Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

p-ISSN: 0972-6268
(Print copies up to 2016)
e-ISSN: 2395-3454

Vol. 24 | No. S1 | pp. 439-448 | 2025

Original Research Paper

https://doi.org/10.46488/NEPT.2025.v24iS1.035

Open Access Journal

Impact of Acid Gases on Total Precipitation Over Iraqi Stations

Nadia M. Abd, Zainab M. Abbood, Nagham Abbas Mohammed, Osama T. Al-Taai† and Wedyan G. Nassif
Department of Atmospheric Sciences, College of Science, Mustansiriyah University, Baghdad, Iraq
†Corresponding author: Osama T. Al-Taai; osamaaltaai77@uomustansiriyah.edu.iq

Nat. Env. & Poll. Tech.
Website: www.neptjournal.com

Received: 25-05-2024
Revised: 19-06-2024
Accepted: 22-06-2024

Key Words:
Total precipitation
Sulfur dioxide
Acid gases
ECMWF

ABSTRACT

Acid gas is a type of natural gas or any other gas mixture that contains significant quantities of hydrogen sulfide, carbon dioxide, sulfur oxides, nitrogen oxides, hydrogen halides, or similar acidic gases. Acid gases form acidic solutions when dissolved in water. A major cause of acid rain is emissions of sulfur dioxide and nitrogen oxide, which react with water molecules in the atmosphere to produce acids. Acid rain refers to a mixture of wet and dry precipitation from the atmosphere that contains more than normal amounts of nitric and sulfuric acids. In this study, the data of the European Center for Medium-Range Weather Forecasts (ECMWF) as total precipitation (Tp), as well as the Vertical Column amount of SO_2 from the Giovanni Center were adopted. The purpose of the research was to find the relationship between rain and sulfur dioxide in Baghdad, Mosul, and Basra cities for the period (2003-2016). The study was carried out for monthly and annual (or yearly) data variations. To find the correlation strengths of the relationship between Total precipitation (Tp) and sulfur dioxide, the correlation coefficients of Spearman's rho test (rs) were used. It was found that the relationship between (Tp Vs. CO_2) and (Tp Vs. SO_2) for Mosul station was inverse and positive, with a value of 0.7 that's due to sulfur water eyes. Also, CO_2 was found throughout all months but with different ratios, where the highest concentration was in 2016 in all the stations.

INTRODUCTION

The definition of acid gases Carbon dioxide (CO_2) and hydrogen sulfide (H_2S) are the two most prevalent types of acid gas, but there are others as well, such as hydrogen chloride (HCI), hydrogen fluoride (HF), sulfur oxides (SO_2 and SO_3), and nitrogen oxides (NOx). Which means it has a low PH and high concentrations of hydrogen ions. Negative effects could befall water plants, wildlife, and infrastructure. Sulfur dioxide and nitrogen oxide emissions cause acid rain because they mix with water molecules in the atmosphere to produce acids (Chestnut & Mills 2005). Some governments have successfully worked since the 1970s to reduce the quantity of sulfur dioxide and nitrogen oxide discharged into the environment. Nitrogen oxides can also naturally be produced by lightning, while volcanic eruptions can naturally produce sulfur dioxide (Hajer 2002). It has been shown that acid rain has bad effects on freshwater, soil, and life. It also affects human health and causes paint to peel, corrodes steel structures like bridges, and weathers stone buildings and statues (Grennfelt et al. 2020).

Sources of Acid Gases

Carbon dioxide and sulfur dioxide are the two principal causes of acid gases (Hajer 2005, Yehia et al. 2022). These gases are by-products of high-temperature combustion operations (such as factory and auto exhaust, forest fires, and fertilizer manufacturing) as well as chemical industries (Larssen & Carmichael 2000).

Sulfur Dioxide (SO_2): Sulfur-containing fossil fuels that are burned release sulfur dioxide, an invisible gas. Several industrial processes, including the production of iron and steel, factories, and crude oil manufacturing operations, produce this gas (Livingston 2016).

Natural catastrophes can cause sulfur dioxide emissions into the atmosphere, which make up about 10% of the total sulfur dioxide emissions from volcanoes, seawater spray, plankton (organisms suspended in water), and decaying plants (Abbood & Al-Taai 2018). Sulfur dioxide is typically created by industrial combustion at a rate of 69.4%. In terms of transportation, it is accountable for 3.7% of sulfur dioxide emissions (Ahmed et al. 2021, Al-Jaf & Al-Taai 2019).

Carbon Dioxide (CO_2): The biosphere, aquifer, rocky atmosphere, and atmosphere of the Earth's atmosphere all contain carbon dioxide. The carbon element that is important for the existence of life on the Earth's surface is in the case of an exchange between the Earth's casing in the so-called carbon cycle (Al-Taai et al. 2021). There is an estimated 800 gigatons of carbon dioxide in the atmosphere, and the

water envelope is 38,000 gigatons, in the form of physically dissolved gas in the form of bicarbonate and carbonate, while the carbon dioxide in the lithosphere is chemically linked to rocks Carbonates such as calcite and dolomite, which contain an estimated 60,000 tons of carbon dioxide (Hashim et al. 2023, Nassif et al. 2021).

Acid rain is created when sulfur-containing gases react. When sulfur dioxide and oxygen mix with UV radiation from the sun, the most significant of these processes produce sulfur trioxide, which reacts with atmospheric water vapor to make sulfuric acid (Al-Taai & Abbood 2020). Which remains suspended in the air as a fine mist that the wind carries from one area to another, and which may combine with some airborne gases, such as ammonia, to create a new chemical called ammonia sulfate (Abbood et al. 2023). Acid rain is created when sulfur and ammonia sulfate particles dissolve in rainwater and fall to the earth's surface and nitrogen oxides and sulfur oxides both contribute to the formation of acid rain (Mahdi et al. 2021).

These particles remain suspended in still air and appear as a light mist, especially when conditions are favorable for rain (Abbasi et al. 2013). When oxygen and ultraviolet light are present, nitrogen oxides are converted into nitrogenous acid (Abbood & Al-Taai 2020).

MATERIALS AND METHODS

The reason for choosing sulfur oxides and carbon in this study is because the main factor in the formation of acid rain and the main reason for choosing the three governorates of Baghdad, Basra, and Mosul, were different due to population density, human activities, and land use, Mosul was similar to the behavior of the Anbar governorate, which includes many sulfurs Springs.

Forms of Acid Rain or Acid Precipitation

Wet Sedimentation: is acid rain where the sulfuric and nitric acids that form in the atmosphere fall to the ground mixed with precipitation such as rain, swell, hail, or fog(Al-Taai & Abbood 2020, Hames et al. 2002).

Dry Sedimentation: When there is no moisture in the atmosphere, labor particles and gases remain suspended in the atmosphere (Chan et al. 2018). The particles and acid gases may be deposited on the surfaces of water bodies, plants, and buildings quickly, or they might interact while being transported by air to create larger particles that could be dangerous to people's health (Chen et al. 2013). The accumulating acids are removed by rain. This water is corrosive and rushes over and across the ground, harming vegetation and wildlife. The amount of rain that the area receives determines how much acidity in the atmosphere is deposited by dry precipitation (Zhang et al. 2012). For example, in desert areas, the percentage of dry precipitation is higher than that of wet precipitation because of the low rate of rain during the year (Nagase & Silva 2007). Numerous studies detail the function of sulfur dioxide on rain acid for certain stations as well as the biological effects that were discovered. Structures and items built by humans are also harmed by acid rain (Singh & Agrawal 2007, Nassif et al. 2023).

RESULTS AND DISCUSSION

The Behavior of the Monthly and Yearly Rate of Tp for Iraqi Stations (Baghdad, Basra, and Mosul)

Figs. 1, 2, and 3, show the highest monthly amount of Tp recorded in November, December, January, February, March, and April months for Baghdad, Basra, and Mosul stations over 2003-2016. In 2013, the highest TP concentration was recorded in Baghdad and Basra stations, while in Mosul station, the highest concentration was in 2006. The weather is erratic and can generate heavy to moderate rain in areas with a wide range of cloud types. During this period, Iraq was distinguished by its different types of clouds, including low, medium, and high clouds. Low and medium clouds had heavy rain during the months of winter and spring. This is brought on by climatic changes, surface characteristics, and atmospheric and astronomical causes. Fig. 4, shows the high annual Tp concentration of the three selected stations during the tested period.

The Manner of the Monthly and Yearly rate of Carbon Dioxide in Iraqi Stations for 2003-2016

Figs. 5 and 6 show the CO_2 concentration during all months of the study period. The concentration of carbon dioxide showed different ratios during the tested years, with the highest concentration appearing in 2016 in all stations.

The majority of fossil fuels that are high in carbon and hydrocarbons, such as coal, peat, oil, and natural gas, as well as the exhalations of humans and other aerobic animals, volcanoes, organic matter decomposition, during the fermentation of sugars, as a byproduct for burning wood and sugars, and organic matter decomposition are to blame for this (Singh & Agrawal 2007). In addition to car smoke, fires, factories, and many other sources of pollution.

The Behavior of the Monthly and Yearly Mean of Sulfur Dioxide for Iraqi Stations

Figs. 7 and 8 show the concentration rates of sulfur dioxide gas during all months of the study period, which show

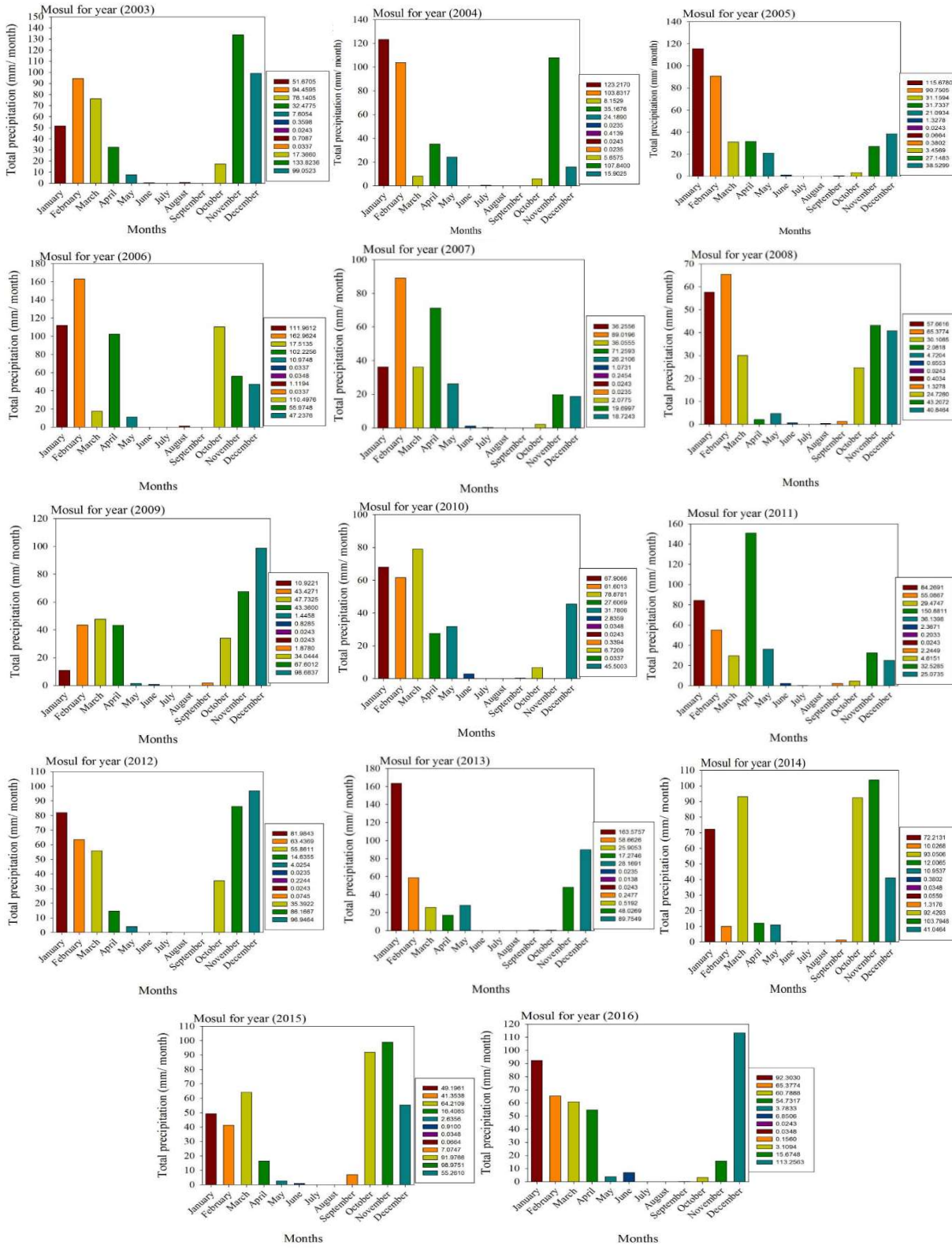

Fig. 1: The high monthly average of Tp of Mosul station.

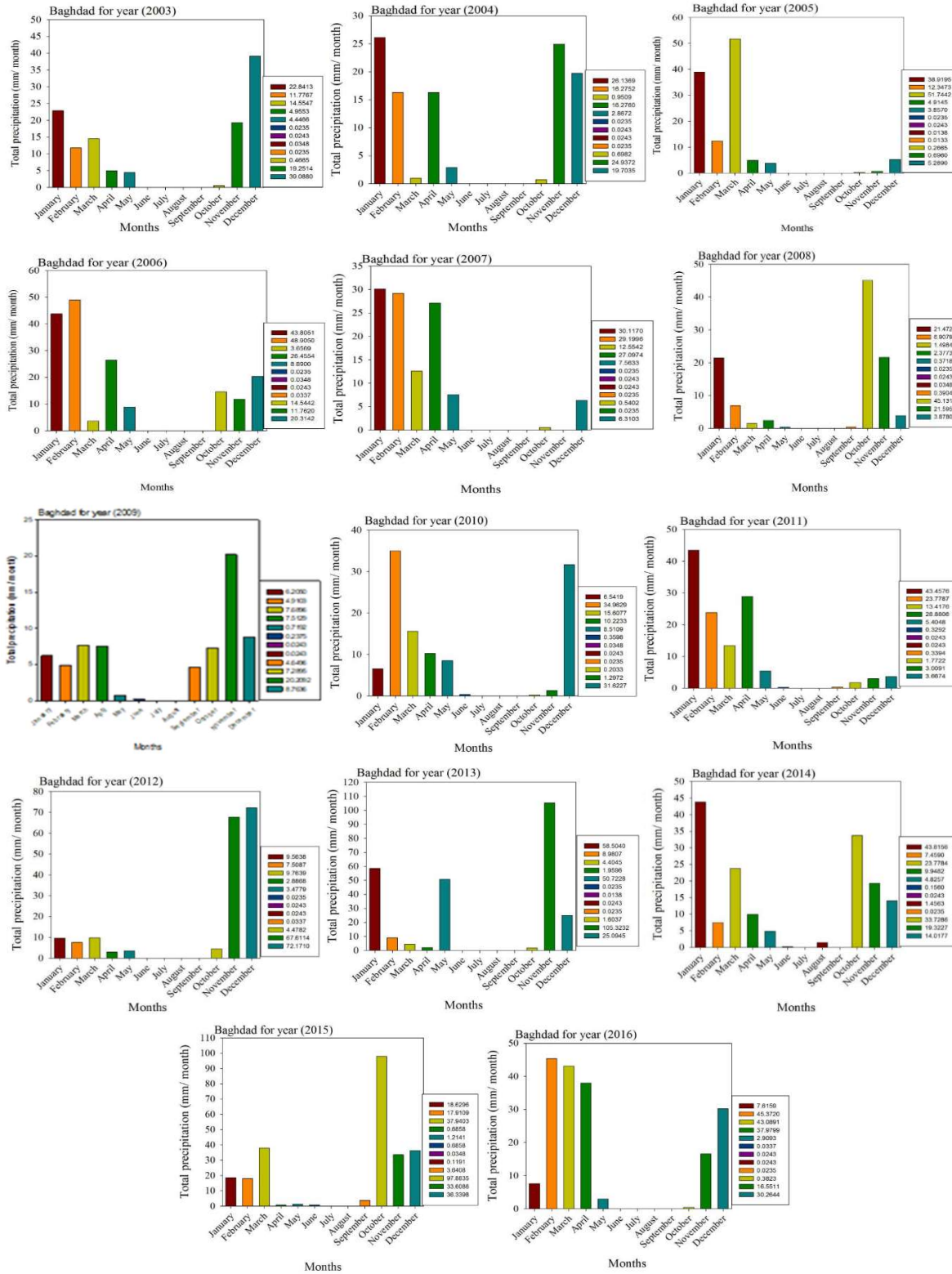

Fig. 2: The high monthly average of Tp of Baghdad station.

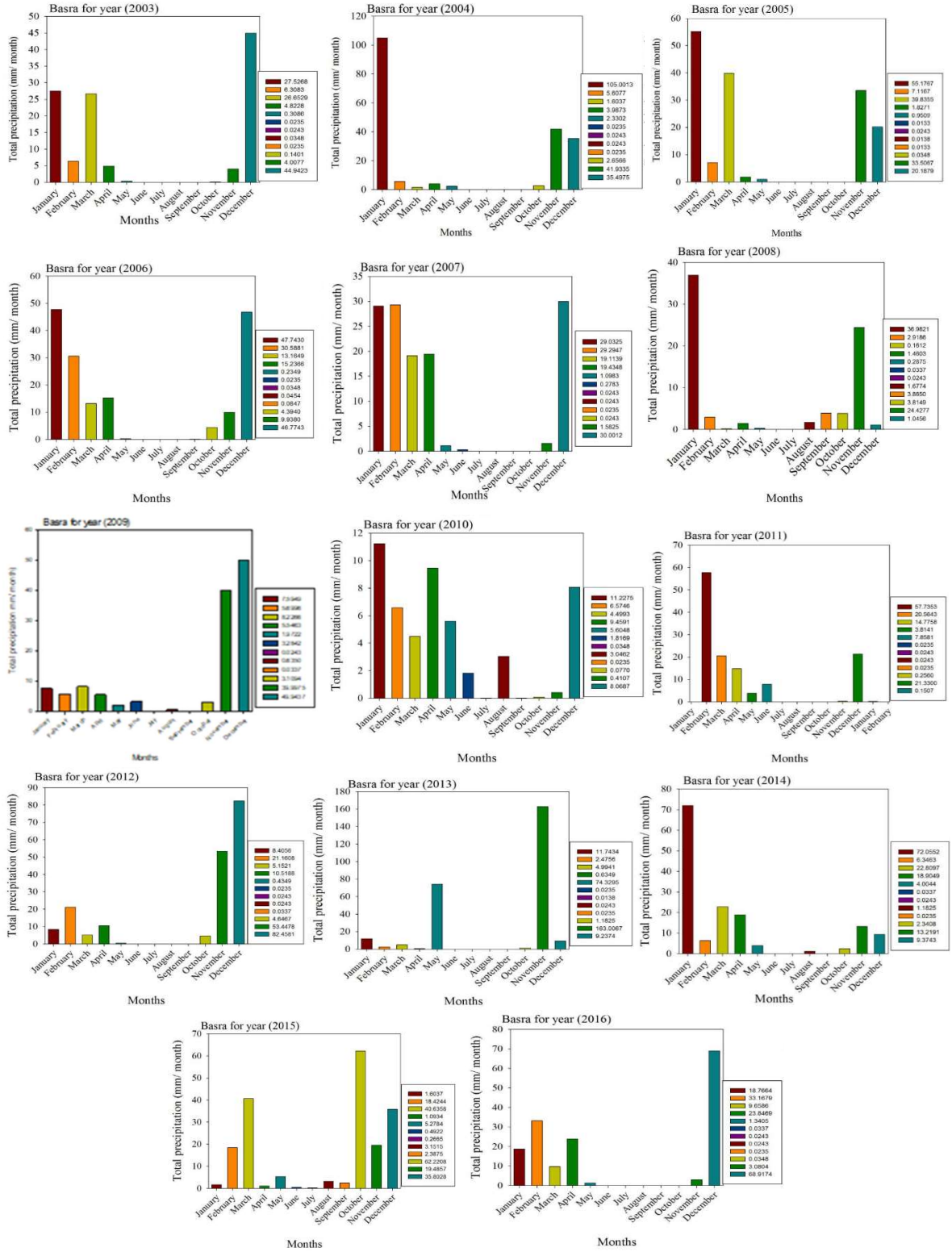

Fig. 3: The high monthly average of Tp of Basra station.

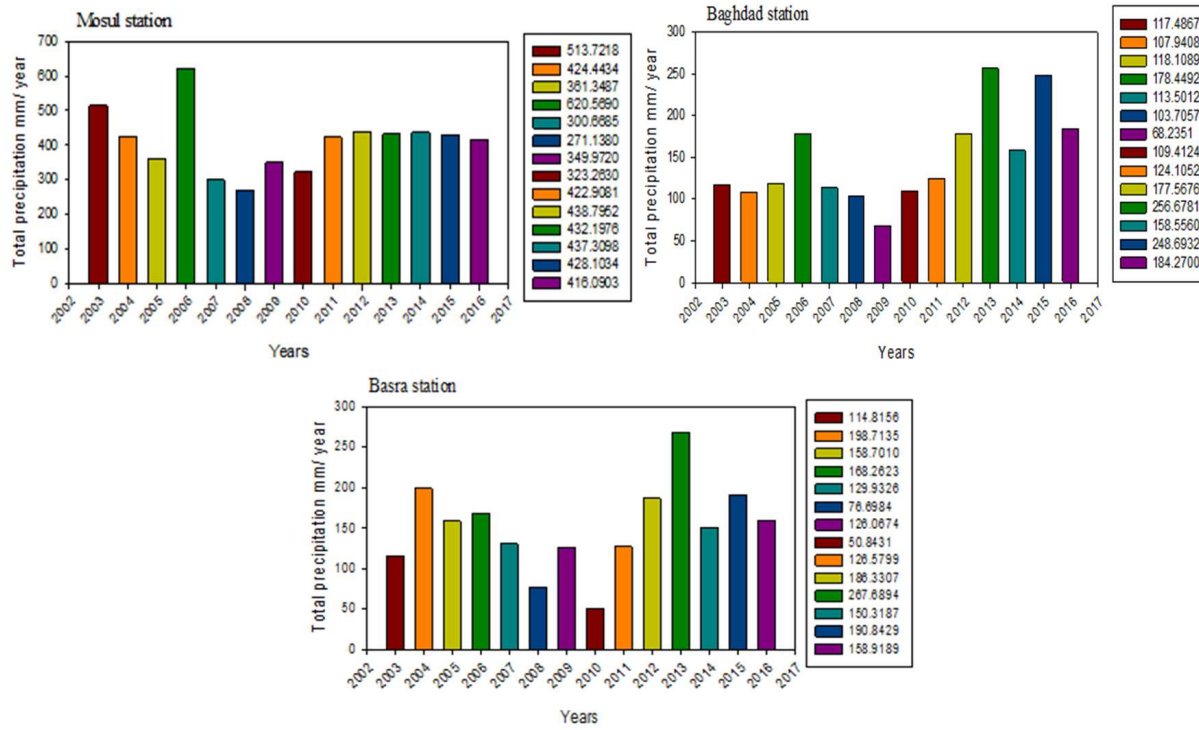

Fig. 4: The high yearly average of Tp for Iraqi stations (Mosul, Baghdad, and Basra) for the period (2003-2016).

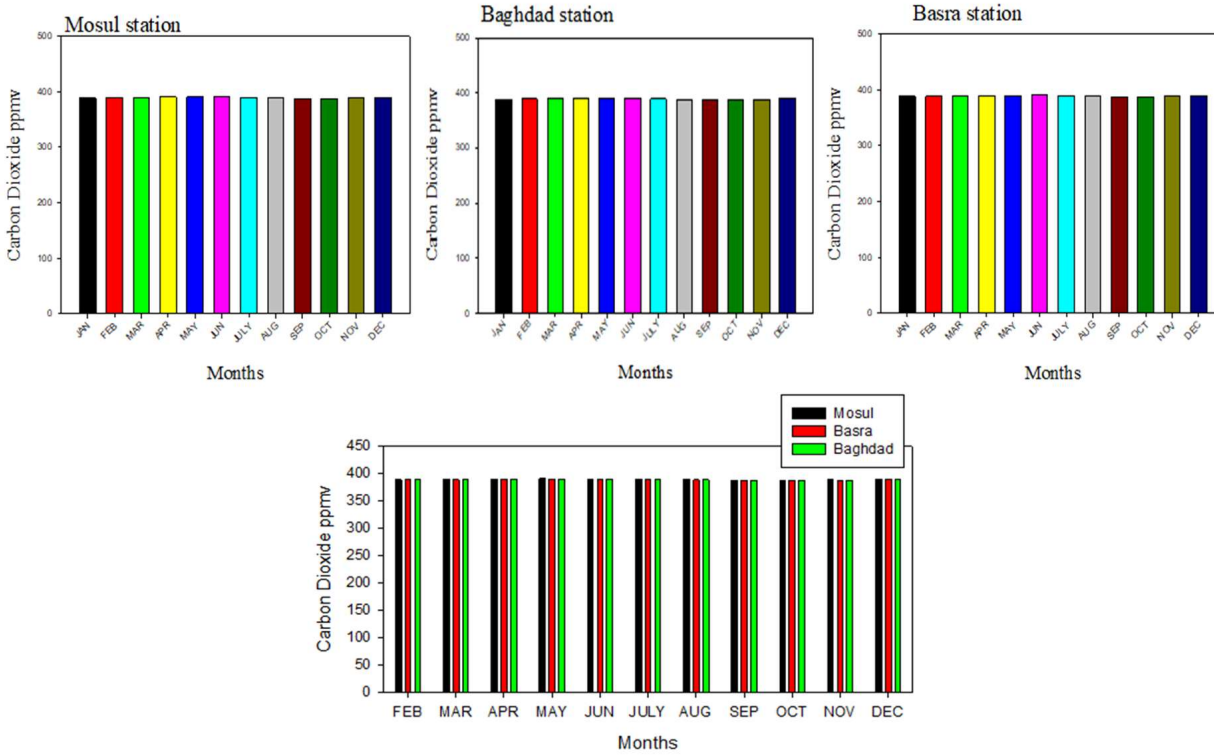

Fig. 5: The monthly average of Carbon Dioxide for Iraqi stations (Mosul, Baghdad, and Basra).

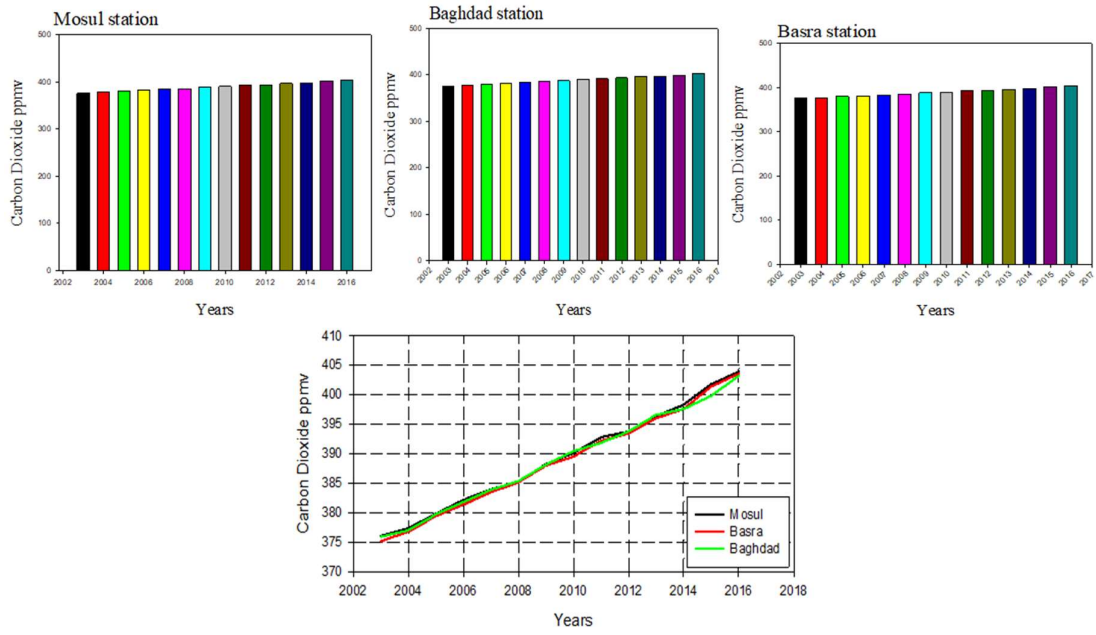

Fig. 6: The year average of Carbon Dioxide for Iraqi stations (Mosul, Baghdad, and Basra) for the period (2003-2016).

different rates of concentrations of sulfur dioxide gas, indicating that the highest concentration rate was in October 2016, which is found in the atmosphere and is often found in large quantities in industrial and urban environments. The burning of fossil fuels is the primary source of sulfur dioxide, as its pollution reaches hazardous levels in and around industrialized areas, close to coal-fired power stations, and oil refineries. Exposure to sulfur dioxide increases the risk

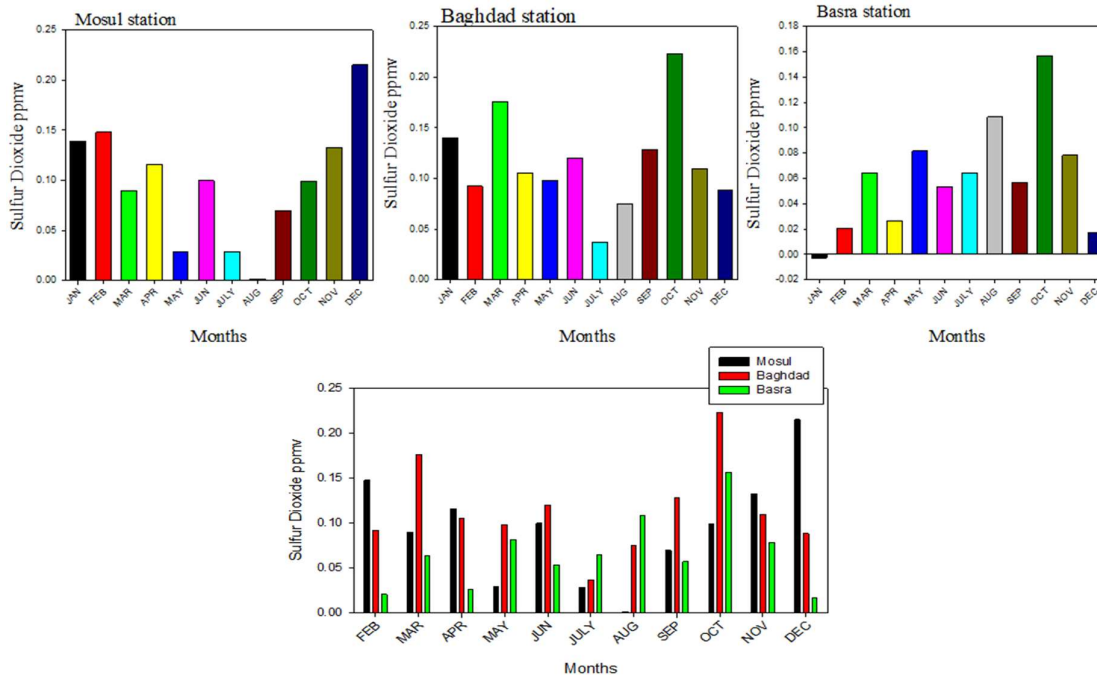

Fig. 7: The monthly mean of sulfur dioxide for the Iraqi stations (Mosul, Baghdad, and Basra).

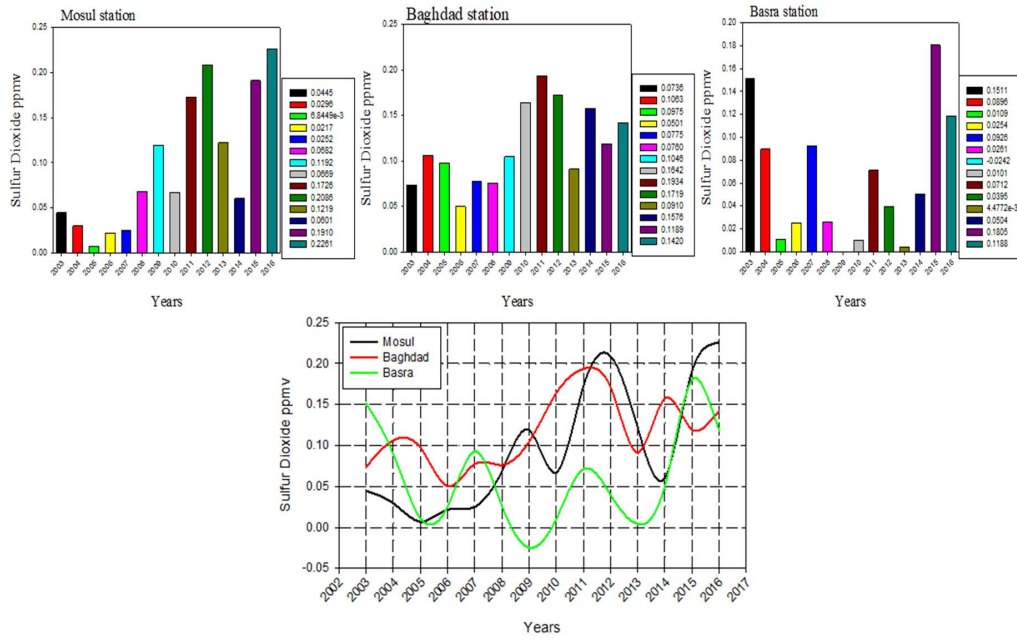

Fig. 8: The year means of sulfur dioxide for Iraqi stations (Mosul, Baghdad, and Basra) for the period (2003-2016).

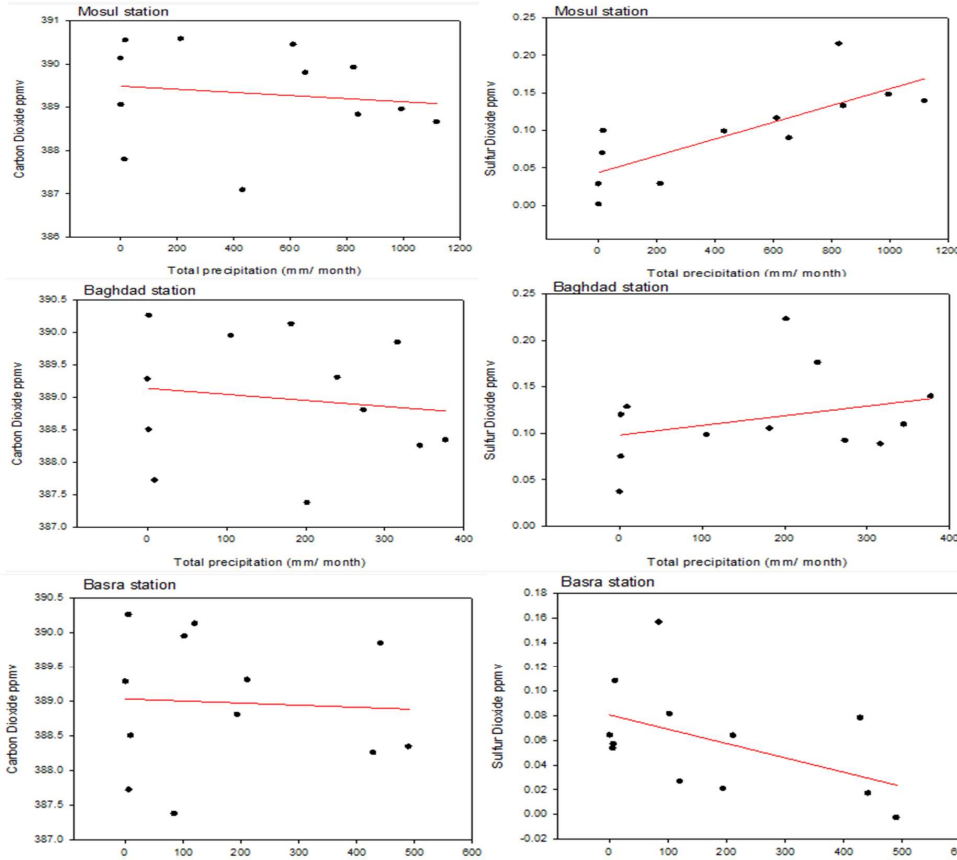

Fig. 9: The relation between the monthly average of CO_2, SO_2, and Tp for Iraqi stations (Mosul, Baghdad, and Basra).

Table 1: The relationship between CO_2, SO_2, and Tp for the 14 years over Iraq.

Station	Relation.	Spearman-rho		Linear Regression Simple	
		R	Correlation	P-value	Interpretation
Mosul	CO_2 vs Tp	-0.10	Very Low	0.0001	Linear
	SO_2 vs Tp	+0.70	High	0.0006	Linear
Baghdad	CO_2 vs Tp	-0.10	Very Low	0.0001	Linear
	SO_2 vs Tp	+0.40	Low	0.0013	Linear
Basra	CO_2 vs Tp	-0.10	Very Low	0.0001	Linear
	SO_2 vs Tp	-0.50	Medium	0.0034	Linear

of early mortality and illnesses like lung cancer, asthma, heart disease, and stroke. Additionally, it causes breathing problems, particularly for people with chronic illnesses (Singh & Agrawal 2007).

The Relationship Between the Monthly Rate of CO_2, SO_2, and Total Precipitation for Iraqi Stations for 2003-2016

Fig. 9, and Table 1 present the nature and degree of the correlation between Tp, CO_2, and SO_2 at the stations in Baghdad, Basra, and Mosul for the period from 2003 to 2016. The findings showed that the relationship between Tp with CO_2 and Tp with SO_2 for Baghdad station is inverse and positive.

The relationship between Tp with CO_2 and Tp with SO_2 for Basra station is inverse and the relationship between Tp with CO_2 and Tp with SO_2 for Mosul station is inverse and positive. That indicates a strong relation due to when solar radiation incident on sulfur water eyes will acts on water evaporate then cloud this led to form acid rain. Also, meteorological factors, and the nature of the region. The large presence of gases led to acid rain, which is caused by many pollutants.

CONCLUSIONS

Acid rain is created when sulfur-containing gases react. When sulfur dioxide and oxygen mix with UV radiation from the sun, the most significant of these processes produce sulfur trioxide, which reacts with atmospheric water vapor to make sulfuric acid. The relationship between Tp with CO_2 and Tp and SO_2 for Mosul station is inverse and positive was 0.7 due to sulfur water eyes. CO_2 was found throughout all months but with different ratios and the highest concentration in the 2016 year for all the stations. The largest amount of Tp occurred in November, December, January, February, March, and April months for Mosul, Baghdad, and Basra stations for the period (2003-2016). While was the highest amount of Tp occurred in 2013 in Baghdad and Basra. And 2006 in Mosul SO_2 was found throughout all months but with different ratios and the highest concentration in October Month and 2016 year. The large presence of gases led to acid rain, which is caused by many pollutants.

ACKNOWLEDGMENTS

An acknowledgment to Mustansiriyah University and the ECMWF center for the data used in this research.

REFERENCES

Abbasi, T., Poornima, P., Kannadasan, T. and Abbasi, S., 2013. Acid rain: past, present, and future. *International Journal of Environmental Engineering*, 5, pp.229-272.

Abbood, Z.M., Al-Jiboori, M.H. and Al-Taai, O.T., 2023. Temporal and Spatial Analysis of Particulate Matter Concentrations in Iraq. *IOP Conference Series: Earth and Environmental Science*, 1215(1), 012018.

Abbood, Z.M. and Al-Taai, O.T., 2018. Calculation of absorption and emission of thermal radiation by clouds cover. *ARPN Journal of Engineering and Applied Sciences*, 13(24), pp.9446-9456.

Abbood, Z.M. and Al-Taai, O.T., 2022. Data analysis for cloud cover and rainfall over Baghdad city, Iraq. *Plant Archives*, 20(1), pp.822-826.

Al-Jaf, S.J. and Al-Taai, O.T., 2019. Impact of carbon dioxide concentrations on atmospheric temperature changes over Iraq and some neighboring countries. *Plant Archives*, 19, pp.1450–1456.

Al-Taai, O.T. and Abbood, Z.M., 2020. Analysis of convective available potential energy by convective and total precipitation over Iraq. *Indian Journal of Ecology*, 47(10), pp.263-269.

Al-Taai, O.T. and Abbood, Z.M., 2020. Analysis of the convective available potential energy by precipitation over Iraq using ECMWF data for the period of 1989–2018. *Scientific Review Engineering and Environmental Sciences*, 29(2), pp.196-211.

Al-Taai, O.T., Abbood, Z.M. and Kadhum, J.H., 2021. Determination Stability Potential Energy of Thunderstorms for Some Severe Weather Forecasting Cases in Baghdad City. *Journal of Green Engineering (JGE)*, 11(1), pp.779-794.

Chan, H.R., Chupp, B.A., Cropper, M.L. and Muller, N.Z., 2018. The impact of trading on the costs and benefits of the Acid Rain Program. *Journal of Environmental Economics and Management*, 88, pp.180-209.

Chen, M.C., Wang, K. and Xie, L., 2013. Deterioration mechanism of cementitious materials under acid rain attack. *Engineering Failure Analysis*, 27, pp.272-285.

Chestnut, L.G. and Mills, D.M., 2005. A fresh look at the benefits and costs of the US acid rain program. *Journal of Environmental Management*, 77, pp.252-266.

Grennfelt, P., Engleryd, A.M., Forsius, Hov, O., Rodhe, H. and Cowling, E., 2020. Acid rain and air pollution: 50 years of progress in environmental science and policy. *Ambio*, 49, pp.849-864.

Hajer, M.A., 2002. Discourse coalitions and the institutionalization of practice: the case of acid rain in Great Britain. *Argument turn policy anal plan*, pp.51-84.

Hames, R.S., Rosenberg, K.V., Lowe, J.D., Barker, S.E. and Dhondt, A.A., 2002. Adverse effects of acid rain on the distribution of the Wood Thrush *Hylocichla mustelina* in North America. *Proceedings of the National Academy of Sciences*, 99, pp.11235-11240.

Hashim, S.A., Kadhum, J.H., Abbood, Z.M., Al-Taai, O.T. and Nassif, W.G., 2023. Determination of the Dynamics of Thunderstorms Through the Dry Adiabatic Lapse Rate and Environmental Lapse Rate. *Nature Environment and Pollution Technology*, 22(3), pp. 1447–1455.

Larssen, T. and Carmichael, G., 2000. Acid rain and acidification in China: the importance of base cation deposition. *Environmental Pollution*, 110, pp.89-102.

Livingston, R.A., 2016. Acid rain attack on outdoor sculpture in perspective. *Atmospheric Environment*, 146, pp.332-345.

Mahdi, Z.S., Abbood, Z.M. and Al-Taai, O.T., 2021. Thunderstorm Dynamic Analysis based on Total Precipitation over Iraq. *Journal of Engineering Science and Technology*, 16, pp.62–70.

Nagase, Y. and Silva, E.C., 2007. Acid rain in China and Japan: A game-theoretic analysis. *Regional Science and Urban Economics*, 37, pp.100-120.

Nassif, W.G., Jasim, F.H. and Al-Taai, O.T., 2021. Analysis of air temperature, relative humidity and evaporation over Iraq using ECMWF reanalysis. *Indian Journal of Ecology*, 48(2), pp.446–452.

Nassif, W.G., Lagenean, F.H.S. and Al-Taai, O.T., 2023. Impact of vegetation cover on climate change in different regions of Iraq. *Caspian Journal of Environmental Sciences*, 21(2), pp.333-342.

Singh, A. and Agrawal, M., 2007. Acid rain and its ecological consequences. *Journal of Environmental Biology*, 29, pp.15.

Yehia, M.A., Al-Taai, O.T. and Ibrahim, M.K., 2022. The Chemical Behavior of Greenhouse Gases and its Impact on Climate Change in Iraq. *Egyptian Journal of Chemistry*, 65, pp.1373-1382.

Zhang, X., Jiang, H., Jin, J., Xu, X. and Zhang, Q., 2012. Analysis of acid rain patterns in northeastern China using a decision tree method. *Atmospheric Environment*, 46, pp.590-596.