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A review on Effects of rainwater contamination on Environment

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Abstract - *Rain water is the condensation of evaporated water. The growing energy demand of nations to fuel the ever increasing number of industries and transport activities, has led to emission of large amount of gaseous pollutants like oxides of carbon, sulphur, and nitrogen and particulate matter from fossil fuel combustion. These oxides can contaminate rain water which turns into acid rain. It also damages man-made materials and structures. Acid rain is one of the most serious environmental problems emerged due to air pollution. In general, acid rain was pH less than 5.6 of atmospheric precipitation.*

Acid rain affects each and every components of ecosystem. The ecological effects of acid rain are most clearly seen in the aquatic water, environments, such as streams, lakes, and marshes. Acid rain also falls directly on aquatic habitats. This study discuses about the different sources of rainwater contamination like heavy pesticide use, vehicular and industrial emissions, roofing materials and its impact on water, photosynthetic rate of plants and plant growth, heavy metal toxicity, harvested water contamination due to roofing material.

Key Words: Acid rain, Pesticide, Photosynthesis, Heavy metal toxicity

1. INTRODUCTION

A world without water is difficult to imagine. It is vital for drinking, sanitation, agriculture, industry and countless other purposes. Rain is one of the major sources that replenish the water bodies and ground water system. These sources of fresh water provide humans water for drinking and other domestic uses. Any changes in the physical or chemical nature of this water will have adverse health impact on humans. The effect of rain on pollutant scavenging depends upon data on physical (rain drop size, rain amount and rain intensity) and chemical (ionic composition of rain water) properties of rain and data on sources of pollutants and their transport. The quality of rain water in turn affects the rivers and other water bodies, soil and ultimately ground water system. The rain water is contaminated by airborne pollutants like exhaust from factories and power plants which can carry sulphur compounds which turn into acid rain. Acid rain was first recognized by Ducros and subsequently described by the English chemist Robert Angus Smith whose pioneering studies linked the sources to industrial emissions and included early observations of deleterious environmental effects (ducros, 1845; smith, 1852, 1872; burns et al., 2016).

1.1 Acid rain effects on environment and human

Buildings and monuments

Acid rain causes severe damage to buildings and marble statues. Acid rain reacts with the calcium carbonate ($CaCo_3$) to form soluble calcium hydrogen carbonate or calcium bicarbonate, is a powdery substance, which is easily washed away with water or more specifically, rainwater. This is the way acid rain has partly eroded many world-famous monuments and buildings like the Taj Mahal in India, St. Paul's Cathedral in London, and the Statue of Liberty in New York. (Aadit Gandhi et al, 2017)

Lakes and rivers (aquatic ecosystem)

It is in aquatic habitats that the effects of acid rain are most obvious. Acid rain runs off the land and ends up in streams, lakes and marshes - the rain also falls directly on these areas. As the acidity of a lake increases, the water becomes clearer and the numbers of fish and other water animals decline. Some species of plant and animal are better able to survive in acidic water than others. Freshwater shrimps, snails, mussels are the most quickly affected by acidification followed by fish such as minnows, salmon and roach. Lakes, rivers and marshes each have their own fragile ecosystem with many different species of plants and animals all depending on each other to survive. If a species of fish disappears, the animals which feed on it will gradually disappear too. (Aadit Gandhi et al, 2017)

Soil

Soil contains many harmful minerals such as mercury and aluminum. These elements can't be absorbed by plants and trees and are thus harmless. Upon contact with acid rain, these chemicals undergo chemical reactions with the acids. 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. As a result, compounds of aluminum, lead and mercury are formed. Plants and trees can easily absorb these compounds. Such elements, which are extremely harmful to living forms, ultimately affect the entire food chain. These chemicals not only harm the flora, but also the animals that feed on them. Soil biology and chemistry can be seriously damaged by acid

rain. Some microbes are unable to tolerate changes to low pH and are killed. (Aadit Gandhi et al, 2017)

Human health

Acid rain looks, feels, and tastes just like clean rain. The harm to people from acid rain is not direct. The acid in the rainwater is too dilute to have direct adverse effects. However, the particulates responsible for acid rain (sulfur dioxide and nitrogen oxides) do have an adverse effect. Increased amounts of fine particulate matter in the air do contribute to heart and lung problems including asthma and bronchitis. Walking in acid rain, or even swimming in an acid lake, is no more dangerous than walking or swimming in clean water. However, the pollutants that cause acid rain sulfur dioxide (SO_2) and nitrogen oxides (NO_x) do damage human health. These gases interact in the atmosphere to form fine sulfate and nitrate particles that can be transported long distances by winds and inhaled deep into people's lungs. Fine particles can also penetrate indoors. Acids are very small and fine particles. They are normally in a liquid state. When they are present in the atmosphere, they easily enter the lungs while breathing. Research has proven that these particles can even lead to cancer. (Aadit Gandhi et al, 2017)

2. LITERATURE REVIEW

Rain water contamination due to use of pesticide

Besides the other pollutants, pesticide residues are also one of the dominant contaminant of water as lot of pesticides are used to combat the insect–pest complex of agriculture and other fields related to health programed. In India, total 186 pesticides are registered under the Indian Insecticide Act 1968. Their injudicious use leads to build up of toxic residues in crop produce as well as environmental components. Residues of different insecticide groups like organochlorines, synthetic pyrethroids and organophosphates have been reported in lagoons, water sheds and municipal water system (Knedel et al.1997, 1998). Thus there is a need for protecting the water resources and their quality. The study on the extent of insecticide contamination of rain water in Hisar, one of the most developed agricultural area of India. In the research, rain water samples were collected and analyzed for the presence of different groups of Organochlorines (OC), Synthetic pyrethroids (SP) and Organophosphates (OP) group of insecticides. The probable reason of the presence of HCH isomers and DDT analogues can be attributed to the vaporization of these pesticides from the contaminated soil of the cotton growing region under study which got dissolved in the rain water whereas the presence of organophosphates and synthetic pyrethroids can be attributed to the frequent sprays of these pesticides in cotton fields. Therefore, presence of residues of these pesticides in rain water is fully justified as the vapors of these applied pesticides accumulate in air and on raining, come along with water. In present study, contamination due to OP compounds is more than SP as OP compounds have more solubility in water. Almost 80% samples showed the residues above mean residual level (MRL) of 0.5 ppb fixed for multi residues and on the basis of single pesticide, 16–50% samples contained residues above the MRL value of 0.1 ppb. (Beena et al, 2007)

Rain water contamination due to Organic acids

Organic acids like formic acids and acetic acid also contribute to the acidity of rainwater. Formic and acetic acids are ubiquitous in rainwater, clouds, snow, aerosols and gas phase in a wide variety of environments. Joan et al studied the concentrations of formic and acetic acid in Wilmington, NC, USA from January 2008 through March 2009 were compared to two previous studies at this location (conducted in 1987-1990 and 1996-1998) .The study of formic and acetic acid concentrations 2008 were lower than during either of the previous two sampling intervals (Avery et al., 1991). The highest concentrations of both acids were observed during the 1996 to1997 sampling period. The rainwater concentration changes were most pronounced for acetic acid where there has been more than a 50% decrease from 1996 to 1997 to 2008 in the volume weighted average concentration. The greatest changes in organic acid concentrations were observed during the growing season, which is also the tourist and high traffic season in this location. During the growing season, each time period was different from each other for both acid concentrations whereas during the nongrowing seasons there were no differences among the studies for formic acid concentrations and for acetic acid only the concentrations for the second two studies were different (Avery et al. 2001). The difference between the first two time periods resulted from increased urbanization of this area, with accompanying excess acetic acid coming from direct emissions from increased vehicular traffic. (Joan et al, 2012)

Rain water contamination due to roofing materials

Roof material is an important consideration when designing a rainwater catchment system .This is because it affects the quality of the harvested rainwater which invariably affects the usage as potable or non-potable. Study on the quality of rainwater from four different roofing materials like asbestos roof materials, aluminum, concrete and corrugated plastic within Ogbomosho North Local Government Area of Oyo State, Nigeria shows that the average temperature of all the samples collected from these roofs conforms to world Health organization standard. All the samples were colorless and odorless. The average pH of rainfall samples collected from the different roof types varied from 6.58 -6.94, 6.13 -6.3, 5.81 – 5.95 and 6.14 -6.45 for asbestos, aluminum, concrete and corrugated plastic roofs respectively. The average hardness of rainwater fell below the W.H.O standards. All the rainwater samples from the four roof types fell below the limit. Average chloride values do not conformed to the recommended values (200-300 mg/l). The average value for alkalinity values conform to the recommended standard value. The mean values for copper,

Nitrate as NO and magnesium fell within the standard value. The WHO specifies that any disease causing organism must not be detectable in any 100ml of water sample and must not be present in 95% of sample taken throughout any 12 months period.(olaye et al,2012)

The study conducted in Al al-Bayt University, to find the impact of roofing material on quality and development of water quality within the harvested area. Forty-five wet atmospheric deposition samples from precipitation, rooftop and parking lot runoff water were collected. The different roofing material types were: thermal insulation, concrete insulation, and water insulation, metal insulation, mixed concrete insulation, mixed asphalt insulation, roll asphalt insulation and seal coat. The characteristic analysis of rainfall result shows that some pH values are slightly below or above the limits of Jordanian Water Standard (JWS) for drinking water (6.5-8.5). Total Dissolved Solids (TDS) concentration and sulfate (SO_4^{-2}) in the rainfall water is within the limits of JWS for drinking water. The nitrate (NO_3^{-1}) ,sodium (Na^{+1}), potassium (K^{+1}), magnesium (Mg^{+2}) and calcium (Ca^{+2}) results in some samples exceeded the JWS limit. Heavy metals were below detection limits in most of the rainwater samples. Aluminum (Al^{+3}) and manganese (Mn^{+2}) were detected in less than 18% of the rainwater samples with values far below the JWS limits. The results for runoff from rooftops and parking lots showed that the average results for all runoff water samples have pH values within the JWS. (hani et al,2018)

Heavy metal contamination due to acid rain

When water bodies receive acid rain the resulting stress causes both the lowering of pH and also the increased release of heavy metals from sediments to the overlying water. This phenomenon takes place as a consequence of higher solubility of most of the metals in water at lower pH. The cooperative effect of pH and metals on the toxicity of aquatic ecosystems is a matter of great concern. The low pH of falling rain can also result in the scavenging of metals from particulate matter suspended in air. The toxic effects of chromium on human beings and other life forms are associated with the metal's concentration and oxidation states. Investigation on whether acid rain, and the result, reduction in pH of the receiving water-bodies, are likely to modify the toxicity of chromium for better or for worse. This is important because chromium is present almost everywhere in soils and sediments. Acid rain can enhance the movement of chromium from these matrices to water and on to plants and animals. Chromium is also present in stainless steel and other materials which are in common use. The organism chosen to assess the impact in this study is the teleost Nuria denricus which occurs in ponds and channels in the tropics. Results shows the impact of pH and chromium was observed in the form of changes in the patterns of normal swimming and balancing. The stressed fish showed erratic, fast, and unbalanced swimming. They also exhibited increased surface breathing and twisting movements. After a few hours of exposure, the fish became unable to maintain their normal position and tended to turn belly up. Independent of the level of ambient pH, chromium is deemed 'toxic' to aquatic organism especially in its hexavalent form, Cr (VI). The presence of Cr(VI) in waters used for irrigation and for protection of aquatic life at levels above 0.05 mg/L makes such water unfit. These studies also reveal that the toxicity of Cr (VI) also increases if the ambient water pH rises above 9 units. Therefore, measures to neutralize the effect of acid rain by the addition of alkalis such as calcium hydroxide are also liable to enhance chromium toxicity if the process control is not rigorous. (Tasneem et al,2009)

Acid rain can cause the increase in the leaching of Cd^{2+} in soil (Wang et al. 2009), and then the increase in the content of Cd^{2+} which can be absorbed by plant. Thus the potential ecological risk of the combined pollution of $Cd^{2+}$and acid rain is a key question in the environmental research. Thus the research on the interactive effects of Cd^{2+} and acid rain on the photosynthetic light reaction in plant is one of theoretical foundations for clarifying the interactive effects mechanism of Cd^{2+} and acid rain on crops. The study about effects of cadmium and acid rain on photosynthetic light reaction in soybean seedlings shows that, the single treatment with Cd^{2+} or acid rain decreased the content of chlorophyll and net photosynthetic rate, leading to the inhibition of the photosynthesis. (Zhaoguo et al, 2012)

pH and Conductivity of acid rain

Unpolluted natural rain water has a pH value around 5.6, as atmospheric CO_2 gets dissolved in rain drops (Bayraktar and Turalioglu, 2005). Any change in the pH, below or above this level, defines rain to be acidic or alkaline, depending upon the type of pollutants transferred to rain water. Li Zong-Jie et al analyzed pH value and conductivity data of 402 precipitation events in Tuotuohe meteorological station in the source region of the Yangtze River. The seasonal variation of pH value and electrical conductivity was analyzed the order of conductivity in the four seasons was Spring > Winter > Summer > Autumn, with the value was 37.62 μs/cm, 31.86 μs/cm, 25.75 μs/cm and 24.04 μs/cm, respectively. The electrical conductivity of spring and winter was far greater than the summer and autumn. This may be mainly associated with the precipitation of winter and spring was less. So the atmospheric leaching of precipitation was weak. In winter and spring, the temperature was low, the air pressure was high, and it was easy to form the phenomenon of static wind. This was not conducive to the diffusion of particulate pollutants in the atmosphere, which made the air floating in a large number of pollutants. (Li Zong-Jie et al,2017)

Possible Solutions

The numbers of possible solutions are available to deal with air pollution and the resultant acid rain. However, what matters more is to consciously enforce these solutions on a wide scale. The most important thing is to educate people all over the world and create awareness, about the causes and

effects of acid rain. Solutions to this problem can only be successful through cooperation.

Given below are a few solutions, which can greatly reduce the threat of acid rain, if strictly followed by a large number of people.

- One of the most fundamental solutions is to utilize fuels that burn more cleanly, or to burn coal more efficiently. This will greatly reduce the amount of acid released in the atmosphere.

- As far as industrial power plants are concerned, the best solution is to attach devices known as 'scrubbers' in the chimneys of these plants. These scrubbers reduce the amount of sulfur released through the smoke by 90-95%. Moreover, industries must regularly inspect and clean all their emission equipment, chimneys, pipes, etc. The scrubbers which can be used in chimneys produce sludge while reducing the sulfur content, and in this process, it also produces a building material called gypsum, which is used to make plaster of Paris and cement.

- Cars and vehicles have a large contribution in polluting the environment, and causing acid rain. Using public transport, resorting to carpool, walking down to nearby places instead of driving, etc., can help us save fuel and gas, as well as reduce the adverse effects. It must be mandatory for vehicles and cars to comply with the efficient emission standards. Fitting catalytic converters into the exhaust pipes of vehicles also reduces the amount of sulfur dioxide emitted into the atmosphere.

- A small step can be taken by turning off our lights, computers, and other electrical appliances, when not in use. While purchasing, we can buy appliances, which consume less energy. If everyone follows this, it can help to a huge extent.

All these solutions will be pointless unless people are informed and educated about the ill-effects and harms of this rain. A widespread and nationwide effort must be made to make people aware of the hazardous effects. Only after that is done, will all the solutions actually make a difference. (Mamta Bhardwaj, 2016)

3. CONCLUSIONS

Rain is one of the major sources that replenish the water bodies and ground water system. Any changes in the physical or chemical nature of this water will have adverse health impact on humans. Acidification of environment is a phenomena caused by human activities. Acid deposition is more precise term for acid rain. Unpolluted natural rain water has a pH value around 5.6, as atmospheric CO2 gets dissolved in rain drops. Any change in the pH, below or above this level, defines rain to be acidic or alkaline, depending upon the type of pollutants transferred to rainwater. Scientists have discovered that the extensive use of pesticide can cause occurrence of pesticides on rain. From the present studies has been concluded that if the rain water is used as such without further processing then it would not be safe (Beena et al,2007). Acid rain would aggravate the adverse effects of heavy metal toxicity on aquatic ecosystems. Some studies revels that the toxicity of Cr (VI) increases if the ambient water pH rises above 9 units. Chromium causes pronounced toxicity in animals by way of carcinogenic and mutagenic impacts. Skin contact with Cr (VI) compounds induces skin allergies, dermatitis, dermal necrosis, and dermal lesion (Tasneem et al,2009). The combined pollution of heavy metal like Cadmium (Cd) and acid rain aggravated the toxic effect on the photosynthetic parameters due to the serious damage to the chloroplast structure. (Zhaoguo Sun et al, 2012)

Among the various catchments for the harvesting of rainwater, roof catchment seems to be the most common. This is because the inhabitants use existing roofs of their houses thereby no additional costs are incurred and the amount and quality of rainwater collected depends on the area and type of roofing material .But it has been reported that roofs can be a serious source of non-point source pollution as well. Some studies showed that the chemical characteristics of roof top water exceeding the standard limits, all the rainwater samples require some level of treatment before it can be fit for drinking.

Acid rain damages the plants the plant cell and hence adversely affects the growth of trees. The various damages caused by acid rain to the plant cell are-Membrane damage, chlorophyll destruction and plasmolysis and it reduce the photosynthesis rate of plants.

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