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## Assessment of the effects of acid rain on the biosphere in Mosul City / Iraq

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### A B S T R A C T

Acid rain is any precipitation with a very low pH, whereas normal rain water is slightly acidic with a pH range of 5-6, but the pH level of rain water falls below this range, becoming acid rain. It happens as a result of wet and dry deposition from the atmosphere of chemical pollutants emitted by various human activities. Dry deposition is more frequent and effective than wet deposition. It was found that the leading cause of acid rain is the emission of gaseous oxides of sulfur, nitrogen and carbon. These environmental pollutants come from various human activities such as the burning of fossil fuels, combustible waste, vehicle exhausts, thermal power projects, the combustion of vegetation and wastes of wars. These chemical pollutants interact with different precipitation such as; rain, cloud, fog and snow water, which is formed in the case of sulfuric, nitric and carbonic acids, then shows its impact on the lithosphere, water and atmosphere, in addition to its impact on other ecosystems such as; Forests, agricultural crops, soil, buildings and aquatic organisms, as well as human health. The risk of acid rain is controlled by reducing the emissions of gases to neutralize acidity which requires enacting laws and do enforce efforts to reduce pollution and control acid rain on all production projects. Our current study aims to assess the acidity of the rainwater, and it has been proven that the relative pH of the rainwater in the city of Mosul has decreased in the past two years (2020/2021-2021/2022) from (6.5 to 5.8), which requires knowing its causes, effects, and methods to limiting its consequences.

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## تقييم تأثيرات الأمطار الحامضية في المحيط الحيوي لمدينة الموصل / العراق

أيهام طه حسين / قسم تقنيات الموارد المائية/ المعهد التقني في الموصل/ الجامعة التقنية الشمالية / الموصل - العراق.

### الخلاصة

الأمطار الحامضية هي أي تساقط للأمطار التي لها درجة حامضية منخفضة جداً، في حين أن مياه الأمطار العادية لها درجة حامضية بحدود 5-6 ، ولكن مستوى الأس الهيدروجيني لمياه الأمطار ينخفض إلى أقل من هذا النطاق. و يحدث ذلك نتيجة لترسب الرطب والجاف من الغلاف الجوي للملوثات الكيميائية المنبعثة من الأنشطة البشرية المختلفة والترسيب الجاف أكثر تواتراً وفعالية من الترسيب الرطب. وجد أن السبب الرئيسي للأمطار الحامضية هو انبعاث أكاسيد الغاز من الكبريت والنيتروجين والكربون وتأتي هذه الملوثات البيئية من مختلف الأنشطة البشرية مثل حرق الوقود الأحفوري والنفايات القابلة للاحتراق وعوادم المركبات و تتفاعل هذه الملوثات الكيميائية مع هطول الأمطار المختلفة مثل: مياه الأمطار والسحب والضباب والثلوج ، والتي تتشكل في حالة أحماض الكبريتيك والنيتريك والكربونيك ، ثم تظهر تأثيرها على الغلاف الصخري والماء والغلاف الجوي ، بالإضافة إلى تأثيرها على النظم البيئية الأخرى مثل الغابات والمحاصيل الزراعية والتربة والمباني والكائنات المائية ، وكذلك صحة الإنسان. يتم التحكم في خطر الأمطار الحمضية عن طريق الحد من انبعاثات الغازات لتحديد الحموضة التي تتطلب سن قوانين وإنفاذ الجهود للحد من التلوث والسيطرة على الأمطار الحمضية على جميع مشاريع الإنتاج. تهدف دراستنا الحالية إلى تقييم تأثيرات حموضة مياه الأمطار، وقد ثبت أن الرقم الهيدروجيني النسبي لمياه الأمطار في مدينة الموصل قد انخفض في العامين الماضيين (2021/2020 - 2022/2021) من 6.5 إلى 5.8 ، الأمر الذي يتطلب معرفة أسبابه وآثاره وأساليبه للحد من تبعاته.

الكلمات الدالة : مطر حامضي، الموصل، المحيط الحيوي، ترسيب رطب، ترسيب جاف.

### 1. INTRODUCTION

The city of Mosul is the center of Nineveh Governorate, is located in the northwestern part of Iraq in the semi-dry region and in the environmental classification of the world between longitudes (41-25), (25-44) and latitude (5 It is dominated by cold weather in winter and low temperatures to below zero on most winter days with snow falling, especially in mountainous areas, and the city is characterized by rainfall between 300-400 mm/year, and a mild summer climate, so it is called the city of Umm al-Rabeein, which makes this the prevailing environmental conditions are suitable for rainfed agriculture for the production of cereal crops (wheat, barley, lentils, chickpeas, beans, vegetables...etc.). It is considered the breadbasket of Iraq, and its lands are covered with natural grasses and mountains with trees and shrubs, and it is characterized by the breadth of natural pastures. The governorate has been characterized by this environmental situation over the past decades, but in the past two decades, the governorate has witnessed major changes in its environment, where the vegetation cover has deteriorated, the soil has lost its agricultural productivity and desertification threatening its lands in four regions: Al-Baaj, Al-Hadder, Tel- Abtah, and Al-Shamal district in the Sinjar region [1]. Owing to the importance of this environmental problem, therefore, we relied on the results of scientific research, which indicates that air

pollution problems have increased dramatically during the twentieth century due to industrial development and non-compliance with environmental legislation, which caused the occurrence of many environmental disasters, including acid rain, such as the disaster in Donora in Pennsylvania, which occurred in the United States of America in 1948, Where a fog carrying acidic pollutants, which lasted for four days due to gas emissions from nearby factories, which caused the death of twenty people and injured 700 others, and the acid fog disaster in London in 1952, which killed 4000 people, and the Indian Bombay disaster in 1984, that caused the death of 200 people, the most gases that contribute in the formation of acid rain are oxides of sulfur, nitrogen and carbon, due to their ability to dissolve in rain water and the formation of acids [2]. Technological progress has served mankind in the exploitation of various natural resources in manufacturing, which is generating pollutants that cause damage to the ecosystem, as well as the use of fuels such as oil, natural gas and coal in energy production these pollutants, are helping to form acidic compounds such as sulfuric acid, nitric acid and carbonic acid in the atmosphere by reacting with snow, fog and rain [3]. For industries and power stations, the use of tall chimneys (exhaust pipes) has led to an increase in the production of atmospheric pollutants that contribute to the emission of pollutants locally, regionally and globally to the

formation of acid rain. The history of interest in acid rain goes back to the middle of the nineteenth century when acid rain was first observed in Europe. Although the scientist Ducrosse diagnosed this phenomenon in 1845. In 1852, the term acid rain was developed by the chemist Robert Angus Smith who observed damage to plant leaves caused by acid rain [4]. Where the study of industrial emissions has been linked as a source of acid rain formation, it also includes early monitoring of adverse environmental impacts. In Sweden, during the sixties and seventies of the twentieth century, it was revealed that nitric acid and sulfur dioxide caused acid rain, and it was later observed in North America [5]. Subsequently, the different environmental effects of acid rain on aquatic animals and plants were also recognized and it was determined that the acidification in fish aquatic habitats was due to sulfur pollutants. In 1936, the first step was taken in London to control acid rain, although the severity of the problem increased after 1970, due to the increased concentration of sulfur dioxide in the atmosphere resulting from the increased use of coal as a fuel. In 1980, after ten years of the National Continuous Acid Sedimentation Assessment Program in the mid-nineties of the past century, the US Congress passed a law regarding the impact of acid rain on buildings, aquatic ecosystems, and monuments. It became clear that the emissions of acid rain pollutants have a relationship with global warming in that it raises the climate temperature and depletes the ozone layer, which is a transboundary environmental problem. Interest in preparing control programs and reducing the impact of pollutants on the ecosystem began by activating and implementing studies, scientific research and financial allocations to reduce environmental pollution. The US Congress approved improvements to the law of clean air in 1990 and emphasized preventive measures for sulfur dioxide and nitric oxide in two stages are aimed at reducing sulfur dioxide emissions where the first stage in (1995) and the second stage in (2000) when sulfur dioxide emissions were reduced by 54%. Several programs have also been implemented to reduce nitric oxide emissions from cars and factories. In March 2005, the Interstate clean air law was passed by the US Environmental Protection Agency to reduce pollution from power project emissions [6,7]. However, as a result of the economic competition between the industrialized countries and the applications of globalization programs currently, the global environmental affair is witnessing a significant deterioration due to technological techniques and the increase in human activities in depleting natural resources and excessive use of traditional energies, which draws the attention of researchers and stakeholders to mitigate and

reduce the pollution of the ecosystem.

## 2. MATERIALS AND METHOD

This study was carried out in the Department of Water Resources - Technical Institute / Mosul - Northern Technical University - for the years 2020/2021 and 2021/2022. The field survey was conducted in Mosul city in three different areas by collecting samples of rainwater during the winter season before hitting the soil for the purpose of evaluating the degree of acidity of rainwater using a pH measuring device which is called a (pH Meter) as in Fig.1. The selected regions were as follows the first was (R1) the industrial zone on the left coast of Mosul, (R2) the center of Mosul city and (R3) represented the industrial zone on the right coast of Mosul. The samples were taken in random form for the three regions above for the winter months (January, February, March, and April) for two years (2020/2021-2021/2022). Then recorded the data of measurements for rainwater and assessed its acidity, Fig.2. Shows the PH scale of level indicators which; are acidic (0-7), (7) neutral and (7-14) alkaline.



Fig.1. Shows the pH meter device for measuring acid rain.

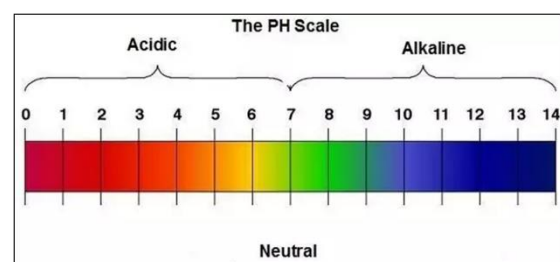


Fig.2. Shows the PH level indicator.

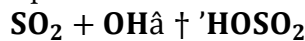
## 3. RESULTS AND DISCUSSION

Acid rain is also called acid precipitation. Acid deposition may be wet where gaseous pollutants interact with snow, rain and fog and then falls as acid rain which is calling as wet deposition. When winds carry acid chemicals pollutants to an area with wet weather, acids fall on the earth in the form of snow, fog and rain and then flow rainwater carrying acids falling towards the earth affecting the nature of life and causing the extinction of the biodiversity [8,9]. Also, the gaseous pollutants

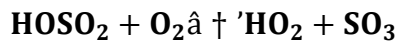
may be blown by winds and dust storms then will be drying and deposited on the surfaces of vegetation, buildings and water resources and interact on these surfaces with pollutants through rain falling forming acid rain which calling as dry deposition. As a result of acid rain flowing according to the slope of the earth, it mixes with different water resources such as rivers and others, causing a decrease in acidity. Among the main causes of acid rain are emissions of sulfur dioxide, nitrogen oxides, and carbon. These environmental pollutants come from the various activities of humans such as the combustion of fossil fuels for oil and natural gas derivatives and coal, vehicle & factories exhaust and thermal power projects. Sulfur pollutants also come from natural sources such as volcanic eruptions [10]. Human activities that produce sulfur dioxide include smelting iron and metal ores, burning petroleum and coal, and other industrial processes. While the natural sources of nitrogen oxide pollutants include biological processes and agricultural fertilization. The sulfur present in the atmosphere reacts with hydrogen peroxide to form sulfur dioxide, and in turn, it reacts with falling rain and forms sulfuric acid, while the reaction of nitrogen dioxide and carbon dioxide produces nitric acid and carbonic acid, respectively. This occurs as a result of the reaction of the oxides of these chemicals with rainwater in the atmosphere and then fall to the ground in the form of acid rain. One of the effects of acid rain on agricultural production is that forest trees act as lungs for air, and trees, agricultural crops and natural plants are affected by the acidity of rain. Also, the accumulation of heavy metal elements near the roots of plants causes the loss of chlorophyll, which reduces the activity of the photosynthesis process. It was also observed that seeds did not germinate in pine trees and other agricultural crops at low pH levels, especially in agricultural areas which contain industrial cities. A study showed that the protein content is reduced due to acid rain, it was observed that plants were dwarfed due to the effect of both sulfur and nitrogen present in acid mist on the growth of the stems of plants. Plants in the early stages of growth are affected more than older plants, which was occurred a decrease in forest density and vegetation cover due to acid rain which contributes to the extinction of biodiversity and the reduction of biomass due to the loss of its habitat. It has been scientifically proven that damage to the roots and leaves of plants and the death of trees occurs due to the effect of acid rain, as well as the low fertility of the soil due to the loss of soil vitality, because of the effect of acidity, acid rain has a harmful effect on physiological activities and the immune system in humans and animals [11]. Acid rain helps to concentrate heavy

metals in the plant and thus when consumes by the plants by humans it causes cancers and biological and chemical changes in the soil in addition to causing harmful effects as a result of the acidity of the soil, and they also harm the animals that feed on these plants. Greenhouse gas emissions from the soil also increase due to acid rain, this is due to the changes that occur in the soil ecosystem and a decrease in pH. The aquatic ecosystem is also affected by acid rain due to the leakage of heavy metals from the soil into the water ocean into nearby rivers, lakes and streams, causing water pollution. These heavy metals enter the food chain of humans and animals, causing poor health and poisoning. Acid rain has indirect effects on human health as a result of heavy metals leaking into the soil, such as lead and mercury, which dissolve in the soil and reach the groundwater. As a result of using this water for drinking, and because of that, heavy metals accumulate in the human body and lead to headaches, coughs, and irritation of the throat and nose. These toxins also cause kidney problems, brain damage, heart disease, as well as lung diseases such as bronchitis and asthma. It is extremely dangerous to swim in an acid lake or walk in acid rain, also inhalation of nitrates and sulfates affects the respiratory system and causes cancer, acid rain causes skin and eye irritation due to polluted droplets. Acid rain is related to climate change in the addition of acid rainwater due to the emission of sulfur dioxide, nitrogen dioxide and carbon dioxide these are the main component of global warming, which is produced due to human activities, and since it is from a light gases, it rises and reaches to a high level in the atmosphere, when its concentration increases, the temperature of the atmosphere increases and leads to global warming. Therefore, acid rain gases are also responsible for climate change and global warming. Acid rain can be controlled by neutralizing the acidity by adding limestone to lakes and water sources and by reducing the harmful effects of heavy metals by raising the pH of acidic water by adding lime, caustic soda, limestone and sodium carbonate [12,13]. It is also possible to reduce the emission of pollutants such as sulfur oxides, nitrogen and carbon, and to control acid rain by using environmentally friendly renewable energies. As well as through political and legal legislation through international organizations and mitigating the burden of the ecosystem and adherence to central legislation that decides to reduce global environmental pollution to control the effects of acid rain [13, 14]. Table 1. shown below clarify that the acidity of the rain falling in Mosul is decreasing from one year to the next, as the pH for the year 2020/2021 with the acidity measurement standard of the samples reached (6.5), and in the year

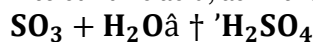
2021/2022 there was a decrease in the acidity of the rain and its measurement was (5.8). This can be explained by the emissions of acid rain gases, due to the presence of 3 cement plants (Hammam Al-Alil, Sinjar and Badoush), car exhaust, petrochemical industries in Hammam Al-Alil, Qayyarah and Ain Zalah, and the burning of oil wells during the liberation of Nineveh Governorate from terrorism in 2016, where terrorist elements burned 19 oil wells out of a total of (113) in the Qayyarah oil fields, which caused a black cloud over the city and rain accompanied by fires ash, which causes a decrease in the acidity of the rain falling [15]. Acid rain also causes a deterioration in facades of all buildings, especially old ones, where many signs of severe decay, such as gypsum formation, pulverized surface, exfoliation, discoloration, and salty sedimentations. Also, the decomposition of many rocks is attributed to acid rainwater [16]. As a result of various human activities that were mentioned, the emission of chemical pollutants to the atmosphere from various sources and their interaction with rainwater is forming acid rain, as in Fig 3., which is shown in the following equations:



This is followed by the following reaction, where the acid sulfur compound is oxidized by reaction with oxygen, and sulfur trioxide is formed:



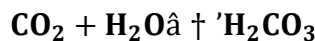
Where in the event of rain, sulfur trioxide (SO<sub>3</sub>) reacts with the falling water and quickly turns into sulfuric acid, as in the following equation:



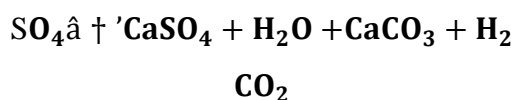
Also, nitrogen dioxide reacts with a hydroxyl radical to form nitric acid, as in the following equation:



The carbon dioxide emitted as a result of burning fossil fuels from factories and factories interacts with the falling rain and forms carbonic acid as in the following equation:



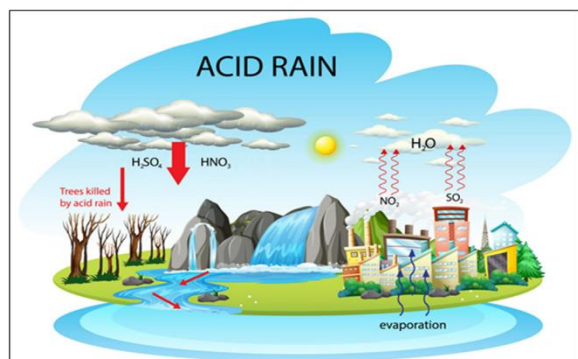
And that all the fallen acids as acid rain interact with the chemical components of natural resources such as calcium carbonate in the rocks and cause them the damage that appears in buildings and statues, as in the interaction of sulfuric acid with calcium carbonate in the equation:



**Table.1.**

Shows the values of pH in selected regions for 2020/2021 and 2021/2022 years.

Years of study	Main regions	Months	Avg. monthly value of pH
2020/2021	R1: The industrial zone on the left coast of Mosul	January	6.3
		February	6.2
		March	6.5
		April	6.3
	R2: The center of Mosul city	January	6.7
		February	6.7
		March	6.7
		April	6.8
	R3: The industrial zone on the right coast of Mosul	January	6.5
		February	6.4
		March	6.5
		April	6.4
<b>The average yearly value of pH in 2020/2021:</b>			<b>6.50</b>
2021/2022	R1: The industrial zone on the left coast of Mosul	January	5.5
		February	5.8
		March	5.8
		April	5.7
	R2: The center of Mosul city	January	5.8
		February	5.9
		March	5.8
		April	5.9
	R3: The industrial zone on the right coast of Mosul	January	5.9
		February	5.8
		March	5.9
		April	5.8
<b>The average yearly value of pH in 2021/2022:</b>			<b>5.80</b>



**Fig.3.** Shows the emissions of pollutant oxides and acid rain falling.

#### 4. CONCLUSIONS AND RECOMMENDATIONS

It is concluded from this study that acid rain is one of the serious environmental issues that occur due to the emission of sulfur dioxide, nitrogen oxide and carbon dioxide, which react with rainwater and produce sulfuric acid, nitric acid and carbonic acid, which are deposited in the form of rain, fog and snow by the method of

wet deposition, or by the volatilization and deposition of pollutants due to dust storms by the method dry deposition. These environmental pollutants come from the various activities of human beings such as the combustion of fossil fuels, combustible waste, vehicle exhaust, and electric & thermal power projects. Acid rain negatively affects forests, trees, crops, plants, buildings, monuments, water systems, soils and human health. The effects of acid rain can be reduced by adding lime to rivers, lakes, streams, and soils which neutralizes the acidity. Several legislations must also be put in place to control acid rain. The study recommends refraining from the use of traditional energies and resorting to the use of alternative and renewable energies, which are ecofriendly and clean energies with small and limited emissions, and to reduce the emission of sulfur dioxide, which is considered the main source of the formation of acid rain, so, it requires a reduction in the use of its sources and coal should also be washed before using it because washing will reduce the sulfur content. It is also possible to use natural gas for burning instead of coal because the amount of sulfur dioxide produced by burning natural gas is less. It also requires limiting the gases coming out of the chimneys of factories that contain sulfur dioxide, and purification devices must be added to wash, filter and chemically remove sulfur dioxide in different industries. The technical system of industrial projects must be developed and reformed by preventing the emission of pollutants into the atmosphere reducing the release of chemical pollutants to the biosphere and increasing the density of vehicles that operate on clean energies to reduce emissions. Converting the work of electric power stations from burning fossil fuels to using alternative energies, by using wind energy, solar energy, nuclear, hydrogen and hydropower energy to produce electricity.

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