e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:05/Issue:06/June-2023 Impact Factor- 7.868 www.irjmets.com

ACID RAIN AND COMPARATIVE STUDY OF RAINWATER

Lekhya Bandapalli*1

*1Student, AS Levels, Primus Public School, Bangalore, Karnataka, India.

DOI : https://www.doi.org/10.56726/IRJMETS42390

ABSTRACT

The composition of rainwater has been changing continuously over the past few years , this is primarily due to rapid industrialisation and rising levels and population overload As the pollution has been constantly increasing, the quantity of harmful gasses (air pollutants) produced have also been increasing, resulting in climate change. This is causing the rainwater to turn more acidic which is harmful not only for humans but also plants and microorganisms. Furthermore, buildings and monuments are also affected by acid rain.

To get a deeper understanding of the quality of rainwater , I conducted an experiment - testing pH of rainwater from different geographical areas and observing plant growth under similar growing conditions but watering them with waters of varying pH. Therefore this paper intends to give a good interpretation of the quality of rainwater in different regions, and the causes and effects of acid rain.

Keywords: Rainwater, Ph, Titration, Acid Rain, Plant Growth, Rainwater.

I. INTRODUCTION

Over the last few decades, there has been a massive increase in pollution as a result of industrialisation, growing population and several other extrinsic and intrinsic factors, which has led to a serious accumulation of toxic gasses in the atmosphere causing air pollution and acid rain.

But what is acid rain ?

Acid rain is a broad term that refers to any form of precipitation (rain, snow, hail or fog) that has a relatively high concentration of hydrogen ions (low pH value) due to the presence of sulfur and nitrogen oxides.

The growing presence of these oxides, especially sulfur dioxide, is a serious threat because it is the chief contributor to acid rain;this trend can be observed in fig (1.1,1.2).

The term acid rain was first coined by Robert Angus Smith in 1852 , when the industrial revolution gave rise to high emissions of these oxides (Biggs B et al , 2022). But, since acid rain can be in the form of wet or dry depositions scientists nowadays prefer to use the term “acid depositions” rather than acid rain.

Wet depositions are formed when the oxides of nitrogen or sulfur combine with molecules of water (moisture) forming their respective acids. They are usually widespread and can be observed over a large area (few kilometers). On the other hand dry deposition can be observed majorly only in and around the region of emission of these gasses. In dry deposition , The acidic particles and gasses may deposit to surfaces (water bodies, vegetation, buildings) quickly or may react during atmospheric transport to form larger particles that can be harmful to human health when the accumulated acids are washed off a surface by the next rain.(EPA,2023).

Another observation is that in the early 19th century acid rain was confined to the industrial areas however as the rate of emissions continued to increase, acid rain has now become a global problem. This is largely due to increase in the sources of sulfur and nitrogen oxides. These pollutants originate mainly from human activities (such as combustion of burnable waste, fossil fuels in thermal power plants and automobiles, smelting plants, industries manufacturing sulphuric acids, and the operation of acid concentrators in the petroleum industry and vehicular emissions).Two thirds of sulfur dioxide and one fourth of nitrogen oxide found in the atmosphere originate from electric power generators(EPA,2023).There are however natural sources as well (this includes volcanic eruptions and oceans for sulfur oxides , and lightnings, biological processes and volcanic eruptions for nitrogen oxides).

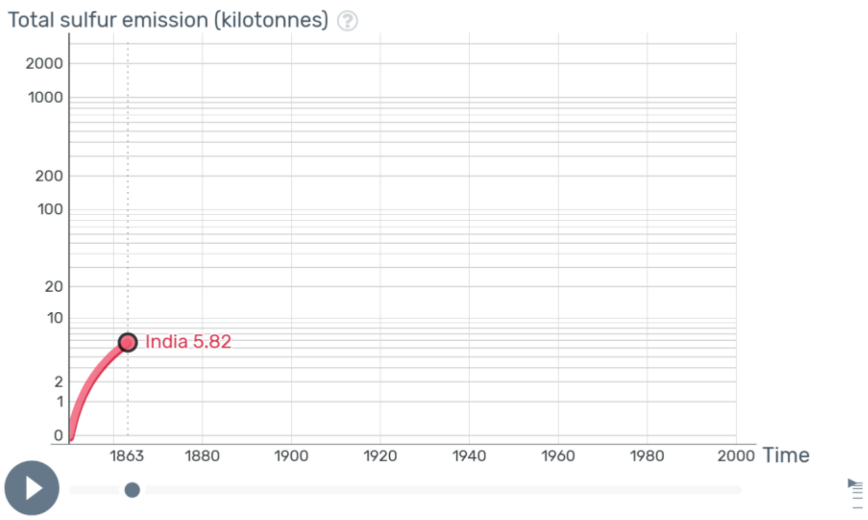
If the pollutants mentioned above continue rising at the same rate in our country as it has been, there would be serious consequences (Currently, the highest rates of atmospheric S and N deposition on earth occur in parts of Asia (Vet et al., 2014)). In Southeast Asia and India, SO_2 and NO_x emissions continue to increase (Duan et al.). Additionally, precipitation pH is higher for given levels of S and N deposition in northern China and in parts of

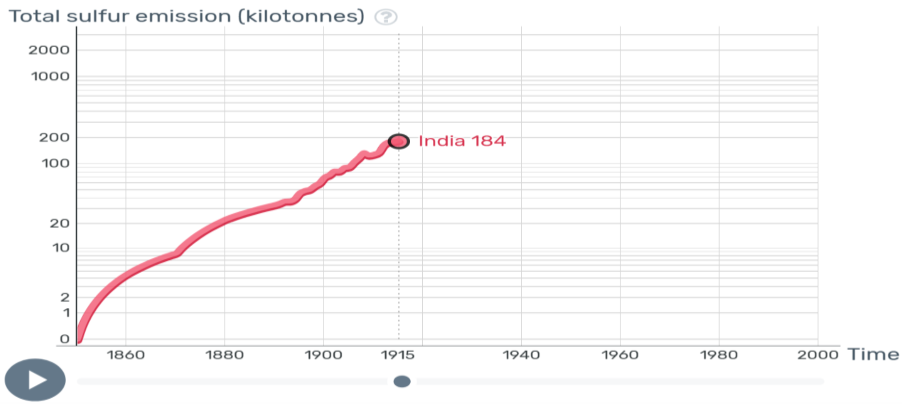
e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:05/Issue:06/June-2023 Impact Factor- 7.868 www.irjmets.com

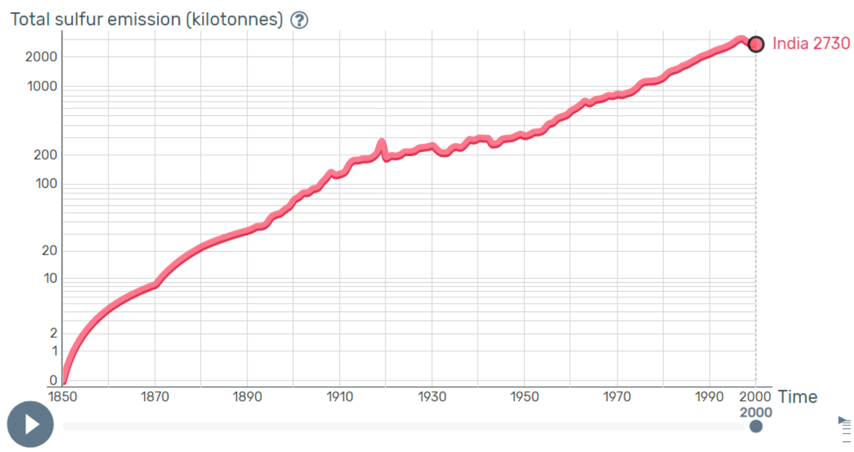
India due to neutralization by high concentrations of base cations such as calcium (Ca^{2+}) and magnesium (Mg^{2+}) (Duan et al. and Rao et al.,2016).

Therefore, in this research I aim to find out how geography and other environmental conditions impact the quality of rainwater, understand the concept of acid rain and its composition , be able to determine the acidity of water based on pH and finally learn about the consequences of acid rain.

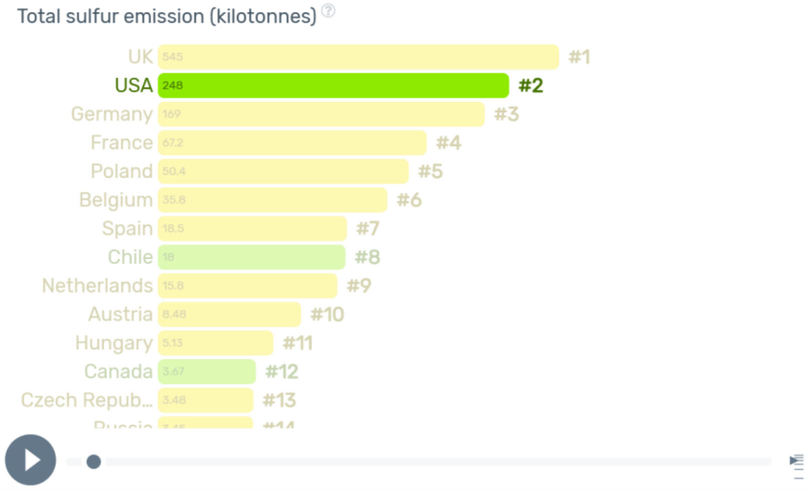
Fig(1.1) Shows the growing trend in emission of sulfur(expressed in kilotonnes) as the primary cause of acid rain, 1850-2000(Gapminder,2023). For the full video of growth by year click on the link given in the reference.

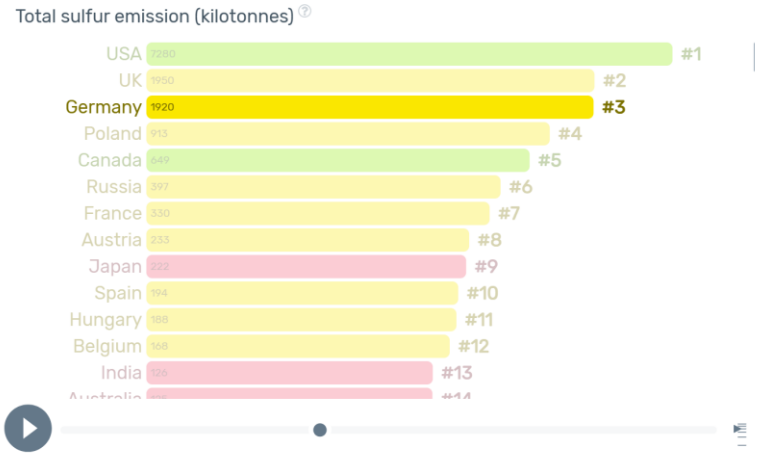


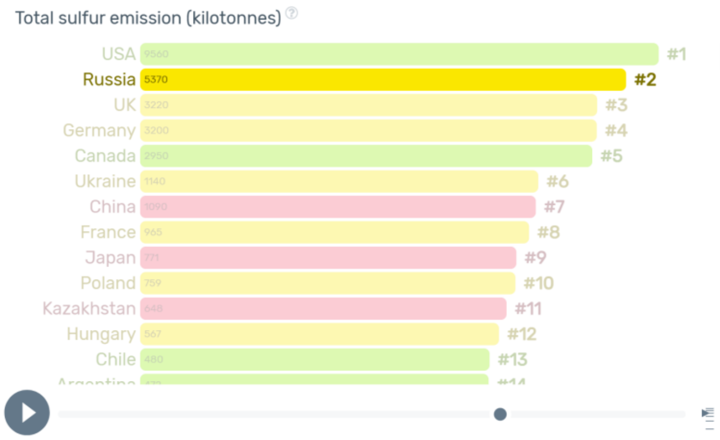




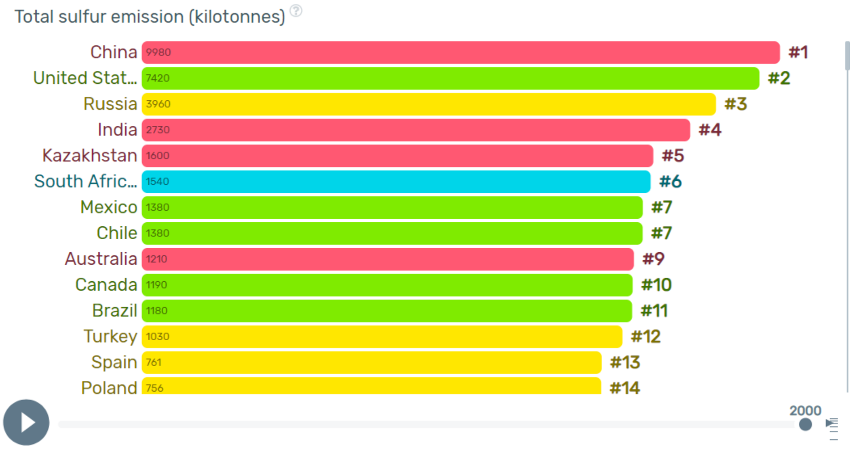
Fig(1.2) Shows the sulfur emission (expressed in kilotonnes) rankings by country, 1850-2000(Gapminder,2023).Focus on the ranking of India, for the full video of ranking by during this time period, check the link in the references.


Total sulfur emission (kilotonnes)
UK 545 #1
USA 248 #2
Germany 169 #3
France 67.2 #4
Poland 50.4 #5
Belgium 35.8 #6
Spain 18.5 #7
Chile 18 #8
Netherlands 15.8 #9
Austria 8.48 #10
Hungary 5.13 #11
Canada 3.67 #12
Czech Repub... 3.48 #13


Total sulfur emission (kilotonnes)
USA 7280 #1
UK 1950 #2
Germany 1920 #3
Poland 913 #4
Canada 649 #5
Russia 397 #6
France 330 #7
Austria 233 #8
Japan 222 #9
Spain 194 #10
Hungary 188 #11
Belgium 168 #12
India 126 #13


Total sulfur emission (kilotonnes)
USA 9560 #1
Russia 5370 #2
UK 3220 #3
Germany 3200 #4
Canada 2950 #5
Ukraine 1140 #6
China 1090 #7
France 965 #8
Japan 771 #9
Poland 759 #10
Kazakhstan 648 #11
Hungary 567 #12
Chile 480 #13

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:05/Issue:06/June-2023 Impact Factor- 7.868 www.irjmets.com



II. METHODOLOGY

For conducting this experiment, rainwater was collected from two different locations (Osla village, Uttarakhand; Bangalore; Karnataka). Each of these locations have different geographical conditions as described in table (1.1).

The rainwater was then tested using pH paper, and simple acid base titration to demonstrate the laboratory method was performed based on which a titration curve was drawn to compare the acidity of these rainwater.

The same was performed with normal tap water as a control. For observing the effect of rainwater of different chemical compositions on plant growth, A plant growth test was performed and the rate of plant growth was observed.

Table (1.1) Geographical features of the places from which samples were collected.

PLACE	Osla village	Bangalore
ALTITUDE (above sea level)	2590m (8500 ft)	920m (3018 ft)
MEAN TEMPERATURE	20.4 °C | 68.8 °F.	22.9 °C | 73.1 °F.
ANNUAL RAINFALL	6731 mm | 265 inch	960 mm | 37.8 inches.
AIR QUALITY INDEX	Excellent	Poor

pH test

A sample of 5ml of rainwater was taken in a beaker and a pH paper was dipped in the water for a few seconds. The color change in the pH paper was observed and the color change of the pH was checked and compared with the pH scale Fig(1.14). Next 5 drops of universal indicator solution was added to each of the water samples and again, the color change was noted and looking at the chart, the pH value was determined. Refer to the table (1.3), Fig(1.3-1.9) for detailed observation.

Titration

Titration is usually performed in a laboratory with advanced equipment; however, for the purpose of this experiment, I performed a simple procedure with minimal equipment.

First I prepared a titrant (alkaline solution) with 80 ml of water + 5 drops of universal indicator and 1 teaspoon of baking soda (sodium bicarbonate).

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:05/Issue:06/June-2023 Impact Factor- 7.868 www.irjmets.com

Next I added 5 ml of rainwater from each of the 2 locations and also 5 ml samples of tap water and filter water to 5 different beakers along with 5 drops of universal indicator as an attempt to demonstrate titration.

As a control the same experiment was performed using vinegar(acetic acid) first,for which I used 5 ml of vinegar with 20 ml of water (analyte).

Then the titrant was added little by little to the rainwater and vinegar solution until they reached a pale green solution. The amount of titrant used was measured and a titration curve was drawn accordingly Fig (1.15).

Plant growth test

Plant growth was another technique that I used to compare the stages of development of plants with different water sources (tap water,filter water, Bangalore rainwater,Osla village rainwater and vinegar solution). I planted Broccoli seeds in 5 different pots(A,B,C,D,E). Each of them were allowed to grow in the same type of soil and under the same conditions ,and were watered on a daily basis with water source assigned.

To identify the growth I did the following:

- Appearance of first cotyledon (seed leaves).
- Percentage of seeds that germinate ((no of cotyledons/total no: of seeds)*100).
- Regular leaf count

This data was recorded in a table. Refer table (1.1).

III. MODELING AND ANALYSIS

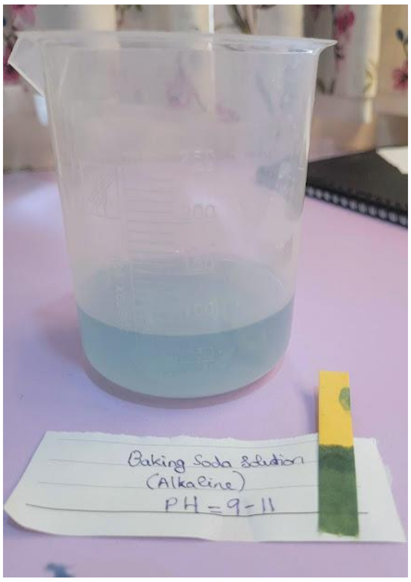


Fig 3.1 ph test of baking soda solution

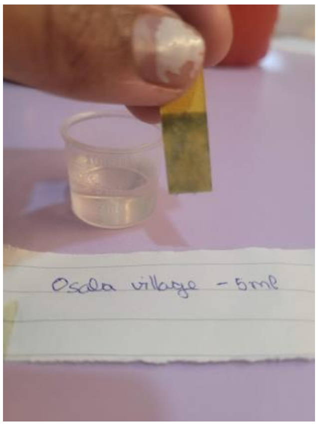


Fig 3.2: ph paper test of rainwater from Osala village

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:05/Issue:06/June-2023 Impact Factor- 7.868 www.irjmets.com

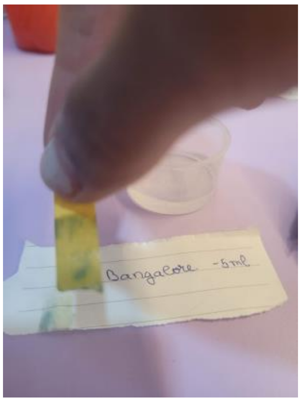


Fig 3.3: pH paper test of rainwater from bangalore

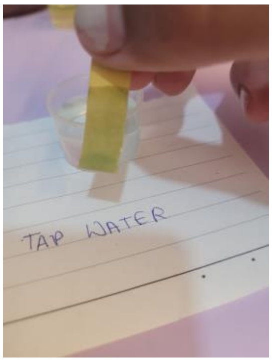


Fig 3.4: pH paper test of tap water

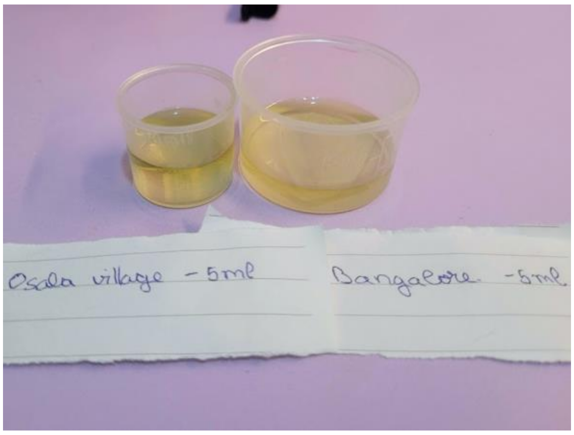


Fig 3.4: universal indicator test of rainwater (greenish yellow and yellow (left and right))

Fig 3.5: universal indicator test on filter water(green)

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:05/Issue:06/June-2023 Impact Factor- 7.868 www.irjmets.com

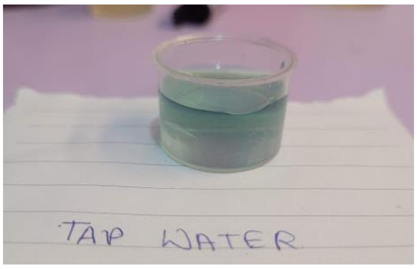
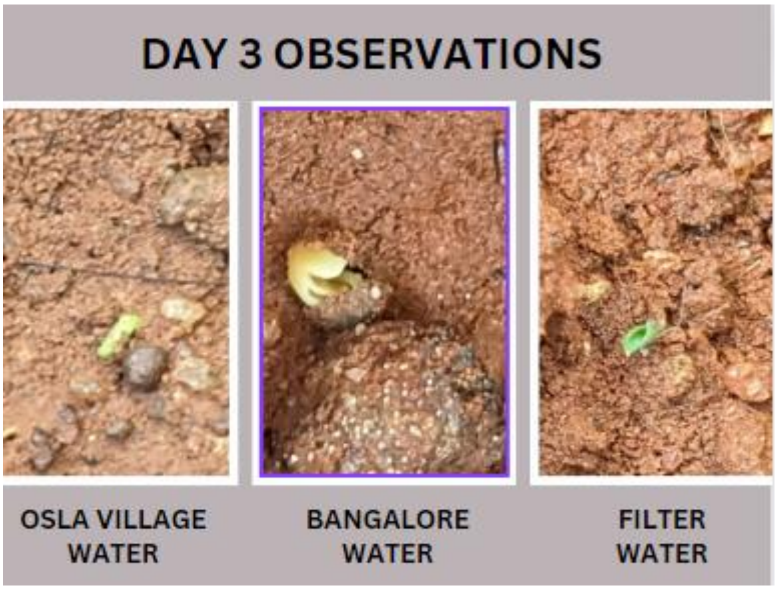


Fig 3.6: universal indicator test on tap water(blue)

Fig 3.10: universal indicator test on vinegar solution(orange)

Fig 3.11: vinegar solution after titration(neutralized)



e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:05/Issue:06/June-2023 Impact Factor- 7.868 www.irjmets.com

DAY 4 OBSERVATIONS

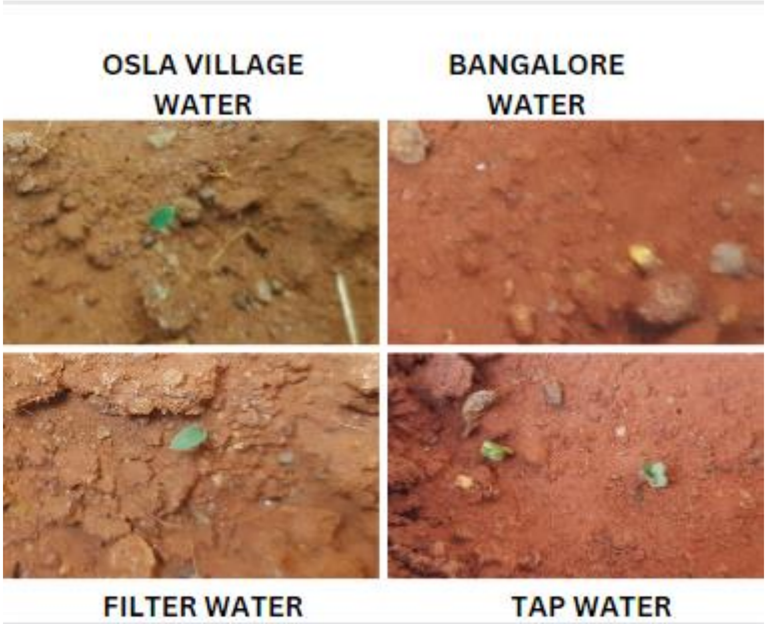


Fig 3.12: plant growth test significant observations

IV. DISCUSSION

There are certain basic terms that must be defined in order to understand and analyze the results of this experiment.

Here I have explained briefly the composition of acid rain, pH (definitions, its measurement, its effect by temperature) and titration (basic definition).

Composition of acid rain-

Normal rain water is slightly acidic and this is because rain water reacts with the CO_2 in the atmosphere forming weak acid(H_2CO_3-carbonic acid).

$$CO_2 + H_2O \dashrightarrow H_2CO_3 \quad - (1).$$

However the acidity increases when there is acid rain.

The chemical reaction that results in the formation of acid rain involves the interaction of SO_2 , NO_x and O_3. When the pollutants are vented into the atmosphere by tall smoke stacks, molecules of SO_2 and NO_x are caught up in the prevailing winds, where they interact in the presence of sunlight with vapors to form sulphuric acid and nitric acid mists. These acids remain in vapor state under the prevalent high temperature conditions. When the temperature falls, condensation takes the form of aerosol droplets, which owing to the presence of unburnt carbon particles will be black, acidic and carbonaceous in nature. This matter is called "acid smut". The presence of oxidizing agents and the characteristics of the reaction affects the rate of acid generation (Calvert et al., 1985) (A.Madhoomika,S.Anita , 2008).

Sulphur as the cause:

$$SO_2 + O_2 \longrightarrow SO_3 \ -(2)$$

$$SO_3 + H_20 \longrightarrow H_2SO_4 \ - (3)$$

$$SO_2 + H_20 \longrightarrow H_2SO_3 \ - (4)$$

(sulfur dioxide oxidation is common in highly polluted areas where oxidation is catalyzed by ammonia and ozone)

$$H_20_2 + HSO_3 \longrightarrow HSO_4 + H_2O \ - (5)$$

$$N_2 + O_2 \longrightarrow 2NO \ -(6)$$

$$2NO + O_2 \longrightarrow 2NO_2 \ -(7)$$

$$4NO_2 + O_2 + 2H_2O \longrightarrow 4HNO_3 \ -(8)$$

$$NO_3+NO_2 \longrightarrow N_2O_5 \text{ -(9)}$$

$$N_2O_5+H_2O \longrightarrow HNO_3 \text{ - (10)}$$

Reactions with ozone:

$$O_3 \longrightarrow O+O_2 \text{-(11)}$$

$$O+H_2O \longrightarrow 2OH \text{-(12)}$$

$$HSO_3+OH \longrightarrow H_2SO_4 \text{-(13)}$$

$$HSO_3+O_3 \longrightarrow SO_4+H+O_2 \text{-(14)}$$

$$HSO_3+O_2 \longrightarrow SO_3+HO_2 \text{ (peroxy radical)-(15)}$$

Peroxy radical reacts with organic acids(formaldehyde, acetaldehyde etc)and contributes to 5-20% of the composition of acid rain.

$$NO_2+OH \longrightarrow HNO_3 \text{-(16)}$$

$$O_3+NO_2 \longrightarrow NO_3+O_2 \text{ - (17) - (A.Madhoomika,S.Anita , 2008)}$$

As we can see, Nitrogen and Sulphur react in a variety of ways forming harmful compounds which contribute to acid rain.

pH

When studying the nature of a substance(i.e acidic/alkaline), it is necessary to get acquainted with the term pH.

In general, pH is the hydrogen ion concentration. pH is defined as the negative logarithm of the concentration of hydrogen ions in a substance, in moles per liter; however, the formal definition of pH is given by :

$$pH = -\log_{10} a H^{+}.$$

Where aH^+ is the activity of the hydrogen ions in solution (Strictly, the hydrogen ions are hydrated and should be denoted as H_3O^+) . The activity of the hydrogen ions is related to its concentration by the expression:

$$aH^{+}= \gamma\, CH^{+}$$

Where the activity coefficient, **γ**, is less than or equal to one. Hydrogen ion activities, (except in strongly acid solutions), are nearly equal to the hydrogen ion concentration, i.e. **γ** is close to one and pH is generally expressed in the notation suggested (Sorenson ,1909):

$$pH=-\log_{10}(cH^{+}/\text{mol dm}^{-3})$$

The pH scale usually extends from 0 to 14. For example, pure water has a hydrogen ion concentration of 10^{-7} moles per liter at standard conditions (25°C), resulting in a pH of 7. If the substance is acidic(more H^+ ion concentration), then its pH will be below 7 and if it is alkaline(more OH^- ion concentration)then its pH would be **greater than 7** (Walsh et al ,1992).

Since pH is measured on a logarithmic scale, each unit increase of pH corresponds to a decrease in concentration by a factor of 10. For example, the concentration of hydrogen ions for pH 3 is 10 times greater than that of pH 4 and 100 times greater than pH 5(Walsh et al,1992).

pOH

As mentioned earlier as well, A solution's pH is dependent on its net concentration of hydrogen ions $[H^+]$ compared to concentration of hydroxide ions $[OH^-]$. These two concentrations are related by $\mathbf{[H^+] * [OH^-]=K\ W}$, where K W, the dissociation constant of water, is dependent on temperature (refer to dependence on temperature below) and equals $1.0 * 10^{-14}$ at 25°C. Expressing the terms above as logarithms yields**(pH + pOH = pKW)**. At 25°C this becomes pH + pOH = 14, which is why the scale for pH usually ranges from 0 to 14 (Walsh et al,1992).

Acid -Base equilibrium

An acid is defined as a proton donor, whereas a base is a proton acceptor

(Brønsted-Lowry,1923). Thus the relationship between an acid (HB) and its corresponding base(B^-) is:

$$HB \rightleftharpoons H^{+} + B^{-}.$$

HB and B are said to be conjugate and to form a conjugate acid base pair. HB is the conjugate acid of B and B is the conjugate base of HB. When the acid HB dissociates in water the following equilibrium is established:

$HB+ H_2O$ □ $B + H_2O^*$

i.e. an acid and water react reversibly to produce hydronium ions and a base(Walsh et al,1992).

Dependence on temperature

The pH of water changes with change in temperature (Le Chatelier's principle-This principle explains how factors like temperature influence the chemical solution in equilibrium.).This is because if you make a change to the conditions of a reaction in dynamic equilibrium then, the position of equilibrium moves to counter the change you have made. Hence, if you increase the temperature of the water, the equilibrium will move to lower the temperature again. It will do that by absorbing the extra heat. That means that the forward reaction will be favored, and more hydrogen ions and hydroxide ions will be formed. The effect of that is to increase the value of Kw as temperature increases(C Jim, 2023).

However the important point to remember is that if the pH falls as temperature increases, this does not mean that water becomes more acidic at higher temperatures. A solution is acidic if there is an excess of hydrogen ions over hydroxide ions (i.e., pH < pOH). In the case of pure water, there always is the same concentration of hydrogen ions and hydroxide ions and hence, the water is still neutral (pH = pOH) - even if its pH changes (C Jim, 2023).

pH measurement

There are several ways to determine the pH of a solution:using pH meter;indicators(phenolphthalein, methyl orange, litmus and universal indicator) and pH paper(eg:litmus paper).

Few of the advanced and more precise methods include using metal or glass electrodes and semiconductor sensor methods.

For this experiment I will be performing the basic pH test using pH paper and a universal indicator solution.(Fig 1.12)

pH paper

The pH level of a substance can be easily and conveniently measured by a pH paper.

pH paper is used to determine the acidity or alkalinity of a substance; This is done by dipping the pH paper into a solution and observing the change in color of the paper. The paper comes with a color-coded scale with the colors representing certain values. Refer to Fig (1.14) and table (1.1) to understand better.

Now, what is the reason for this color change? Well, pH paper is treated with a chemical called Flavin. This molecule, which is an anthocyanin is soluble in water and changes color in the presence of various types of solutions.Such chemical indicators can be found in foods such as red cabbage, strawberries or blueberries, to name a few, according to professors at Purdue University(Labpro,2022).

In general, pH paper is preferred to Litmus paper as Litmus paper is a pass or fail test.doesn't give the level of acidity or alkalinity but only determines if a substance is an acid or an alkaline.The blue paper turns red when the pH is acidic and the red paper turns blue when the pH is alkaline. Neutral doesn't result in any change of color. Thus, pH paper gives a more precise reading than litmus paper.

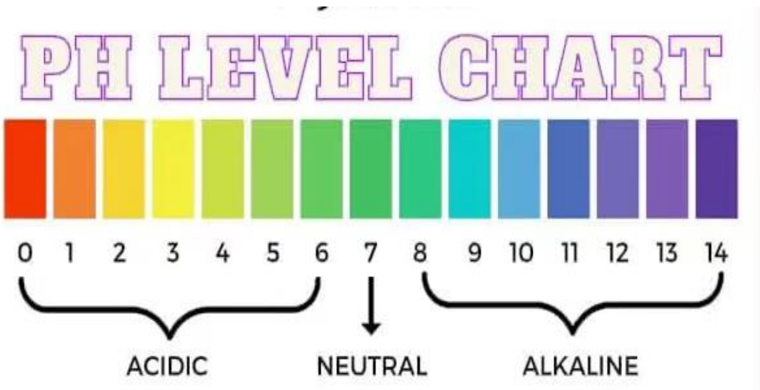


Fig 4.1: A pH paper or universal indicator scale(Ryazaan,2023)

Table 4.1: pH scale for reference(Labpro,2022)

pH range	Description	Colour
< 3	Strong Acid	Red
3-6	Weak Acid	Orange or Yellow
7	Neutral	green
8-11	Weak Alkaline	Blue
>11	String Alkaline	Indigo or Violet

Universal indicator solution

A universal indicator solution works on the same principle as pH paper. It is prepared by mixing several dyes which change color in accordance to the pH of the solution. A universal indicator can be prepared by making a solution with Methyl red, Phenolphthalein, Bromothymol blue ,95% ethanol and Distilled water.

First, Dissolve 0.18 g methyl red and 0.36 g phenolphthalein in 550 ml of 95% ethanol and 0.43 g bromothymol blue in 300 ml of distilled water in separate containers. Mix the two solutions together and dilute using distilled water to a final volume of 1 L.Finally, add 0.1 M sodium hydroxide (NaOH) dropwise until the indicator solution turns green(A.Helminstine,2021).

However, for this experiment I have purchased a ready made universal indicator solution.

Titration

Titration is an analytical method used in biomedical sciences and analytical chemistry laboratories to determine the quantity or the concentration of a known or unknown substance.

In a titration experiment, the concentration and volume of the base added is proportionally equal to that of the acid and the concentration of the substance is determined by following this principle(Pierre David,2019).

There are many kinds of titration, the most common ones are acid-base, reduction-oxidation, and precipitation as well as complexometric titrations(Pierre David,2019).

Titration curve

Titration curve is a graph of the pH as a function of the amount of titrant (acid or base) added. The equivalence point of the titration is the point at which exactly enough titrant has been added to react with all of the substance being titrated with no titrant left over. In other words, at the equivalence point, the number of moles of titrant added so far corresponds exactly to the number of moles of substance being titrated according to the reaction stoichiometry. (In an acid-base titration, there is a 1:1 acid:base stoichiometry, so the equivalence point is the point where the moles of titrant added equals the moles of substance initially in the solution being titrated (UBC, accessed 2023).Refer Fig(1.15).

V. RESULTS

pH test

For the pH test, the results were not clear with the pH paper as the color change was nearly the same for all samples of water (the pH value did not vary much and was very close to the neutral point) which is why I used a universal indicator solution with which I could make certain observations based on the color change in the samples as seen in the figures above.

According to my observations after performing the experiment 3 times , I could conclude the following reason for obtaining invalid results using pH paper:

1. I was able to see that, no sooner had I taken the pH paper out of the water sample being tested than the air particles around came in contact with the moist paper and changed its pH.

2. As mentioned earlier, the pH varied very minutely amongst the samples and therefore making appropriate conclusions was not feasible.

However, when I performed the pH test using indicator solution instead of paper, The color changes between samples was slightly different, and hence I made my conclusions as given in the Table(1.2), Fig (1.3-1.9).

Table 5.1: Observations of pH test

Sample	Colour	Ph level
Bangalore	yellow	3-4
Osla village	Pale green	5-6
Tap water	blue	9-10
Filter water	green	7-8
Vinegar solution	orange	1-2
Baking soda solution	blue-indigo	11-12

Titration

With the titration experiment, I was initially anticipating a positive result ,however on performing the experiment I realized that the acid solution was not acidic enough to perform basic titration. The vinegar solution on the other hand being an acidic sample served as an appropriate analyte and therefore a successful titration experiment was possible with the same and the titration curve was graphed.

Although the Bangalore rainwater was slightly acidic, determining the results from titration with the minimal equipment that I had was not feasible and the sample was easily over titrated which means it turned blue on adding less than a drop of alkaline solution to it. The same was the case with rainwater from Osla village which was even less acidic. The samples of filter water and tap water were not tested as they were neutral and alkaline respectively.

Table 5.2: Titration experiment observations

Substance	Titrant used (Initial volume - Final volume)
Rainwater from osla village	Easily overtitrated(turns blue)
Rainwater from bangalore	Easily overtitrated(turns blue)
Vinegar (control)	(80ml-75ml) 5ml

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:05/Issue:06/June-2023 Impact Factor- 7.868 www.irjmets.com

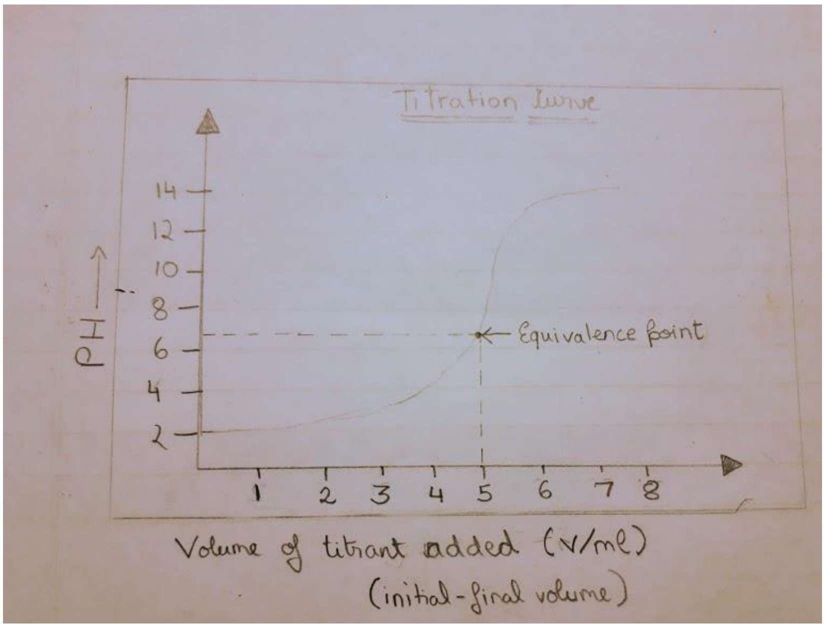


Fig 5.1: Titration curve for vinegar solution when titrant used was baking soda solutions

Plant growth test

For this test I made use of broccoli seeds, The plant growth was observed for a week, during this tes there were several impediments- I started the plant growth test with radish seeds but due to unpredictable weather, all 5 pots which were to be watered using water from different sources got watered in the rain(Bangalore). After this I continued the experiment however, I didn't water it regularly therefore they died. Another error that I had made was that I did not put an equal number of seeds in each pot which would have obviously hindered the results. Thus, I had to redo the entire process. When I started the experiment again with the broccoli seed, I was careful to add the same number of seeds in each pot, I watched them closely for a week watering them correctly on a daily basis (25ml) An additional observation made was that too much sunlight/ water damages young seedlings, as a result of which all my plants died after 7 days. The observations were nevertheless noted in the table below.

Table 5.3: Plant growth experiment observations

Plant Growth Test	**Plant Name: Brassica oleracea (Broccoli)**	**Number of seeds added : 5**	**Quantity of water: 25ml**	**Soil Type: red loamy soil**	
Day	Sample 1 **(Osla village)**	Sample 2 **(Bangalore)**	Sample 3 **Tap water**	Sample 4 **Filter water**	Sample5 **Vinegar solution**
1	-	-	-	-	-
2	-	-	-	-	-
3	tiny shoot appearance(1)	seed sprouting noticeable(1)	-	leaf appearance(1)	-
4	leaf from shoot appearance (1)	same	shoot appearance(2) with leaflets(4 each)	leaf size slight increase	-

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:05/Issue:06/June-2023 Impact Factor- 7.868 www.irjmets.com

5	same	no seed visible	same	shoot(2) visible	-
6	same	seed seen again	shoot height slightly increased		-
7	plant died	plant died	plant died	plant died	-
8	not watered	not watered	not watered	not watered	-
Percentage of seeds germinated : (no:of cotyledons/total no of seeds)*100	(⅕)*100=20%	0	(⅖)*100=40%	(⅕)*100=20%	0
Number of leaflets	1	0	8	1	0

Accuracy:- Accuracy can be defined as the degree of agreement between result and true value (can be +ve or -ve).

In this experiment several extrinsic factors may affect the accuracy of the experiment

A. Some plants may get more light than others (although closely placed).

B. Some seeds may be damaged while some may not.

C. Although each pot has soil from the same location, the nutrient content may vary from 1 put to another.

Therefore the observations made are not very accurate.

Analyzing this data, one can also conclude that the broccoli seeds grow best in slightly alkaline water(Tap water).

VI. CONCLUSION

Air pollution that has lead to acid rain continues to be an alarming issue in our country, having understood the causes of acid rain, its composition, and observing the effect of different samples(different pH)of water on the rate of plant growth, we must look at the broader picture and see how it affects the planet as a whole for if the trend (rate of emission of SOx gasses i.e contributors of acid rain) seen in Fig (1.1) continues to grow at the same rate, it will have several ill effects on living organisms (humans, animals, plants, microorganisms); non living entities (monuments, rocks) might also be transformed by the precipitation.

Plant growth

A United States Environmental Protection Agency (EPA) shows that acid rain is particularly hard on trees. It weakens them by washing away the protective film on leaves(cuticle), stunts growth, can interfere with plant root growth by making the potting material too acidic, can increase or decrease the solubility and availability of micronutrients and also cause minerals like iron to precipitate out and clog irrigation equipment. The pH actually unlocks the nutrients in the environment or from the substances you use such as plant fertilizers. Although most plants prefer a slightly acidic nature (pH around 5.5) over acidity leads to disastrous growth (Ryazan,2022).

Acid water decreases the water uptake of the plants as well as the disruption of photosynthesis which creates energy for them. The following are the common symptoms of a low pH that you can easily observe:

- The growth is stunted meaning the size of the plants is smaller than usual.
- The dark green leaves have red, bronze, or purple tinges.
- There are brown spots on the leaves.
- Some parts of the plants are dead (leaf necrosis).
- Leaves are unusually withered, stunted, or twisted.
- There is a presence of leaf tip burn.

- There is blossom end rot in the fruit.
- Leaf chlorosis is present (Ryazan,2022).

To conclude, In general plants thrive best when watered with rainwater as it contains all essential nutrients minerals and nitrates essential for the growth of the plant, it also has the right pH (5.6). Therefore if we control the emission of toxic gasses that pollute the atmosphere, the acidity of rainwater would then be the best suitable for any plant to grow.

Aquatic life

Water bodies and aquatic life are also suffering severely by - acid rain run offs that end up in streams, lakes and marshes, the rain also falls directly on these areas. Freshwater shrimps, snails, mussels are the most quickly affected by acidification followed by fish such as minnows, salmon and roach. The roe and fry (eggs and young) of the fish are the worst affected as the acidity of the water can prevent eggs from hatching properly, and can cause deformity in young fish which also struggle to take in oxygen (ypte, accessed 2023).

Soil

The acidity of the water does not just affect species directly; it also causes toxic substances such as aluminum to be released into the water from the soil. Upon contact with acid rain, chemicals like aluminum and mercury undergo chemical reactions with the acids forming harmful compounds. Soil chemistry can be dramatically changed when base cations, such as calcium and magnesium, are leached by acid rain thereby affecting sensitive species, such as sugar maple. These chemicals not only harm the flora, but also the animals that feed on them and microbes which cannot survive in low pH.

Certain areas are not affected by the acidification of soil as it is prevented by buffering. The buffering capacity depends on the thickness, composition of the soil and the type of bedrock underneath it. In areas where the soil is thin, it lacks the ability to adequately neutralize the acid in the rain water. As a result, these areas are particularly vulnerable and the acid and aluminum can accumulate in the soil, streams, or lakes. Therefore, if soil thickness is restored, that is soil erosion is augmented as much as plausible, the effects of acid rain can be negated.

Human Health

Human health is another major concern. Even though walking in acid rain doesn't necessarily cause any harm to humans, we are vulnerable to pollutants that cause acid rain (SO_x and NO_x gasses) which circulate in the air. As these gasses interact in the atmosphere, they form fine sulfate and nitrate particles that can be transported long distances by winds and can also penetrate indoors. Research has proven that these particles can even lead to cancer, affect heart functioning(heart attack) for people with increased heart disease risk, cause breathing difficulties for people with asthma, and eye irritation and effect on visibility is also common.

Solutions

In order to prevent the extremes of acid rain, certain measures can be taken. Listed below are a few solutions to prevent Acid rain.

- As we have learnt, SO_x and NO_x are the main contributors of acid rain and, the main sources are vehicles thus, the obvious solution to this would be reducing vehicular pollution. Using public transportation, walking, riding a bike or carpooling is a good start to reduce carbon footprint
- Fossil fuels are another important cause to be addressed. The emission of fossil fuels can be reduced by switching to non conventional (renewable) sources of energy such as wind, solar and hydro power as electricity generation generally involves burning of fossil fuels. Some other techniques for energy conservation - turning off lights or electrical appliances when not using them; using public transport; purchasing energy-efficient electrical appliances; and use of hybrid vehicles or those with low NO_x emissions.
- Washing coal, use of coal composed of low sulfur, and use of devices known as “scrubbers” can provide a technical solution to SO_2 emissions. “Scrubbing” also called flue-gas desulfurization (FGD) typically works to chemically eliminate SO_2 from the gasses leaving smokestacks.

- NO_x emissions from automobile fossil fuel combustions can be mitigated upon by the use of catalytic converters. Catalytic converters are fixed on the exhaust pipe system to reduce NO_x emission. Improvement of gasoline that combusts cleaner is also a strategy for reducing the emission of NO_x gasses.
- Use of limestone or lime, in a process called liming, is a practice that can be done to repair the damage caused by acid rain to lakes, rivers and brooks. Adding lime into acidic surface waters neutralizes the acidity however this only offers a short-term solution at the expense of solving the broader challenges of SO2 and NOx emissions and risks to human health. Nevertheless, it helps to restore and allows the survival of aquatic life forms by improving chronically acidified surface water(conserve-energy-future, 2023).

By following these steps the pollutants leading to acid rain can be checked and the acidified areas can be restored.

In conclusion, rainwater is of the best quality when not acidic and is best suitable for plant growth and consumption; however, such pure rainwater would be present only in regions where urbanization(eg:Osla village) is absent. Also we have learnt how to test the quality of water at home using minimal equipment which is essential to check the water supplied to you before consuming it.

According to me, acid rain has not yet reached its worst and can easily be negated \with cooperation between government and citizens.

VII. REFERENCES

[1] The United States Environmental Protection Agency(EPA,2023)- What is acid rain ?
https://www.epa.gov/acidrain/what-acid-rain

[2] Campbell, Sheelagh & Walsh, Frank. (1992). pH Measurements. Transactions of the IMF. 70. 148-151. 10.1080/00202967.1992.11870963.
https://www.researchgate.net/publication/316809214_pH_Measurements

[3] Agrawal Madhoolika , Singh Anita .2008 . Acid rain and its ecological consequences , Journal of Environmental Biology. http://www.jeb.co.in/journal_issues/200801_jan08/paper_02.pdf.

[4] Biggs Ben , Bradford Alina .2022 .Acid rain:Causes, effects and solutions, live sciences.
https://www.livescience.com/63065-acid-rain.html#section-causes-of-acid-rain

[5] Campbell, Sheelagh & Walsh, Frank. (1992). pH Measurements. Transactions of the IMF. 70. 148-151. 10.1080/00202967.1992.11870963.
https://www.researchgate.net/publication/316809214_pH_Measurements

[6] University of British Columbia,(accessed April , 2023).Strong acid-Strong base titrations.
https://groups.chem.ubc.ca/courseware/pH/section14/index.html

[7] Douglas A. Burns, Julian Aherne, David A. Gay, Christopher M.B. Lehmann,Acid rain and its environmental effects: Recent scientific advances, Atmospheric Environment, Volume 146, 2016. ISSN : 1352-2310, https://doi.org/10.1016/j.atmosenv.2016.10.019.

[8] Science Buddies (accessed April , 2023).Measuring plant growth.
https://www.sciencebuddies.org/science-fair-projects/references/measuring-plant-growth

[9] Farrer Dianne, Frankie Jones , 2008. North Carolina Department of Agriculture & Consumer Science - Irrigation water with low pH can harm plants. https://www.ncagr.gov/agronomi/release/1-08farrer.htm

[10] Science Buddies Staff., 2021. It's Raining, It's Pouring: Chemical Analysis of Rainwater.
https://www.sciencebuddies.org/science-fair-projects/project-ideas/EnvSci_p015/environmental-science/chemical-analysis-of-rainwater

[11] Carberry Andrew, MPH , 2022.How to Measure Growth Rate of Plants.
https://www.wikihow.com/Measure-Growth-Rate-of-Plants

[12] Ryazan ,2023.Zany plants world - PH Water Levels For The Plants: Definition, Benefits, And Effects.
https://zanyplantworld.com/ph-water-levels-for-the-plants/

[13] Conserve energy future (accessed April , 2023)- Acid Rain: Causes, Effects and Solutions to Increase in the pH Level.https://www.conserve-energy-future.com/causes-and-effects-of-acid-rain.php

[14] Clarke Jim, 2023- LibreTexts, Temperature Dependence of the pH of pure Water. https://chem.libretexts.org/@go/page/1293?pdf

[15] GapMinder. 2023 . Data visualization tools. https://www.gapminder.org/. Accessed (April 2023).

[16] Pierre, David. (2019). Acid-Base Titration. Undergraduate Journal of Mathematical Modeling: One + Two. DOI : 10. 10.5038/2326-3652.10.1.4913. https://www.researchgate.net/publication/336266913_Acid-Base_Titration

[17] AccuWeather.2023.Air quality and weather tools .https://www.accuweather.com/. Accessed(April 2023).

[18] Climate-data.2023.Rainfall and temperature .https://en.climate-data.org/. Accessed(April 2023).

[19] Besttravelmonths.com.Osla village climate. besttravelmonths.com/india/osla-1797659/. Accessed(April 2023).

[20] ypte.2023.Acid rain effects and causes. https://ypte.org.uk/factsheets/acid-rain/lakes-and-rivers#section Accessed(April 2023)