Yajna A Solution to Air Pollution

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Abstract— Eight continuous years of experimenting on "Yajna" or "Agnihotra", a process in which fire is established in an inverted truncated pyramid or a different shape of fire pit and materials like ghee, saffron, sandalwood, and herbs etc., are offered at given intervals of time while chanting Vedic hymns. These materials are burnt, and vapors are emitted which rise high in the atmosphere. It is found that these vapors are capable of reducing PM (Particulate Matter) pollution in the atmosphere up to a period of 96 hours after the Yajna and the effect can be observed to a distance of 50 kilometers. We have varied the size of the fire pits, the materials offered, and number of fire pits. The results were found to be reducing the PM pollution in the atmosphere in all the experiments but with varying levels. The data of the PM (Particulate Matter) values were obtained from the Georgia government published site on the internet.

Keywords-Air pollution, Yajna, Agnihotra, Solution to air pollution, Yajna reduces pollution.

I. INTRODUCTION

Air pollution is a mixture of solid particles and gases in the atmosphere and according to the United States environmental protection agency the following are considered as the six common air pollutants. It is important that we reduce or eliminate the air pollution as it is very harmful for the health of humans, animals, and plants on the earth. We focused our experiments on reducing the particulate matter as it is the major pollutant that makes up the AQI (air quality index) in general.

A. What are the Six Common[1] Air Pollutants?

1. Ground Level Ozone, 2. Carbon Monoxide, 3. Sulphur Dioxide, 4. Nitrogen Oxides,
5. Particulate Matter, and 6. Lead

B. What is Air Quality Index (AQI)?

An air quality index (Table-1) is used by government agencies to communicate to the public how polluted the air currently is or how polluted it is forecast to become.

Table-1 AQI Values and Consequence

Air Quality Index Value	Consequence
301 – 500	Hazardous
201 – 300	Very Unhealthy
151 – 200	Unhealthy
101 – 150	Unhealthy for Sensitive Groups
51 – 100	Moderate
0 – 50	Good

Source: Environmental Protection Agency, USA

C. Particulate Matter or PM

Most PM^2 particles form in the atmosphere as a result of chemical reactions between pollutants. Particulate Matter is a mixture of solid particles and liquid droplets found in the air. Some PM can be seen with naked eye

and some can only be seen with electron microscope. There are mainly two types of Particulate Matter and are called PM_{10} and $PM_{2.5}$.

According to EPA, "PM_{10} are inhalable particles that are 10 microns are less in diameter and $PM_{2.5}$ are fine inhalable particles that are 2.5 microns and less in diameter". According to EPA, "some sources of PM are those emitted directly from construction sites, unpaved roads, fields, smokestacks or fires. Most particles form in the atmosphere as a result of complex reactions of chemicals such as Sulphur dioxides and Nitrogen Oxides, which are pollutants emitted from power plants, industries, and automobiles".

D. What are the Harmful Effects of PM?

According to EPA, "Particulate matter contains microscopic solids or liquid droplets that are so small that they can be inhaled and cause serious health problems. Some particles less than 10 micrometers in diameter can get deep into your lungs and some may even get into your bloodstream. Of these, particles less than 2.5 micrometers in diameter, also known as fine particles or $PM_{2.5}$, pose the greatest risk to health. Fine particles are also the main cause of reduced visibility (haze) in parts of the United States, including many of US treasured national parks and wilderness areas".

E. Does wood combustion cause CO2 (Carbon dioxide) pollution[3]?

The CO_2 in wood combustion emissions is considered "carbon-neutral" because the amount of CO_2 emitted during combustion is basically equivalent to the amount of CO_2 trees need to grow the same quantity of wood. Hence the combustion of wood does not contribute to the net increase in atmospheric levels of CO_2 (a greenhouse gas) as does the combustion of fossil fuels.

On Earth Day[4], the U.S. Environmental Protection Agency announced a policy that incentivizes the destruction of US forests, in the name of fighting climate change. EPA Administrator Scott Pruitt decreed that burning wood for energy will be treated as "carbon neutral," meaning that it adds no CO_2 to the atmosphere and falls into the same category of energy sources as solar and wind.

F. Aim of this paper is to show that "Yajna" or "Agnihotra" will reduce PM in the air.

II. MATERIALS AND METHOD

A. WHAT IS YAJNA or AGNIHOTRA?

Figure - 1

"Yajna" or "Agnihotra" is a Scientific process that is carefully carried by specialists who are well trained in executing the process. As shown in the above "Fig – 1", a fire pit is prepared, and fire is kept inside the pit with the help of special sticks known as "Samidhas". These "Samidhas" are obtained from various trees such as Ashwath, Udumbar (Ficus Glomerata), Palaash (Butea Frondosa), Shami (Propsopis), and Vikadgand (Capparis

Spinosa) etc. Then cow ghee (Butter turns to ghee on heating), and other food materials, precious metals, and scented materials such as sandalwood, and herbs are kept in the fire at regular intervals.

B. YAJNA AND ITS BENEFITS

In these Yajna's four types of materials are used for offering in the fire (Yajna). (1) Scented materials such as kasturi, saffron etcetera. (2) Sweet materials such as jaggery, honey etcetera, (3) Strength producing materials such as cow ghee, cow milk, rice etcetera. (4) Health preserving materials such as herbs and precious metals. These materials are acquired and purified before offering them in proper proportions in the Yajna. Because of this air and rainwater get purified and everyone gets pleasure. The above said materials when offered in the fire (Yajna), become minute and mix with the air. These materials in the vapor state clean the atmospheric air and reduce pollution.

When these materials are offered in the fire (Yajna), hot smoke and steam are produced. Due to heat these materials get dried by releasing the vapors from them. These vapors mixing with the air enters the atmosphere. In that vapor the water part is steam and particles mixed with steam part is smoke. These vapors and particles interact with the atmospheric particles and purify the air. These vapors and particles collect together and form clouds. Because of this we get good rains with purified water.

An ahuthi is the selected/allowed material that is offered in the fire pit or Yajna fire. Each ahuthi is equal to about 10 grams of either ghee, herbs, or cooked food like sweets etc. For our experiments we have offered anywhere from 5,000 to 10,000 ahuthis depending on the Yajna design.

C. What happens inside the "Yajna" fire?

The Yajna fire generally is between 200 to 1000 degrees Celsius and above. At this temperature generally all materials (eatables, and herbs etc.) are vaporized and the molecules/atoms/ions rise high into the atmosphere. These molecules have high kinetic energy and travel long distances and climb great heights as the density of these vapors are lesser than the surrounding air. These molecules/atoms/ions have the capacity to interact with the atmospheric gases/particles and cause reducing the pollution. For example, Sulphur dioxide can be removed using Carbon (Sappok and Walker) **[5].**

Experimental results [6] showed that the pollutants like SO_x, NO_x, CO, and PM could be reduced by "Agnihotra" or "Yajna". It was shown that SO_x reduced by about 51% and NO_x reduced by about 60% while RSPM and SPM were reduced by 9% and 65% respectively.

Using herbs and scented materials in the "Agnihotra" or "Yajna" give medicinal smoke to cure illness [7] such as pulmonary, neurological and dermatological apart from being beneficial to health and include smoke for social use. The authors also demonstrate that medicinal smoke can be extended to use in modern medicine as a form of drug delivery and is a promising source of new active natural ingredients.

III. RESULTS AND DISCUSSION

Yajna experiment was done every year from 2012 to 2019 at different instances of the year near Atlanta in the state of Georgia, USA. Most of the time Yajna was performed in McDonough in the state of Georgia, USA which is at a distance of 30 miles from Atlanta. The data about PM values before and after the Yajna were collected from https://airgeorgia.org/ which is an Ambient Air Monitoring Program by the Office of the Georgia State Climatologist within the Environmental Protection Division.

A. Year 2012 Experiment

16 fire pits (called Yajna kund) were placed with 11 of them having equal size truncated inverted pyramids (8-inch x 6-inch x 2 inch) made of copper metal. Remaining 5 fire pits are of different shapes made of bricks. 3 of them were rectangular, one semicircular and one is circular. Materials used were cow ghee, mango sticks, sandalwood, sweets made from rice, saffron, kasturi, and herbs etc. The Yajna process started at 6:30 AM on

September 30th, 2012 and the process ended at about 11:30 AM on the same day. The distance between the measuring instruments and the Yajna is about 8-10 miles.

Results shown in Table-2 are for $PM_{2.5}$ values from the McDonough Center for 30th September 2012 to 4th October 2012. On 30th September the maximum value was 20.5 and 12 hours after the Yajna the value dropped to 2.4. A comparison shows that $PM_{2.5}$ has dropped to a minimum of 0.2 in 24 hours and its maximum didn't cross 7.3. The PM values remained low for about 72 hours before the maximum value of $PM_{2.5}$ reached to 19.8 (after 96 hours of the Yajna).

Table-2 Particulate Matter values in McDonough - 2012

McDonough Center Measurements of Particulate Matter:		
Date	Maximum Value (microgram/cubic meter)	Minimum Value (microgram/cubic meter)
30th September, 2012	20.5	2.4
1st October, 2012	7.3	0.2
2nd October, 2012	6.3	0.6
3rd October, 2012	14.7	2.2
4th October, 2012	19.8	7.8

On 30th September 2012 Atlanta, GA AQI (Table-3) shows that the $PM_{2.5}$ has a Maximum of 62.0 and a minimum of 55 microgram/cubic meter. Yajna was performed on 30th September 2012 between 6:30 AM and 7:30 AM at McDonough, GA that is about 30 miles from the measuring instruments in Atlanta, GA.

Table-3 Particulate Matter Values in Atlanta - 2012

Atlanta Georgia Tech Center Measurements of Particulate Matter:		
Date	Maximum Value in (microgram/cubic meter)	Minimum Value in (microgram/cubic meter)
30th September, 2012	62	55
1st October, 2012	54	16
2nd October, 2012	25	19
3rd October, 2012	42	21

Comparing the AQI of Atlanta area from 30th September to 3rd October 2012, it indicates that after 32 hours of the Yajna, at about 30 miles from the Yajna place, the AQI had fallen to its lowest value 16. The AQI didn't cross the 42 mark even 72 hours after the Yajna.

Rainwater collected at the site of the Yajna on 1st October 2012 was sent for analysis to "Water Test America LLC". The result shows that the sample meets the U.S.E.P.A guidelines for the primary drinking water and that the Fluoride is elevated. This rainwater is compared with Ozark and Nestle drinking water in Table-4.

Yajna rainwater shows that the Total dissolved solids (TDS) are 34.1 whereas Ozark (75) and Nestle (110) are higher indicating the purity of Yajna rainwater.

Floride, Alkalinity and Hardness of Yajna rainwater are higher that Ozark and Nestle. The MCL (Maximum contamination level) of Floride set by EPA is 4 and Yajna rainwater is 3.16. Even though the Floride of Yajna rainwater is less than the limit set by EPA, it is still higher when compared to other commercial drinking water. But why is it high? This is analyzed in the subsequent paragraphs. Similarly, the Alkalinity and Hardness must be high for drinking water. But why? This is also discussed in the subsequent paragraphs.

Table-4 Comparison of Rainwater after the Yajna with bottled water - 2012

Parameter	Rainwater after Yajna	Ozark	Nestle
Alkalinity	64	22	13.4 to 46.9
Floride	3.16	1.1	0.13
Hardness	250	33	17.2 to 51

pH	6.75	6.9	6.3 to 7.6
Total Dissolved Solids	34.1	75	61 to 110
Total Coliform Bacteria	Nd	Nd	Nd
E.Coli Bacteria	Nd	Nd	Nd

Generally, the rain is obtained from the clouds that are on the top edge of Troposphere. Whereas the Floride is present in the Stratosphere due to Chlorofluorocarbons. Since Floride is not present anywhere in the atmosphere other than Stratosphere, it indicates that the Yajna decreased the pollution even in the Stratosphere.

The Alkalinity of Yajna rainwater is 64 (greater than Ozark (22) and greater than Nestle (13.4 to 46.9)) and Hardness of Yajna rainwater is 250 (greater than Ozark (33) and greater than Nestle (17.2 to 51)).

Aquatic organisms benefit from a stable pH value in their optimal range. To maintain a fairly constant pH in a water body, a higher alkalinity is preferable. High alkalinity means that the water body has the ability to neutralize acidic pollution.

The U.S. E.P.A (United States Environmental Protection Agency) developed 6 categories (Table-5) to describe alkalinity status of lakes and ponds. As the concentration of $CaCO_3$ increases, the alkalinity increases and the risk of acidification decreases.

Table-5 Alkalinity category based on $CaCO_3$ concentration

U.S.E.P.A. Classification of lakes and ponds based on alkalinity as measured in concentration of $CaCO_3$	
U.S.E.P.A. category	Concentration of $CaCO_3$ (mg/L)
Acidified	<1 and pH < 5
Critical	< 2
Endangered	2 – 5
Highly Sensitive	5 – 10
Sensitive	10 – 20
Not Sensitive	>20

The rainwater is purer than Ozark and Nestle drinking water as the number of TDS is the least in it, has good Floride content indicating decrease in pollution in stratosphere, and having good hardness which decreases risk of acidification of lakes and ponds.

B. Year 2013 Experiment

On May 25th we conducted a Yajna at Sakthi Mandir in Lake City, GA. The Yajna site is about 20 miles from the AQI measuring site in Atlanta, GA. The Yajna was conducted with 40 Yajna Kundas, 35 Yajna Kundas of size (6-inch x 6-inch x 2-inch) made of copper, and the remaining five made of brick. Out of the five one is in circular shape with a radius of one feet, the second one is in the shape of a semicircle with a radius of two feet, the third and fourth are in the rectangular shape with 2 feet on each side, and the fifth Yajna Kunda is in the shape of a lotus with an inner radius of about 3 feet. All these 5 Yajna kundas were of equal depth of one foot.

Table-6.

Average AQI between 28th May and 31st May in Atlanta, GA	
Year	Average AQI
2013	35.90
2012	40.74
2011	67.55
2010	47.32
2009	46.52
2008	67.48
2007	89.78
2006	59.15
2005	43.12
2004	50.18

Table-7

Average AQI between 19th May and 31st May in Atlanta, GA	
Year	Average AQI
2013	39.50
2012	47.84
2011	62.36
2010	47.31
2009	39.58
2008	65.67
2007	88.35
2006	60.82
2005	49.69
2004	54.54

AQI of Atlanta, GA for the period of 19th to 31st May (Table-6) was collected and averaged. This averaged AQI value was found to be 39.50 in year 2013. This result is compared with the past ten years results of AQI in Atlanta, GA for the same time period between 19th May to 31st May. Table-6 gives these values and we will find that during 2013 and 2009 the AQI value is the least and it can be concluded that it is due to the Yajna the AQI value has become low.

In 2009 around 20th May, Hindu Temple of Atlanta did a very big Yajna and that is the reason the AQI is low in that year too. Hindu Temple of Atlanta is about 20 miles from Atlanta. In Table-7 the AQI values between 28th May and 31st May are given for the same ten years. Since the data for 26th and 27th May was not available, the interval 28th May to 31st May is chosen for analysis of the effect of the Yajna. We can clearly see that the average AQI is the lowest during 2013 because of the Yajna.

C. Year 2014 Experiment

In 2014 we conducted a Yajna on May 14th in McDonough, Georgia, USA. Only one Yajna Kunda or fire pit in a cubic shape with dimensions (18-inches x 18-inches x 18-inches) is utilized for this purpose. From May 4th there was continuous pollution of PM in and around Atlanta GA region and we decided to conduct Yajna on May 14th. Pollution continued on May 12th and 13th as shown below in "Fig-2". On May 14th, 2014, we did Yajna. As we can see in "Fig-2" the pollution reduced on 14th, 15th, and 16th May 2014.

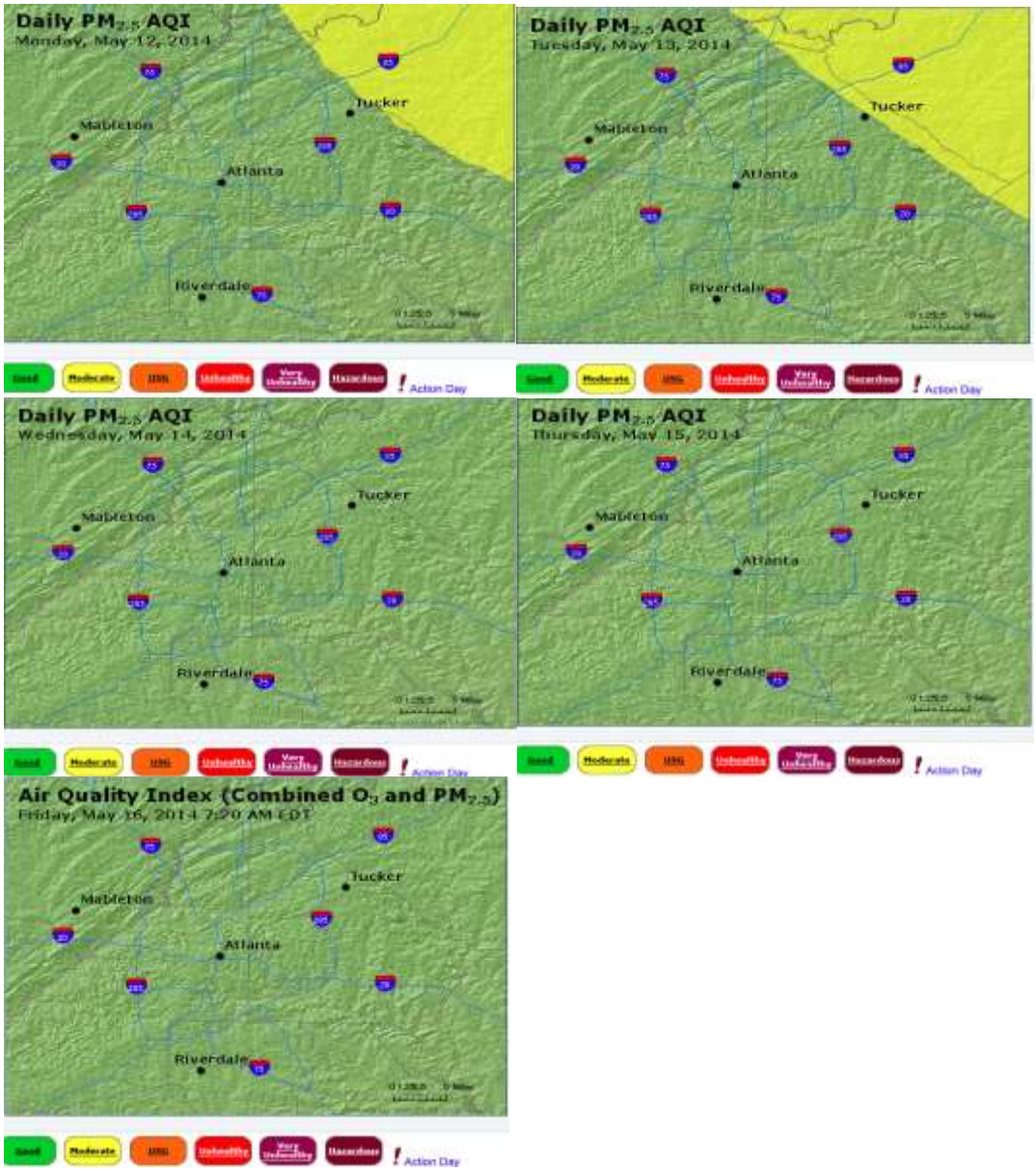

Figure-2

Yellow color indicates moderate pollution and green indicates no pollution.
As we can see in "Fig-2" the Yajna effect continued even on May 16th and the pollution reduced for 60 hours after the Yajna.

D. Year 2015 Experiment

On April 4th Yajna was performed in McDonough with 43 triangular fire pits closely packed as shown below in "Fig-3".

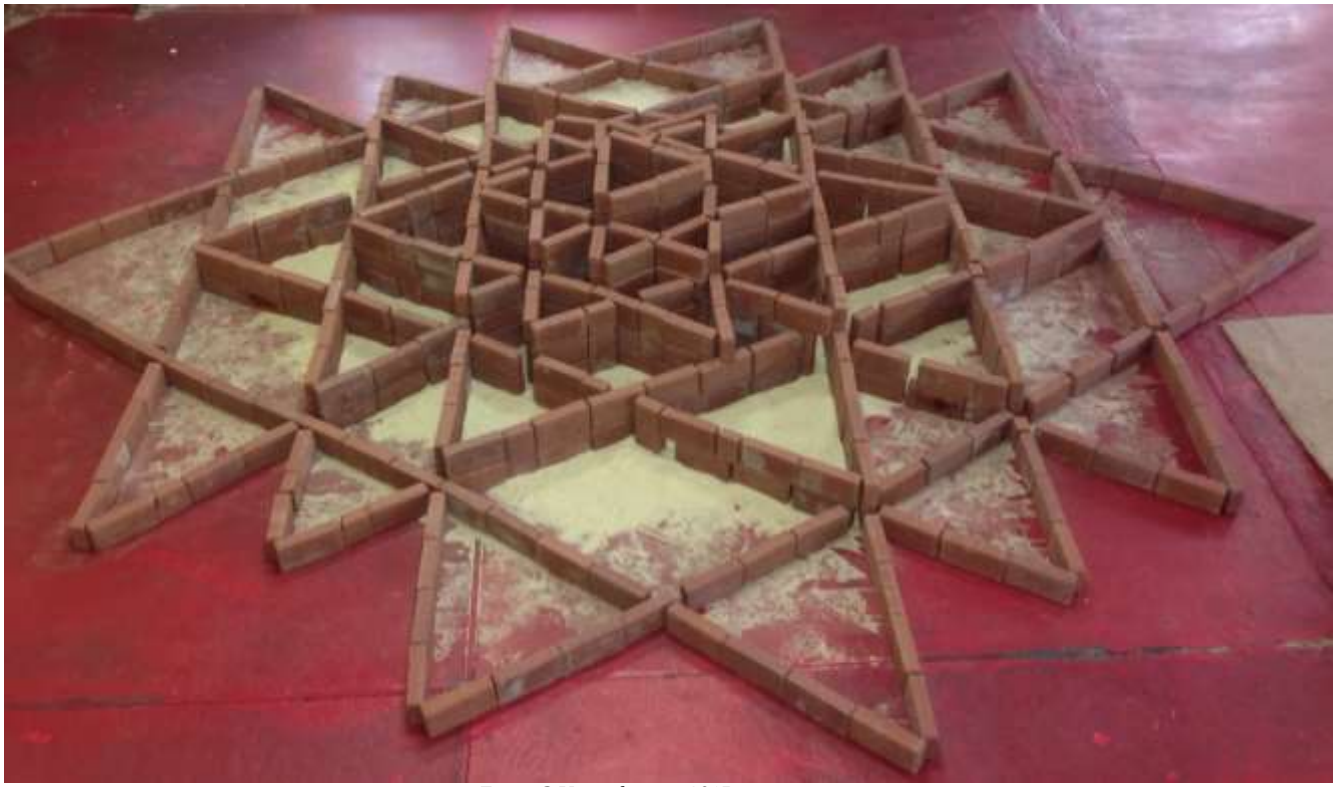

Figure-3 Yajna design - 2015

The results of PM (Particulate Matter) in microgram/cubic meter on 2nd, 3rd, 4th, and 5th of April 2015 are as shown below at McDonough, GA. Yajna was performed on 4th April between 6:30 AM and 11:30 AM at 8 to 10 miles from the site of these measuring instruments.

Table-8 Average PM values McDonough – 2015

Average PM (Particulate Matter) values from 2nd April to 7th April 2015 in McDonough, Georgia USA	
Time intervals for PM Values	Average PM in microgram/cubic meter
60 hours before the Yajna completion (2nd April to noon of 4th April)	13.87
60 hours after the Yajna completion (noon of 4th April to 6th midnight)	4.94
84 hours after the Yajna completion (noon of 4th April to 7th April)	6.03

We can see that the average PM values 60 hours before the Yajna is 13.87 and 60 hours after the Yajna is 4.94. We can further see that 84 hours after the Yajna the average PM value did not exceed 6.03 which is lesser than 50% of the value in the 60 hours before the Yajna.

South Dekalb is about 20 miles (32 Kilometers) from the Yajna location. The average PM values for that location are as given below.

The average PM values from 1 AM of 2nd to 12 noon 4th April (till 11 AM) = 25.21
The average PM values from 12 noon of 4th to 6th April is = 16.14
The above data indicates that the PM pollution reduced by 36% even at a distance of 20 miles (32 Kilometers).

United Ave is about 25 miles (40 Kilometers) away from the Yajna location. The average PM values for that location are given below.

Average $PM_{2.5}$ value between 2nd and 4th April (till 11 AM) is = 11.20
Average $PM_{2.5}$ value between 4th (from 12 AM) to 6th April is = 6.92

The above data indicates that the PM pollution reduced by about 39% even at a distance of 25 miles (40 Kilometers).

Even though the distance of United Ave is more than the distance of South Dekalb, the PM pollution reduced by more. This need not be a surprise as the number of units reduced (9.07) in the South Dekalb is more than the number of units reduced (4.28) in United Ave. Whereas in McDonough the number of units reduced (8.93) in the next 60 hours after the Yajna.

E. Year 2016 Experiment

We have arranged 39 Yajna Kundas or fire pits with 30 of them being inverted copper pyramidal shape with dimensions (4-inch x 4-inch x 2-inch) and the rest being brick with six of them being square shape with 2-feet x 2 feet on the top and 6-inches deep. One is circular with one-foot diameter and one foot deep. Another is semi-circular with 2-feet diameter and one-foot deep. The last one is bigger in the shape of a sand clock with a total length of 5-feet and width of 3-feet and depth of 6-inches.

On 21st May 2016 we did Yajna at Duluth, GA close to Gwinnet Tech where the instruments were present for measuring air pollution. The Maximum PM values for each day are as shown below in Table-9. The table indicates that the Maximum PM value after the Yajna is the least and the pollution remained reduced for about 36 hours.

Table-9 Maximum PM values - 2016

Date	Maximum
5/19/2016	11.4
5/20/2016	7
5/21/2016 before the Yajna	7.2
5/21/2016 After the Yajna	6.6
5/22/2016	13.1

F. Year 2017 Experiment

In this experiment we arranged 18 Yajna Kundas or fire pits with 17 of them in the shape of square tops with dimensions 18-inch x 18-inch and with a depth of 6-inch. One was in the shape of a semi-circle with radius of 24-inch and a depth of 6-inch. All the fire pits were made of brick with the interior covered with aluminum foil.

On 10th June we did Yajna at McDonough, GA between 6:30 AM and 11:30 AM. The average PM (Particulate Matter) values from 8th June 2017 to 14th June are given below in Table-10. These average PM values are for 2 consecutive days before the Yajna, the day of the Yajna, and 4 consecutive days after the Yajna. The average values before the Yajna were greater than 8 and after the Yajna the values have dropped below 6.40 indicating Yajna reduces pollution due to Particulate Matter.

Table-10 Average PM values at McDonough - 2017

Date	Average PM Value
06/08/2017	8.16
06/09/2017	8.30
06/10/2017	9.40
06/11/2017	6.03
06/12/2017	5.60
06/13/2017	5.30
06/14/2017	6.40

Before the Yajna the average PM values were as high as 9.40 and after the Yajna the values reduced to as low as 5.30 as shown in the Table-10 and the reduced pollution levels remained for more than 96 hours after the Yajna.

G. Year 2018 Experiment

The Yajna Kundas or fire pits were similar to that of year 2017 except one being circular with one-foot diameter and 6-inch deep. On 25th August 2018 we did Yajna at McDonough, GA between 6:30 AM and 11:30 AM. The average PM (Particulate Matter) values for each day from 23rd to 31st August 2018 are given below in Table-11. That is 2 days before the Yajna and 6 days after the Yajna.

Table-11 Average PM values - 2018

Date	Average PM Value
08/23/2018	17.37
08/24/2018	16.50
08/25/2018	12.52
08/26/2018	10.65
08/27/2018	10.03
08/28/2018	10.57
08/29/2018	7.34
08/30/2018	2.80
08/31/2018	4.14

From Table-11 it is evident that the average PM values have reduced to more than 84% by the end of 30th August. If we take the average for the 60 hours before the Yajna and compare it with the average for the 154 hours after the Yajna, we see that the average PM values have reduced by about 50%.

Year 2019 Experiment:

The Yajna Kundas or fire pits were in the same shape and dimensions as mentioned in the year 2015 (Fig-3).

On 6th October 2019 we did Yajna at McDonough, GA between 6:30 AM and 10:30 AM. The average PM (Particulate Matter) values for the 10 days is given below in the McDonough, Georgia region. The average PM (Particulate Matter) values for the five days from 1st to 5th and that from 6th to 10th October are given below.

Table-12 Average PM Values at McDonough - 2019

Date	Average PM Value
From 10/01/2019 to 10/05/2019	14.82
From 10/06/2019. To 10/10/2019	4.93

The average value of PM 5 days before the Yajna is 14.82 and 5 days after the Yajna is 4.93 which indicates that the PM pollution reduced by 66%. Similar results were observed at a distance of 50 Kilometers from the site of the Yajna.

IV. CONCLUSION

In the year 2012 Yajna reduced PM pollution even at a distance 30 miles (48 Kilometers) away from the location of Yajna for about 60 hours. The rainwater is purer than Ozark and Nestle drinking water as the number of TDS is the least in it, has good Floride content indicating decrease in pollution in stratosphere, and having good hardness which decreases risk of acidification of lakes and ponds. In the year 2013 Yajna reduced the PM pollution even at a distance of 50 Kilometers of the Yajna site for about 5 days after the Yajna. In the year 2014 Yajna reduces PM pollution for a period of about 60 hours after the Yajna. In the year 2015 it is observed that after the Yajna PM pollution is reduced for more than 84 hours in the radius of 10 miles (16 Kilometers) and pollution is reduced for more than 60 hours at a distance of 40 Kilometers from the Yajna site. In the year 2016 Yajna Particulate Matter pollution is reduced but the reduction was for a period of 36 hours only. The reason could be the smaller size of the Yajna Kundas and lesser number of ahuthis. In the year 2017 it is observed that after the Yajna the PM pollution reduced for more than 96 hours and the results were very satisfactory. In the

year 2018 it is observed that the PM values have drastically decreased after the Yajna for a period of one complete week. In the year 2019 it is observed that Yajna reduced PM Pollution for about a week in a radius 50 Kilometers from the site of the Yajna.

Since the results have repeated regularly every year without fail, we conclude that Yajna is a process that is suitable for the reduction of PM (Particulate Matter) air pollution.

V. ACKNOWLEDGMENT

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