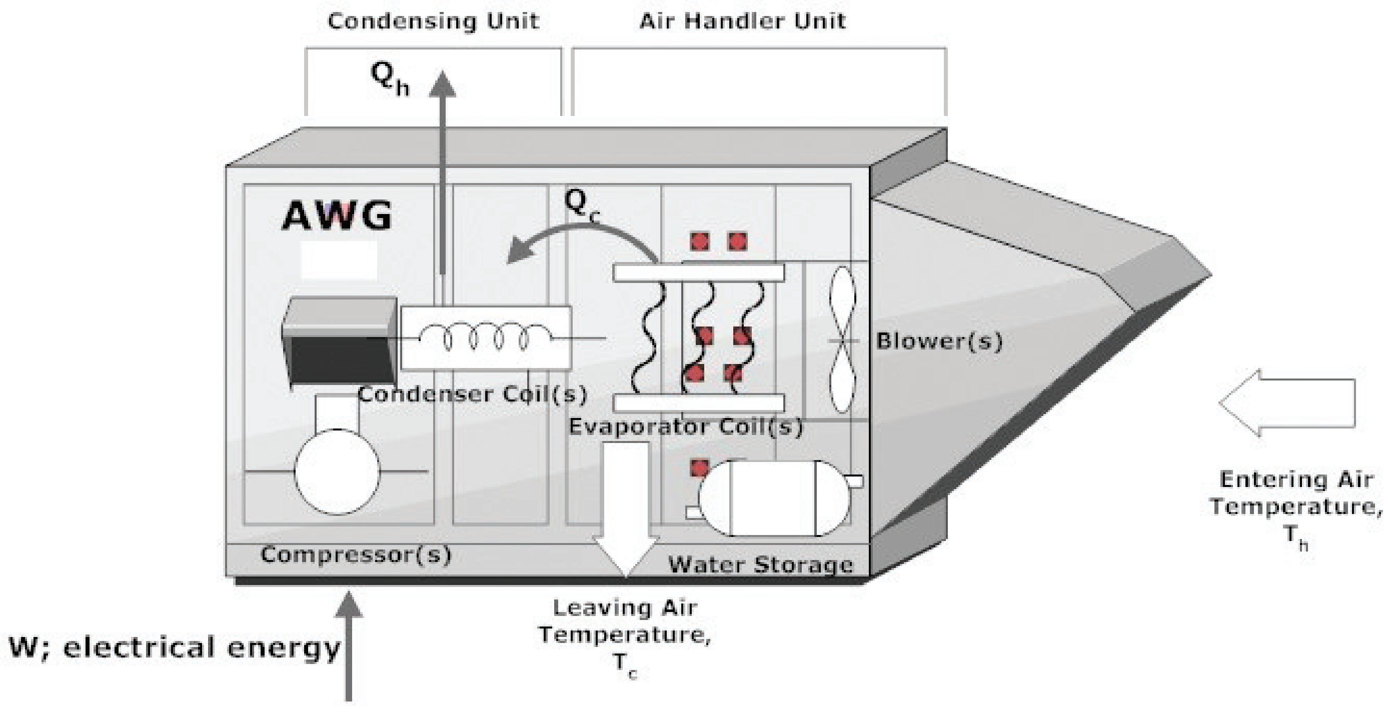
USING THE DRINKING-WATER-FROM-AIR RESOURCE IN INDIA

By Roland Wahlgren



$$COP = \frac{benefit}{cost} = \frac{Q_c}{W}$$

$$COP \leq \frac{T_c}{T_h - T_c}$$

Figure 1: The Diagram Depicts a Generic Atmospheric Water Generator (AWG) with its Design Based on Mechanical Dehumidification. Basic Components Include an Air Handler Unit (Blower, Evaporator Coil) and a Condensing Unit (Compressor, Condenser Coil) and Water Storage. Water Treatment Details are Not Shown. Entering Air Temperature is Th While Leaving Air Temperature is Tc. The Mechanical Refrigerating System Uses Electrical Energy, W. Energy Removed from Airflow by Refrigeration System, at Evaporator Coil, is Qc. Energy Expelled into Atmosphere from Condenser Coil is Qh. Two Equations for Coefficient of Performance (COP) are Shown. Diagram Copyright Roland Wahlgren; Used with Permission.

AIR-TO-WATER GENERATORS (AWGS) ARE PURPOSE-BUILT TO PROCESS OUTDOOR AIR, MAXIMIZE CONDENSATION OF THE WATER VAPOR INTO LIQUID WATER, AND TREAT THE WATER.

Moderate drought probability for most of the landmass of India exceeds ten percent. These researchers at the India Meteorological Department in Pune defined moderate drought as when the rainfall deficit is 26% to 50%. Their study used daily rainfall data collected from 1901 to 2000 for stations in 319 districts in India.

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The relatively high probability of drought in much of India has led to at least three suppliers of air-to-water generators (AWGs) setting up business in India. An AWG is a machine (Figure 1) designed to process atmospheric water vapor into drinking water. Although similar to dehumidifiers, AWGs are purpose-built to process outdoor air, maximize condensation of the water vapor into liquid water, and treat the water to meet World Health Organization or similar drinking water guidelines.

Water-from-Air as a Potable Water Resource in India

The water-from-air resource can be quantified in terms of specific humidity which has the units [g/kg] representing grams of water per kilogram of moist air. The Monthly/ seasonal climate composites application provided at the website of the U.S. Department of Commerce National Oceanic and Atmospheric Administration facilitated the production of specific humidity maps of India.

Water-from-Air Resource at High-Sun Season

Figure 2 shows the water-from-air resource for India during the Northern Hemisphere summer solstice month of June. Specific humidity values range from 12-20 g/kg, quite adequate for the operation of AWGs. The lowest values are in the north. Values are highest in the south. A trough, delineated by the 16 g/kg specific humidity value, corresponds approximately to the location of the Eastern Ghats chain of mountains.

Water-from-Air Resource at Low-Sun Season

Figure 3 shows the water-from-air resource for India during the Northern Hemisphere winter solstice month of December. Specific humidity values range from 4-16 g/kg. Values below 8 g/kg are too low for satisfactory

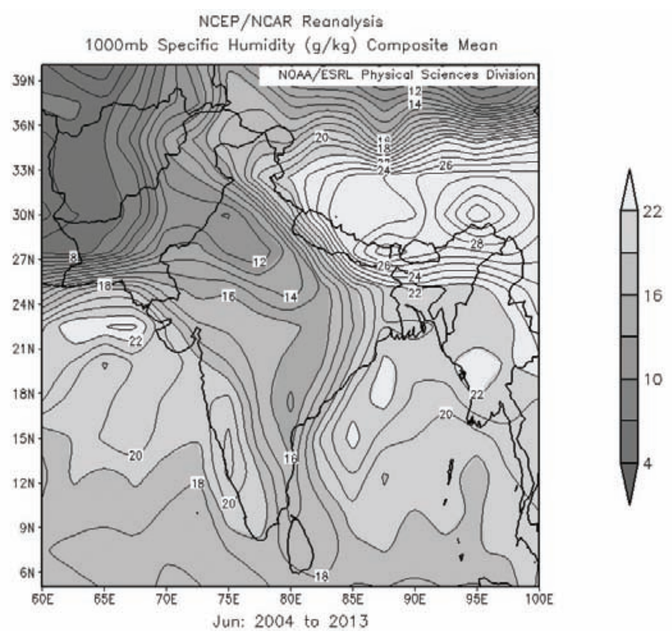


Figure 2: India's Water-from-Air Resource During June. The Resource is Represented by Composite Mean Specific Humidity for Ten June Months During 2004–2013. Image Provided by NOAA/ESRL Physical Sciences Division, Boulder, Colorado from Their Website at www.esrl.noaa.gov/psd/, NCEP Reanalysis Dataset (Kalnay, E. and Coauthors, 1996).

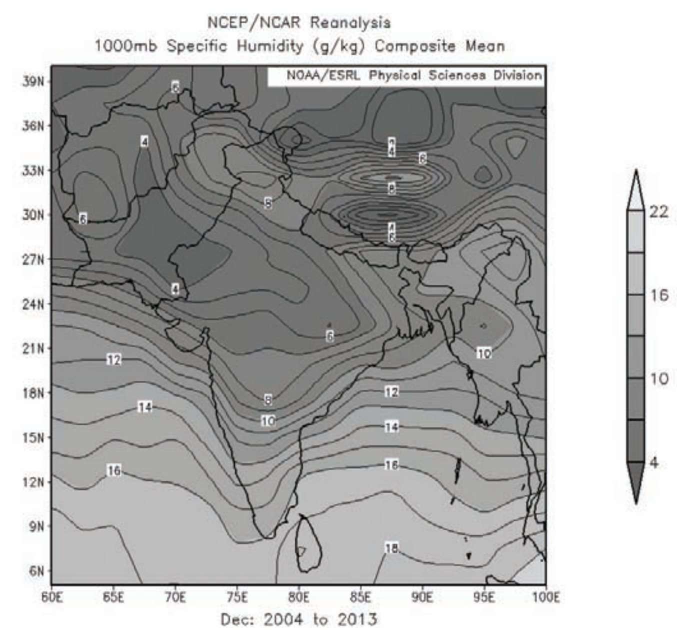


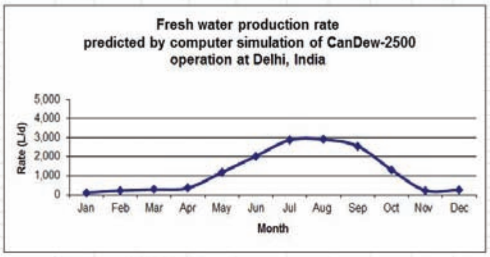
Figure 3: India's Water-from-Air Resource During December. The Resource is Represented by Composite Mean Specific Humidity for Ten December Months During 2004–2013. Image Provided by NOAA/ESRL Physical Sciences Division, Boulder, Colorado from Their Website at www.esrl.noaa.gov/psd/, NCEP Reanalysis Dataset (Kalnay, E. and Coauthors, 1996).

Climate, Refrigeration Load, and Water Production Model—CanDew-2500

Delhi, India — *Northern Plains of India*

Elevation: 218 metres above sea level — Lat: 28° 36′ N
Standard atmosphere: 1.013 bar — Long: 077° 12′ E
Controller setpoint used to adjust Delta T.
Model Input value
Climate data from: E. A. Pearce and C. G. Smith, *Fodor's World Weather Guide*

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Airflow, cfm	6,750	6,750	6,750	6,750	6,750	6,750	6,750	6,750	6,750	6,750	6,750	6,750
Airflow, m^3/s	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19
Temperature*, db, °C	14	17	23	28	34	34	32	30	29	26	20	16
Relative Humidity, %	57%	51%	36%	27%	28%	45%	67%	72%	62%	44%	41%	56%
Wet bulb, wb, °C	9.5	11.0	13.5	15.8	19.7	23.7	26.3	25.8	23.2	17.6	12.4	10.7
Air pressure, bar	0.987	0.987	0.987	0.987	0.987	0.987	0.987	0.987	0.987	0.987	0.987	0.987
Delta T (°C) - adjusted for ≤ 40 Tons or leaving air temp ≥ 5°C	9.0	11.5	17.5	23.0	28.5	22.0	16.0	15.0	18.5	21.0	15.0	10.5
Leaving air temp, db, °C	5.0	5.0	5.0	5.0	5.0	11.5	15.5	15.0	10.5	5.0	5.0	5.0
Leaving RH, % - conservative setting	99%	99%	99%	99%	99%	99%	99%	99%	99%	99%	99%	99%
Req'd Total capacity, Tons	10.6	14.2	20.8	26.9	38.8	39.0	39.8	39.1	40.0	32.7	17.9	13.5
Total capacity, kW	37	50	73	94	137	137	140	138	141	115	63	48
Sensible capacity, kW	35	44	65	84	103	80	59	56	68	78	57	40
Difference: Latent capacity, kW	3	6	8	10	34	57	81	82	72	37	6	7
Expected water prod'n, L/d	95	212	266	351	1,174	2,017	2,872	2,905	2,551	1,306	218	254
Efficiency of water recovery from air	5%	11%	13%	17%	42%	44%	46%	47%	51%	43%	11%	12%



Energy cost of water — Average: 1.78 kWh/L

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Voltage (V), 50 Hz, 3-phase	460	460	460	460	460	460	460	460	460	460	460	460
Average current (A)	35	35	52	52	70	70	70	70	70	70	35	35
Power (W)	22,282	22,282	33,105	33,105	44,565	44,565	44,565	44,565	44,565	44,565	22,282	22,282
Time (hours)	24	24	24	24	24	24	24	24	24	24	24	24
Energy (kWh)	535	535	795	795	1070	1070	1070	1070	1070	1070	535	535
Energy cost of water (kWh/L)	5.62	2.52	2.98	2.27	0.91	0.53	0.37	0.37	0.42	0.82	2.46	2.10

Figure 4: Water-from-Air Production Model Using Climate Data from Delhi for an AWG with 40 Tons of Refrigeration Capacity

operation of AWGs. This corresponds to sites in India north of 18° to 21° N latitude. The lowest values are in the northwest over the Thar Desert and increase towards the south.

Comparison of AWG Operations at Northern and Southern Sites

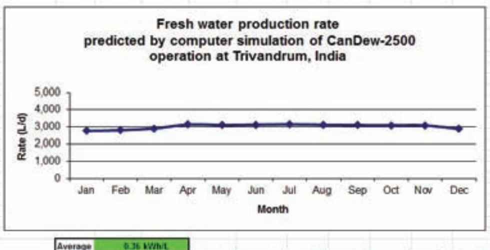
Better understanding of how seasonal and geographical variability impacts the practical use of the water-from-air resource comes from computer simulation models of, for example, a machine rated at 2500 L/d water production. The rating is for standard test conditions of ambient air at 26.7°C, 60% relative humidity, with an air pressure of 1.013 bar (approximately sea level).

Climate, Refrigeration Load, and Water Production Model—CanDew-2500

Trivandrum, India — *Western Coast of India*

Elevation: 62 metres above sea level — Lat: 08° 29′ N
Standard atmosphere: 1.013 bar — Long: 076° 57′ E
Controller setpoint used to adjust Delta T.
Model Input value
Climate data from: www.weatherbase.com

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Airflow, cfm	6,750	6,750	6,750	6,750	6,750	6,750	6,750	6,750	6,750	6,750	6,750	6,750
Airflow, m^3/s	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19
Temperature*, db, °C	27	27	28	29	28	26	26	26	27	26	26	27
Relative Humidity, %	74%	75%	77%	82%	83%	88%	87%	86%	85%	87%	86%	78%
Wet bulb, wb, °C	23.4	23.4	24.7	26.4	25.6	24.4	24.2	24.2	25.0	24.3	24.1	24.0
Air pressure, bar	1.006	1.006	1.006	1.006	1.006	1.006	1.006	1.006	1.006	1.006	1.006	1.006
Delta T (°C) - adjusted for ≤ 40 Tons or leaving air temp ≥ 5°C	15.5	15.5	14.5	13.0	13.0	13.0	13.5	13.5	13.0	13.0	13.5	14.5
Leaving air temp, db, °C	11.5	11.5	13.5	16.0	15.0	13.0	12.5	12.5	14.0	13.0	12.5	12.5
Leaving RH, % - conservative setting	99%	99%	99%	99%	99%	99%	99%	99%	99%	99%	99%	99%
Req'd Total capacity, Tons	38.9	39.2	38.9	39.1	38.9	39.2	40.0	39.7	39.0	38.9	39.4	38.8
Total capacity, kW	137	138	137	137	137	138	141	140	137	137	139	136
Sensible capacity, kW	59	59	55	49	50	50	52	52	50	50	52	55
Difference: Latent capacity, kW	78	79	82	88	87	88	89	88	87	87	87	81
Expected water prod'n, L/d	2,751	2,789	2,891	3,121	3,088	3,111	3,140	3,104	3,087	3,075	3,068	2,863
Efficiency of water recovery from air	51%	51%	49%	47%	48%	51%	52%	52%	49%	51%	52%	50%



Energy cost of water — Average: 0.36 kWh/L

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Voltage (V), 50 Hz, 3-phase	460	460	460	460	460	460	460	460	460	460	460	460
Average current (A)	70	70	70	70	70	70	70	70	70	70	70	70
Power (W)	44,565	44,565	44,565	44,565	44,565	44,565	44,565	44,565	44,565	44,565	44,565	44,565
Time (hours)	24	24	24	24	24	24	24	24	24	24	24	24
Energy (kWh)	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070	1070
Energy cost of water (kWh/L)	0.39	0.38	0.37	0.34	0.35	0.34	0.34	0.34	0.35	0.35	0.35	0.37

Figure 5: Water-from-Air Production Model Using Climate Data from Trivandrum for an AWG with 40 Tons of Refrigeration Capacity

Northern Site - Delhi

Figure 4 is the output of a computer simulation model representing an AWG operated in Delhi. Water production capacity is constrained by the 40 Ton refrigeration capacity of the dehumidification module and the minimum acceptable coil temperature of 5°C. Below this temperature, the coil is liable to freeze-up, damaging the AWG's compressors. The seasonal variation of the water-from-air resource is quite marked at Delhi's latitude of 28.5° N. Economically viable operation is during May-October.

Southern Site - Trivandrum

Figure 5 is the output of a computer simulation model representing an AWG operated in Trivandrum. The seasonal variation of the water-from-air resource is slight at Trivandrum's latitude of 8.5° N. Economically viable operation is possible year-round with the monthly average energy cost of the water being 0.36 kWh/L. The capital cost of a 2500 L/d machine can range up to USD 250,000 depending on features and quality. Typical service life is fifteen years.

Results of Study

Knowledge gained from this brief study includes:

- Water-from-air systems can be operated successfully in India almost anywhere in the country during June;
- Viable operation of AWG's in December is restricted to sites south of 18° to 21° N latitude; and
- Operating seasons for AWGs are shortest in the north and year-round in the south.

Although this study focused on using the water-from-air resource for potable water, the water can also be used for value-added beverage or food processing, or industrial processes with specific water quality requirements. In some cases, it may be appropriate to use the water for hydroponic horticulture or to water livestock.

About the Author

Roland Wahlgren is President of Canadian Dew Technologies Inc., a research & development service provider to the water-from-air industry. Roland is a physical geographer, with a B.Sc. degree from the University of British Columbia and an M.A. degree from Carleton University, Ottawa. He has been involved in the water-from-air field since 1984.

Canadian Dew Technologies Inc. has developed water-from-air systems since 2003 for clients and for its own product line.

To know more about the author, you can write to us. Your feedback is welcome and should be sent at: mayur@eawater.com. Published letters in each issue will get a one-year complimentary subscription of EverythingAboutWater Magazine.