Proof

The project began with research and study to thoroughly understand the working principle of the atmospheric generator. A device that closely relates to the working of an atmospheric water generator is an air conditioner. Since both devices use the same set of components, spare parts from the local air conditioner service and repair workshop could potentially become the first prototype.

A shared junkyard served as a collection and holding facility for workshops in the vicinity. Components, segments, parts of all kinds of air conditioning fittings had made their way to the junkyard. Sifting through the parts needed additional workforce. Mechanics and technicians, frequent visitors to the area, volunteered to join the search for parts. Local vendors such as the Perfect Air Conditioning trading company shared their inputs on the blueprints of the device and the parts most suitable for the same.

Cool Breeze AirCon Pvt. Ltd., New Delhi, a local air conditioner repair workshop supplied the spare parts for the first prototype. The purpose of the first prototype was to create a working model to prove the concept of extracting water from the atmosphere. When allowed to run continuously, the device had an output of 60 litres of water a day, surpassing the targeted 20 litres at the beginning of the project.

There was, however, one severe limitation. The water generated by the atmospheric water generator was not safe for consumption. The next prototype needed to generate potable water.

Figure 7: Water Generated from Air

Figure 8: Modifications

2nd Trial and Modifications

After the concept and principle cleared the implementation test, the device capacity needed minor adjustments for better efficiency. Additionally, the water generated was not fit for human consumption, hence the need for a filtration process came to light.

Over several group discussions, the verdict was to reduce the size and capacity of the cooling coils and condenser. At a lower rate, the air could then be filtered at the time of intake to remove any airborne dust and pollutants. A recycled filter from a home air purifier, stitched into the cooling coils and secured using multipurpose sealant putty allowed testing the hypothesis. Before fitting the filter, the cooling coils, inner walls, frame and water tray needed a thorough cleaning to remove as much dust as possible. At run time, the filter drastically altered the airflow; however, despite the constriction, the water generated was significantly cleaner.

The water collected from filtered air did contain visible debris. Even though the debris could have been an environmental consequence keeping in mind the conditions of the workshop, it reflected the conditions wherein water scarcity would have diminished quality of life. A possible resolution added yet another unexpected step to the process. The water generated from filtered air needed an evaluation against acceptable safety standards for consumption. A detailed assessment of the impurities in the water also highlights the necessary filtration processes to make it safe for human consumption.

The team of engineers at the workshop suggested a collaboration with Mr K V Karunakaram, Managing Director, DeltaPure Water India Limited. The team of experts from DeltaPure, under the leadership of their director, gathered detailed information on the atmospheric water generator, its development, working, intended use and inception. The team accepted the collaboration request for testing the water quality. In addition to the acceptance, as a gesture of goodwill, the senior executives identified technical flaws in the design and suggested solutions to rectify them. The team also participated in the trial run to test their recommendations.

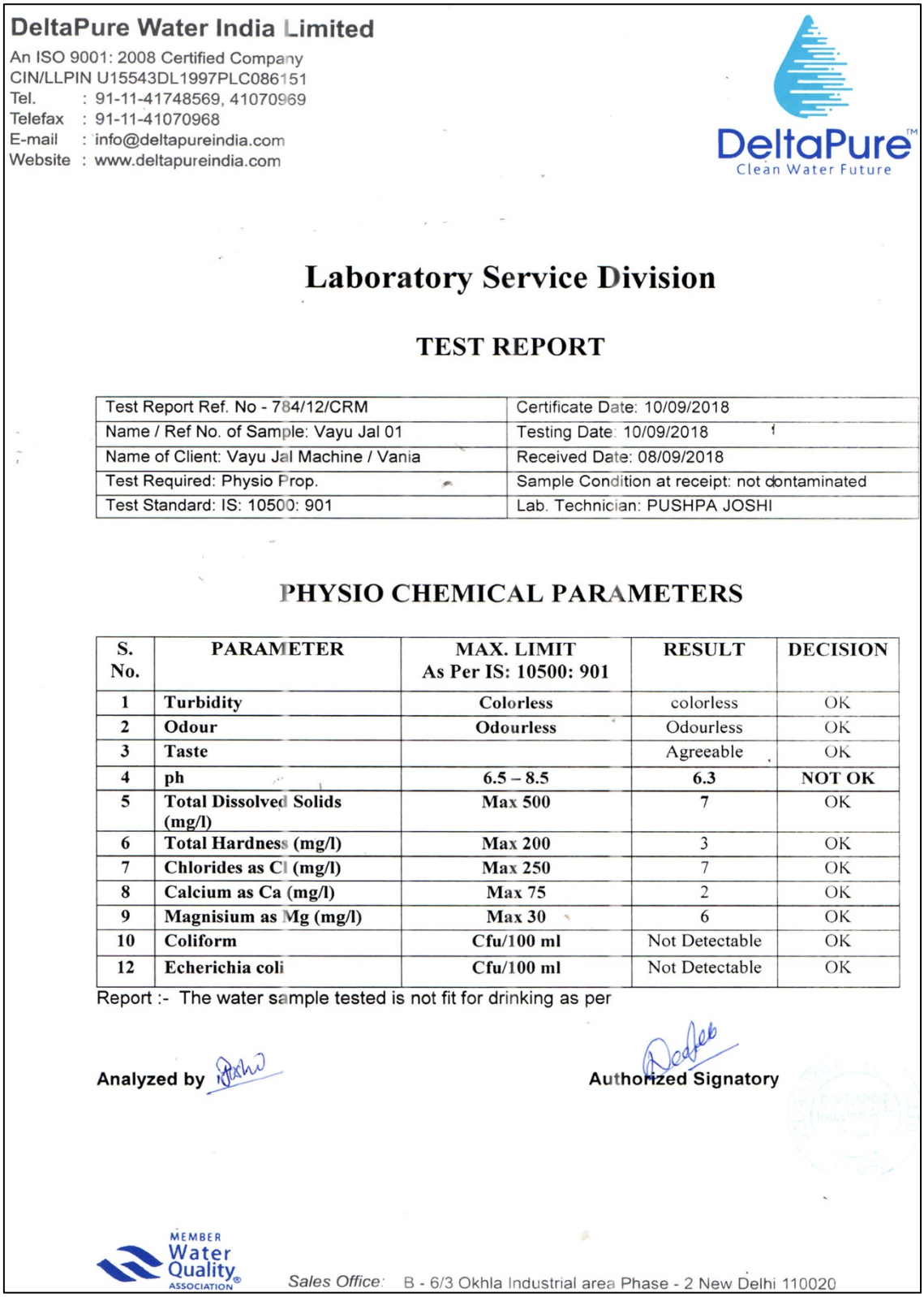
DeltaPure Water India Private Limited: 2 Takeaways

- **Cleaning Standards and Protocol:** These are the mandatory industry standards for safety, hygiene and cleanliness for an individual/organisation working with portable drinking water. All steps for further development, testing and deployment needed modification to comply with the industry standards. The step-by-step detailing and compilation of guidelines ensured the water generated would pass all quality checks.

- **Device Modification:** The use of scrap and spare parts for building the prototype made the water vulnerable to contamination. It was unlikely to meet quality check requirements despite filtration. The atmospheric water generator design meant categorised it as a major domestic appliance. However, its intended function meant that it needed to fit the small, domestic electricals category instead. The suggested replacements of parts made the atmospheric water generator more economical, consumer-friendly in terms of usage and more comfortable to clean in terms of maintenance.

Water Quality Test Report

The water generated by the device was laden with impurities, even if it appeared to be clean to the naked eye. The water quality tests revealed contamination, making the water unfit for human consumption.



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DeltaPure™ Clean Water Future

Laboratory Service Division

TEST REPORT

Test Report Ref. No - 784/12/CRM	Certificate Date: 10/09/2018
Name / Ref No. of Sample: Vayu Jal 01	Testing Date: 10/09/2018
Name of Client: Vayu Jal Machine / Vania	Received Date: 08/09/2018
Test Required: Physio Prop.	Sample Condition at receipt: not contaminated
Test Standard: IS: 10500: 901	Lab. Technician: PUSHPA JOSHI

PHYSIO CHEMICAL PARAMETERS

S. No.	PARAMETER	MAX. LIMIT As Per IS: 10500: 901	RESULT	DECISION
1	Turbidity	Colorless	colorless	OK
2	Odour	Odourless	Odourless	OK
3	Taste		Agreeable	OK
4	ph	6.5 – 8.5	6.3	NOT OK
5	Total Dissolved Solids (mg/l)	Max 500	7	OK
6	Total Hardness (mg/l)	Max 200	3	OK
7	Chlorides as Cl (mg/l)	Max 250	7	OK
8	Calcium as Ca (mg/l)	Max 75	2	OK
9	Magnisium as Mg (mg/l)	Max 30	6	OK
10	Coliform	Cfu/100 ml	Not Detectable	OK
12	Echerichia coli	Cfu/100 ml	Not Detectable	OK

Report :- The water sample tested is not fit for drinking as per

Analyzed by

Authorized Signatory

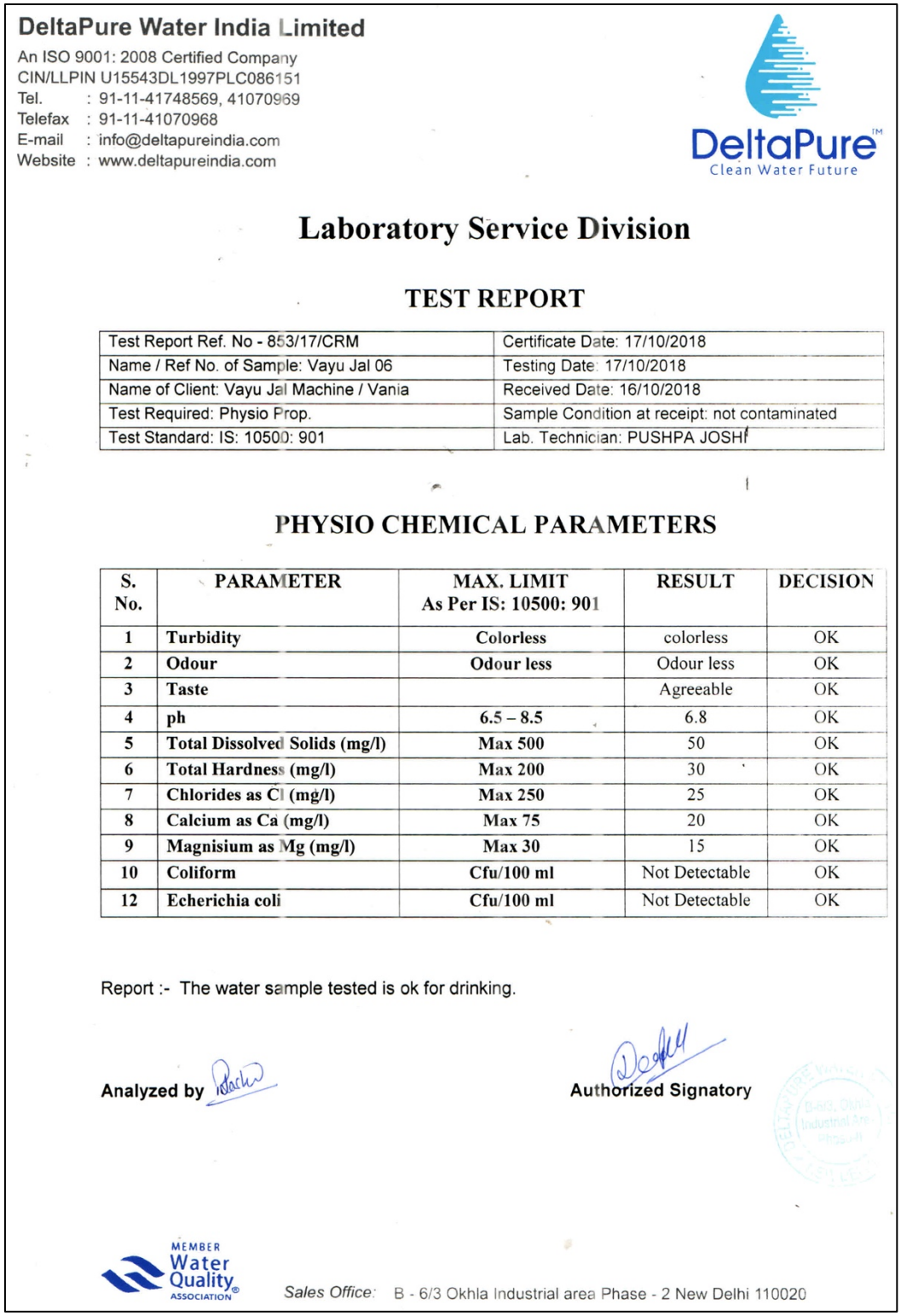
MEMBER Water Quality ASSOCIATION

Sales Office: B - 6/3 Okhla Industrial area Phase - 2 New Delhi 110020

Figure 9: Water Quality Test - Water Unfit for Consumption

Modification to Add a Water Filter

The experts at DeltaPure suggested a water filtration design correlating to the contaminants detected. Before the final fitting of the filter into the device, the water collected in the storage tray underwent quality checks. As shown below, the water collected by the atmospheric generated, once passed through the additional water filter was fit for human consumption.



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DeltaPure™ Clean Water Future

Laboratory Service Division

TEST REPORT

Test Report Ref. No - 853/17/CRM	Certificate Date: 17/10/2018
Name / Ref No. of Sample: Vayu Jal 06	Testing Date: 17/10/2018
Name of Client: Vayu Jal Machine / Vania	Received Date: 16/10/2018
Test Required: Physio Prop.	Sample Condition at receipt: not contaminated
Test Standard: IS: 10500: 901	Lab. Technician: PUSHPA JOSHI

PHYSIO CHEMICAL PARAMETERS

S. No.	PARAMETER	MAX. LIMIT As Per IS: 10500: 901	RESULT	DECISION
1	Turbidity	Colorless	colorless	OK
2	Odour	Odour less	Odour less	OK
3	Taste		Agreeable	OK
4	ph	6.5 – 8.5	6.8	OK
5	Total Dissolved Solids (mg/l)	Max 500	50	OK
6	Total Hardness (mg/l)	Max 200	30	OK
7	Chlorides as Cl (mg/l)	Max 250	25	OK
8	Calcium as Ca (mg/l)	Max 75	20	OK
9	Magnisium as Mg (mg/l)	Max 30	15	OK
10	Coliform	Cfu/100 ml	Not Detectable	OK
12	Echerichia coli	Cfu/100 ml	Not Detectable	OK

Report :- The water sample tested is ok for drinking.

Analyzed by

Authorized Signatory

MEMBER Water Quality ASSOCIATION

Sales Office: B - 6/3 Okhla Industrial area Phase - 2 New Delhi 110020

Figure 10: Water Quality Test - Fit for Consumption

Final Layout of Vayu Jal

The entire layout of the atmospheric water generator needed reorganising to add in the water filter. The tentative component placement within the mechanism, large and small parts as well as the pipelines once created, underwent trials and errors while finding their positions. An AutoCAD graphic of the layout served as a blueprint for constructing the final device.

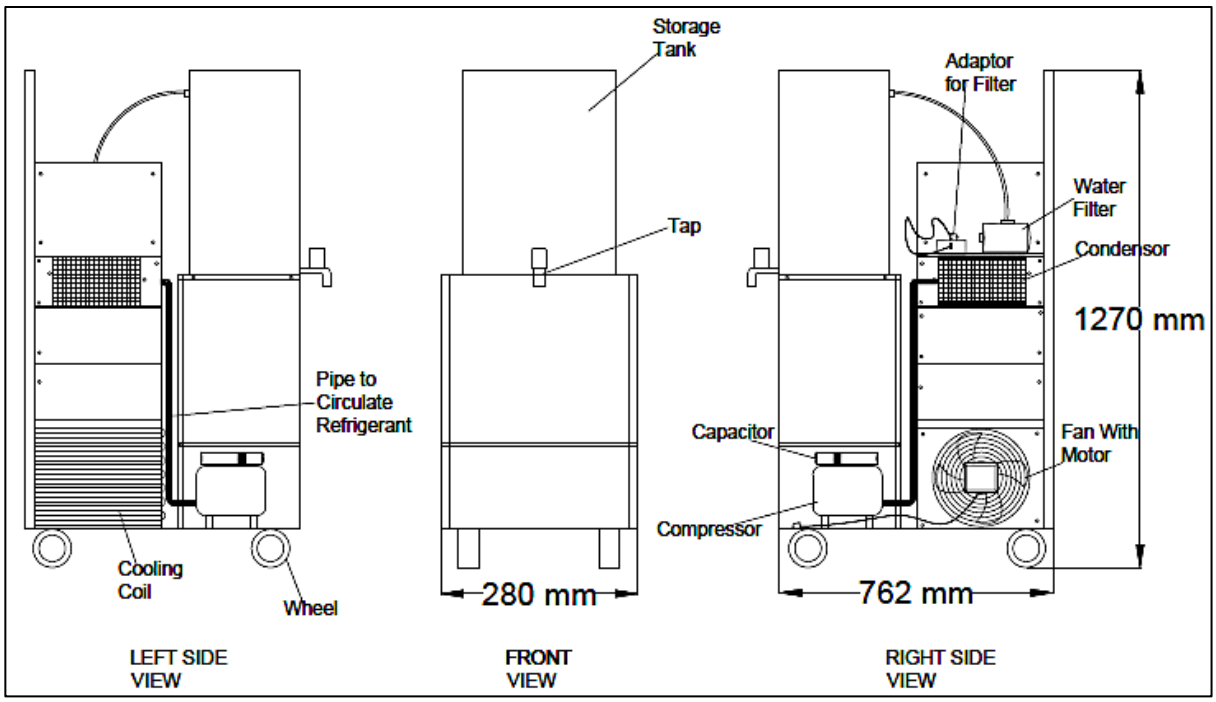

Figure 11: AutoCAD Layout of Vayu Jal

Endurance Test

The adjustments in the layout, adaptations for each part in the assembly to perform at a balanced, efficient pace and minor repairs and updates continued. The painstaking efforts, catalysed by the contributions made by AirCon and DeltaPure all came to fruition when the final prototype of Vayu Jal Atmospheric Water Generator was complete.

The durability of the device, as well as the water filtration, needed testing and analysis. The device programmed to run at optimum capacity for an extended period got installed at the DeltaPure testing laboratory. The water generated during this time also needed periodic testing to ensure the quality did not drop. Critical learning during this installation at the DeltaPure laboratory was the realisation that the atmospheric water generated needed wheels. The final prototype measuring 762mm X 280mm X 1270mm (L X B X H) needed easy mobility when used in domestic or disaster relief scenarios.

The trial run was continuous, and the device operated all through the day, every day of the week, for four months. The day to day monitoring and recording compiled by the DeltaPure team allowed tracking and adjustments during visits to the laboratory over the weekend.

Working Principle [2]

Atmospheric air enters the atmospheric water generator, passing through an air filter that removes dust, pollen and other particulate contaminants. It is cooled down to below dew point using a refrigerant to extract water from it using condensation.

Meanwhile, the compressor helps the refrigerant to reach the superheated vapour conditions, the conditions at which it can be condensed, by decreasing its volume and increasing its pressure. The refrigerant, as well as the air in the condenser, cool down and the refrigerant releases the latent heat. The refrigerant absorbed the latent heat on coming in contact with the incoming air. absorbed from incoming air at the cooling coil) to the outgoing air which is carried out of the AWG by air. The air begins changing from gaseous to a liquid state after being cooled below the dew point temperature.

The water extracted from condensed air collects in a storage tank. The water outlet, when opened at the time of need, draws water from the storage tank. Before the water exits the outlet, it goes through a filter to remove impurities and contaminants and enriched with minerals. Thus clean drinking water, with no impurities or pathogens is drawn from the air and made accessible to those in need.

Working Principle

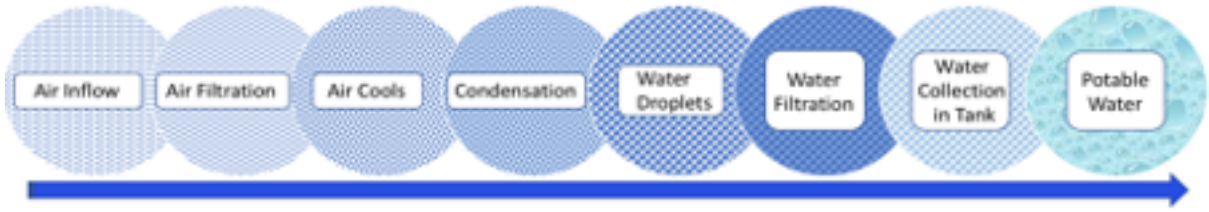

Figure 12: Step by Step Process of Vayu Jal

Application and Deployment

Water is an essential need to sustain life. The need for water not only for consumption but also to maintain a particular lifestyle is expressed in the Sustainable Development Goal proposed by the United Nations, calling for the need for Clean Water and Sanitation for everyone. Growth and development enabled .5 billion in gaining access to clean drinking water since 1990. However, 666 million people continue in a state of water starvation. Amongst the deaths in children caused by diarrhoea, 1 in every five children is from India. [8] The overwhelming population load strains the resources and their consumption making even a renewable resource become a non-renewable commodity.

- The atmospheric water generator offers a solution for these communities, ensuring they remain in good health and improve their wellbeing using a reliable and continuous supply of clean water.

- The device also addresses the need for clean, safe drinking water during disaster management and rescue and relief activities. The atmospheric water generator overcomes the limitations of a contaminated water supply source or the absence of a source altogether reducing the number of lives lost during a disaster or calamity.

Naya Prayas Pahal School at GB Road New Delhi in February 2020, marked the first successful installation of Vayu Jal Atmospheric Water Generator to facilitate a community in overcoming its water scarcity. On seeing the positive response, mass production and deployment schedules slated device installations in April 2020. However, the nationwide lockdown imposed in March 2020 to contain the spread of COVID-19 caused unforeseen delays. Large scale production and installations will tentatively resume in Spring 2021.

Cost

Cost of Components in INR ₹

Component	Specification	Cost with ISI Grade Parts	Cost with non-ISI Grade Parts
Air Filter	20-micron non-woven	250	180
Cooling Coil	Aluminium fins with copper pipe 13" x 19" x 4 rows	3,800	2000
Refrigerant	1800 gms Refron	900	900
Condenser	Aluminium fins with copper pipe 19" x 22" x 3 rows	4,500	2000
Condenser Pipe	½" for suction & 3/8" for discharge & ¼" for charging	400	400
Compressor	Emerson Single Phase 18000 BTU 4500K Cal/hr	8,500	3500
Fan with axle motor	Aluminum Blade with 1/5 HP Single shaft 1400rpm motor Single Phase Fan	4,500	1800
Runner / Capacitor	36 mfd EPCOS 440VAC	150	150
PTC (relay + Starting Capacitor)	Marut 2 point	150	150
Water Filter	Pre, secondary, fine	6,500	6500 (IS)
Water Pipe	Food Grade Plastic	175	175
Water Storage Container	Stainless Steel	4,000	3000
Tap	Plastic	250	200
Tray	Metal Powder Coated	250	250
Sensor	RH Sensor	3,000	1600
Control Panel	Digital RH displayer cum controller	5,500	2000
Electric Wiring	Fire retardant 2.5mm circuit wiring single-core & 3 core 2.5mm² main lead	350	350
Capillary	Metal Sales Bore 0.60. 28" x 2 No	200	200
Copper Strainer	3/8" 2 Bore Vijay	50	50
Nuts		20	20
Bolts		20	20
Paint	Power Coating outsourced	1,000	750
Labels	Safety and Functions	30	30
Electrical Plug		20	20
Packing Box		150	150
Assembly + SG&A		+15%	+ 12.5%
Total Machine Cost		**51,364**	**28,974**

Cost of Water per litre in INR ₹

Cost of Water per litre	
Electricity Consumption per day	19.2 KWh Vayu Jal consumes 800W
Electricity Consumption per month	576 KWh
Cost per day *(average cost of electricity in rural India INR 3 per KWh)*	Rs. 57.6
Cost per month	Rs. 1,728
Litres per month *for a family of 4 for drinking and used in cooking*	600 Liters
Cost per litre	**Rs. 2.88**

The annual maintenance cost of the machine: ₹300 ~ ₹500.

The cost of Vayu Jal is high and to evaluate and estimate a fair price at which the device should sell and run, the evaluation will not only include costs of water supply lines (installation as well as activation). Also, the cost evaluation will account for the total cost incurred as a result of the use of unsafe drinking water, i.e., of medical consultations, medicines and costs incurred due to illness and work absenteeism caused by use of unsafe drinking water.

Projects undertaken by the Government of India include solar and renewable energy provisions in villages at subsidised cost or free of cost. If the atmospheric water generated gets coupled with such provisions, the cost of water per litre will drop substantially.

Conclusion

This system will, in the future, can become similar to solar, hydro and other renewable energy sources. It saves groundwater, meant for the growth of vegetation, flora and fauna and human consumption. Today excessive human consumption and exploitation of natural resources with low rainwater harvesting has led to fast depletion of groundwater levels. The atmospheric water generator redirects the exploitation of groundwater and improves accessibility.

The device termed Vayu Jal, taking the word Vayu symbolising air and Jal symbolising Water in Sanskrit. The design needs further improvements towards becoming cost-effective, thus making it eligible for government funding and subsidy. Once achieved, Vayu Jal has great potential both as a service to the community where water is scarce and as a commercial product.

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