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Forecasting Models Based CO_2 Emission for Sultanate of Oman

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Abstract
Objectives: This paper aims to predict models for controlling and monitoring greenhouse gases efficiently. Besides, find best mathematical forecasting models for the main greenhouse gas CO_2. Statistical and simulation approaches are implemented and evaluated to investigate the contribution of atmospheric processes and predicate the level of the CO_2 emission level in sultanate of Oman. Three regression models were implemented and compared (Linear, Exponential and Polynomial) in the simulation phase based on the two factors the accuracy and the complexity of model. The Polynomial predicting model is best fitting the desired data 99% based on the value of R^2=0.991. Whereas, the Exponential and Linear models are achieved less fit 92.6% and 84.6% correspondingly. The predicting models prove that there is a significant increase in level of greenhouse gases (CO_2) in Oman.

Keywords: Greenhouse gases, air pollution, CO_2 emission, forecasting models, EMS, Environment in Oman

INTRODUCTION

Today, the people are suffering from overpopulation and urban extension and industrial problems on resources and environmental circles account. According to the World Health Organization estimates that air pollution causes the death of more than two million deaths per year [1]. There is no doubt that the keeping the air quality clean and protect it from various sources of emissions represents a major global issues and concern for any government. In addition, the massive escalation in columns of vehicles on the roads and in major cities is considered as other sources of emissions. Therefore, the protection of the air environment surrounding is considered as a main tasks and duties of the central units of environmental protection in any country [2]. The most important function of these central units is discovering the general system of environment and executive regulations in order to develop and monitor the implementation of international standards quality. The general framework policy in the Sultanate of Oman is emphasizing on saving the human health and protection of environment from any problems [3]. The climate in Sultanate of Oman is hot and dry, with temperatures reaching 50°C in the summer season [4]. Climate change is the increase in surface temperature and the heat medium in the world with the increasing amount of carbon dioxide, methane and some other gases in the atmosphere. These gases are known as greenhouse gases because they contribute to the warm atmosphere of the earth surface (global warming) [5]. The increase in global temperatures will lead to rising sea levels, changing precipitation amount and pattern of precipitation, likely also expand tropical deserts. Therefore, it has to be an appropriate response to the global warming. One of the available options are mitigation of emissions; adaptation to reduce the damage caused by warming, and the use of climate engineering to reduce global warming [6]. Note that most of national governments have ratified the Kyoto Protocol which is aimed to reduce greenhouse gas emissions. The Precise information about air pollutants in the atmosphere, such as ozone, particles, and precursors is necessary to evaluate the strategies and management policies for the air quality efficiently. This is because, the interest to the human health, environmental protection, climate change, and agriculture. Typically, an environmental management system (EMS) is a framework that assists the association for accomplishing its environmental objectives and improvement of its environmental performance. The ISO 14001 EMS [7] standard comprises of five subdivisions. These include the following: define the environmental policy, describe the planning, system implementation and operations, the checking and correction action, and lastly the management review, as depicted in Figure1. There is an increasing need to document the climate changes in the world as a result of growing pollutants in the atmosphere and its potential harmful effects on life of humans, animals and plants. This will increase the needs for enhancing the atmosphere of the risks of sedimentation impacts on aquatic and terrestrial ecosystems [8].

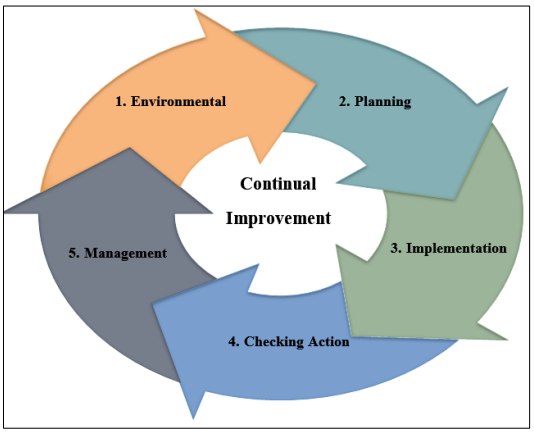


Figure1: ISO 14001 EMS Architecture

This paper proposes predictive models for monitoring and forecasting the level of greenhouse gases and issue suitable alert messages for Global and Sultanate of Oman. The data will be collected and examine through a weather and environmental stations that are capable of recording the relevant environment information such as the level of gases Ozone (O_3), Carbon dioxide (CO_2), Hydrogen chloride (HCl), Methane (CH_4), Sulfur dioxide (SO_2), Hydrogen sulfide (H2S) and Nitrogen dioxide (NO_2). Besides, it is determining the dust level, wind direction and speed, humidity and temperature [9, 10].

RELATED WORK

The effect of atmospheric processes on air quality and air pollutants were investigated and analyzed at different regions in many studies and researches which are mentioned in [11]. Ministry of Environment and Climate Affairs (MECA) has established a number of monitoring systems in order to monitor and control the behavior of the environment, especially in the industrial zones. The mobile stations are located in the Sohar Industrial region (Sohar Port) and the other one in the commercial zone in Muscat (Ruwi). In addition, the Ministry installed three fixed environment monitoring stations in Al Rusail Industrial State, Sohar Industrial State, and Al Fahal Port. This framework can help, for example, to locate the controlling industrial air pollution sources, to estimate the contributions from each pollution source to pollutant concentrations at specific locations, to characterize, understand and predict quantitatively the pathways of industrial air pollutant transport. The resulting exposure is to establish quantitative links between sources exposure and risk of effects in order to avoid unacceptable contamination from excessive pollution sources. Alwahaibi, A and Zeka, A. [12], suggest and implement a study in 2006 in order to determine the effects of air quality on human residential around the industrial port region. The study comprised a data collected from the Ministry of Health in Oman for the period between 1st January, 2006 and 1st December, 2011. The study included four exposure regions; they are High, Intermediate, Control zones and Sohar city respectively. The study relied on diseases accounts respiratory rate, and heart disease rate of allergic reactions in the four zones. Results of each region was compared with the exposure area of Control one to conclude the comparison results. The study also showed that the rate of skin infection (dermatitis) for the three regions and increasing rates of infection in the high exposure zone of both diseases (skin and respiratory) in the period between 2007 and 2009. The study proved detriments to public health in the high and intermediate exposure areas which need to issue strict laws to limit the negative effects of trimester on the environment and human health. Dinesh K. S. [13], he launched the using of Soft Computing (SC) methodologies to design and implement an environmental management monitoring system. The used the artificial neural network in decision making for more accurate and reliability. They presented the using of Self-Organizing Feature Map (SOFM) unsupervised model to monitor and analysis the real-time and static datasets acquired through pollution monitoring sensors and stations. The SOFM is used to predicate the behavior of environmental system and feed the results for interactive and dynamic reporting services and the alarming systems.

Air Pollution in the Gulf Countries Region

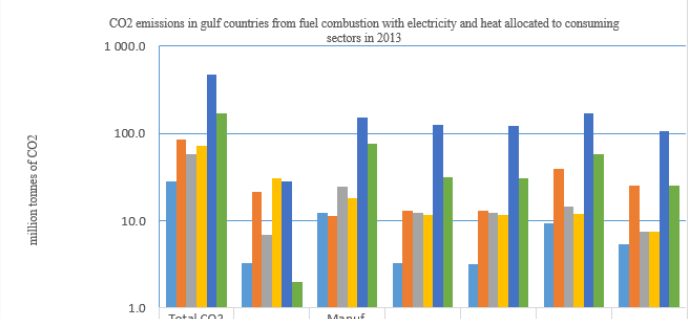
Air pollution is becoming a serious and ongoing issue worldwide. Many regions of the world have shown extremely high levels of particulates that greatly affect air quality [14, 15, 16]. The more development in new life will influence to increase the emission of Sulphur dioxides levels that degrade our air quality. Additionally, many areas have experienced an increase in nitrogen oxides. Preliminary information suggests that our pattern of development is needed to be changed. This is only to decrease the dangerous of poisonous emissions over the next twenty to fifty years [17, 18]. Coupled with the climate changes we expect to see; these predictions present a serious issue that needs to be addressed immediately [19].

The primary goal of this section is to examine air pollution in the gulf countries. So, there is need to look into the policies and regulations already in place in an effort to find new avenues that will help us combat this growing crisis in the gulf region. Natural and anthropogenic components of air pollution have been noted and studied for decades globally. The effects of long-term cross-boundary dust storms as well as short range local emission issues have been recognized as well. However, the release of dangerous greenhouse gases and the toxic affect climate change on all countries worldwide. Therefore, we need to implement national and international policies and regulations in order to control hazardous emissions. The natural air pollution is synergistic with specific anthropogenic air components as well, which leads to increased damage of health, environment, economy and quality of life. This means a current air quality is a major cause of many factors that affects the quality of human life worldwide [20].

Recently, many governments have been taken steps locally and globally to control air pollution. This is a good sign, but the continuous research to find and develop effective solutions for the problem is much needed. International organizations have made great efforts to identify and assess problems in air quality control and they have spent two decades in the search

for solutions. However, some progress on a global level it reached, but still there are many problems in different regions and on local levels need to solve. Thus, it is necessary to focus attention on coupling global and local solutions for air pollution.

Further efforts in preliminary stages are still needed for developing research and institutional capabilities in the area of air pollution management. The using of land for industrial purpose and the degradation of natural resources will certainly increase in order to follow the requirements of the industrial revolution. As well as, the transportation systems are contributing the air pollution problems. Figure2 depicts the CO_2 emissions from fuel combustion for Gulf Countries. Saudi Arabia has the highest level of CO_2 emissions, while Bahrain and Oman has the lowest level. The objective of this paper is to present the development of regulations, policies and institutional capabilities of air quality control. Also, identify gaps and prioritize actions for further solutions in order to have a clean environment. Lastly, develop forecasting models for predicating the needs in future.



	Total CO2 emissions from fuel combustion	Other energy industry own use*	Manuf. industries and construction	Transport	of which: road	Other sectors	of which: residential
Bahrain	28.3	3.3	12.3	3.3	3.2	9.4	5.4
Kuwait	84.1	21.1	11.5	12.9	12.9	38.7	25.2
Oman	57.9	6.9	24.2	12.3	12.3	14.5	7.5
Qatar	72.4	30.7	18.1	11.7	11.7	11.9	7.5
Saudi Arabia	472.4	28.1	150.1	124.5	122.2	169.7	105.1
United Arab Emirates	167.6	2.0	76.7	31.5	30.8	57.5	25.4

Figure 2: CO_2 Emissions in Gulf Countries from Fuel Combustion with Electricity and Heat Allocated to Consuming Sectors in 2013

Air Pollution in Oman

The air pollution is potentially a serious problem in thickly populated and industrialized areas in Oman, especially in the industrial regions in the Sohar city and surrounding urban areas [21]. Omani government has initiated special laws to regulate and manage the ecosystem, which is aimed to preserve the environment and the prevention of pollution.

Omani government stipulates strict laws to impose sanctions on companies and individuals who are releasing gases, environmental pollutants in air, land or marine waters. The laws RD 10/82, RD 114/2001 and RD 115/2001 are issued for managing the relation between the users and protecting the environment from any damage. Later the low MD 118/2004 is issued as an amendment to the environmental standards levels for stationary emission sources. After one year, the low MD 159/2005 is approved for dealing with marine discharges. A study of the effects of air pollution on the atmospheric corrosion of metals in the Sultanate of Oman is implemented in 2004 [22]. This study gives evidence that the Sohar region has a high percentage of corrosion record. Besides, the regions closest to the coast have higher concentrations of chlorides. Moreover, the highly industrial areas have the maximum carbonate levels in Oman are Al-Rusail in Muscat and Sohar zones. An air quality and meteorological investigation was conducted surrounding the Sohar mine area, focusing on SO_2, TSP, PM_{10}, dust fall, and other meteorology factors [23]. The result of the investigation is summarized by the fact that SO_2 concentrations at four monitoring points located downwind of the Oman Mining Company (OMCO) plant exceeded the EEC SO_2 standard.

The main air pollutants emitted from OMCO's plant are SO_2 and particulate matter from the processes. The constituents of the particulate matter include Cu, Fe, Zn, As, Cd, Pb and Hg. In addition, the environmental impact investigation consisted of personal interviews with local residents based on an environmental questionnaire concerning air pollution, water pollution, effects on health, and damage from pollution. Interviews were conducted with 23 persons living within a radius of 23 km from the OMCO plant site. Consequently, diseases such as respiratory illnesses, a decrease of livestock, and some impact on plants and insects were observed. In 2005 Abdul-Wahab [24] presented a study summarized environmental impact assessment on the plants as a result of pollution caused by the use of trains operating in Oman natural gas liquid (OLNG). The study included a number of environmental pollutants such as particles and gases methane (CH4), and non-methane hydrocarbons (NMHC), and carbon monoxide (CO), and nitrogen oxides (NOx). The study used a range of data on levels of air quality and the amount of the monthly pollution and then calculates the amount of periodic changes. The meteorological data were analysis using statistical methods for the purpose of obtaining rate changes and measure the rate of purity of air pollutants. The study has shown that there is low rate concentration of pollutants and safe at the standard levels. However, the accumulative effects of the mixing of CO and/or N_2O with other pollutants can cause significant environmental problems. In addition, the ratio of carbon dioxide (CO_2) and nitrous oxide (N_2O) were in air quality standards levels. The CO_2 is produced during the burning of coal, oil and natural gas in power plants, cars and factories, etc. However, there is a random relationship between the levels of carbon monoxide and oxides of nitrogen and methane. The study also proved that the measured concentrations of N_2O, NOx and CO rates are higher in the

winter than in the summer. Figure 3 shows the CO_2 emissions for Oman from fuel combustion with electricity and heat allocated to consuming sectors in 2013.

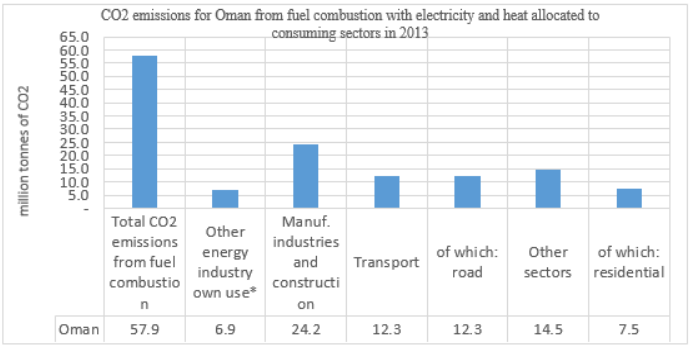


Figure 3: CO_2 Emissions from Fuel Combustion for Oman

Proposed models and Results

The effect of atmospheric processes on air pollutions has been discussed and analyzed practically and statistically in many studies. The main objective of this paper is to propose efficient mathematical models for predicting and monitoring gas emissions in Sultanate of Oman. This will allow government to take effective solutions for solving the problems of air pollution and preserve the lives of the people [25]. Besides, these models will help to estimate the amount of the necessary infrastructure and the amount of budgets that needed for such solutions. The atmosphere keeps some of the sun's energy to heat the planet and maintain the weather where carbon dioxide is one of the most important gases that contribute to double the level of warming in the atmosphere. Also, the forests contribute significantly to rid the atmosphere of gaseous pollutants and particularly carbon dioxide. It is also the methane gas emitted from rice farms and breeding cattle, landfills, mines and gas pipelines, and gases for CFCs (Chlorofluorocarbons = CFCs) responsible for the erosion of the ozone layer and global warming. As well as, the studies have proven that increased a small amount of greenhouse gases such as CO_2 and methane, water vapor, will raise the surface of the earth warm by 30 degrees Celsius (54 Fahrenheit). Note that it is difficult to separate the effects of natural and man-made changes over short periods of time.

The widely model used for data fitting is the regression technique, which is help to forecasting an independent variables x_i and produce a dependent variable y [26].

$$yi = \alpha 0 + \alpha 1 Xi + \varepsilon i \quad i=1,\ldots,n \qquad (1)$$

where εi is an error value and the subscript i indexes a specific observation.

A typical linear equation to map the relationship between one dependent and many independent variables is defined as follows:

$$\hat{y} = \dot{\alpha}0 + \dot{\alpha}1 X_i \qquad i=1,,n \qquad (2)$$

A small difference between the values of predicted by the model $\hat{y}i$ and the values of original data yi is called residual. Therefore, the residual is defined as in equation 3.

$$ei = yi - \hat{y}i , \qquad (3)$$

In order to determine how "good" the estimated data fits the observed data, the coefficient of determination (R^2) is used. The value of (R^2) in range of $0 \leq R^2 \leq 1$, therefore if R^2 is closely to1, then the estimated model well-fitting the original data. And if R^2 is closely to 0 that means poor fitting.

$$R^2 = SSR/SST = 1 - SSE/SST . \qquad (4)$$

The sum of squared residuals (SSE) which is estimated as follows:

$$SSE = \sum_{i=1}^{n} (e_i)^2 \qquad (5)$$

And the sum of squares of the regression (SSR) is the variation of the estimated data around their mean which is calculated as follows:

$$SSR = \sum_{i=1}^{n} (\hat{y}_i - \bar{y})^2 \qquad (6)$$

Lastly, the total sum of squares (SST) is simply calculated as the total variation in estimated data y around its mean. SST is determining as follows:

$$SST = \sum_{i=1}^{n} (y_i - \bar{y})^2 \qquad (7)$$

Figure 4 shows clearly that there is a linear relationship between the rates of dioxide carbon (CO2) emissions and time for Oman. However, the emitted amount of gas in 2013 is the highest rate as a proportion at 57.9 ppm, which is still within safe and the standard acceptable limits in outdoor places. For the sake of forecasting the behavior of CO2, a linear regression is implemented to estimate the original data of CO2. This model will use to simulate the behavior of CO2 emission in Oman as illustrated in Figure 4, which is determine based a polynomial of fourth degree as defined in equation (8).

$$y = 7E\text{-}05x^4 - 0.0045x^3 + 0.1188x^2 - 0.7081x + 1.3806 \qquad (8)$$

This model is fitting the original data 99.1%. For the sake of choose the best forecasting model a linear regression model is also proposed as defined in equation (9).

$$y = 1.2117x - 10.286 \qquad (9)$$

Besides, a forecast model based exponential function is implemented as in the equation (10).

$$y = 0.5637e^{0.1181x} \qquad (10)$$

This model is fitting the original data 92.6%. However, the fitting model (illustrated in the equation 9) is fitting the desired data 84.86%, which means it has an error rate of 0.1514. This model is implemented as a simple linear regression, which is generated the output data fast, but it has less accuracy in comparison with other models (8,10). So, the researcher needs to decide the priority of factors fast processing and generating output or seeking for high accuracy of results.

CONCLUSION AND FUTURE WORK

This paper aims to forecast models for controlling and monitoring CO_2 level in Oman, which is one of main greenhouse gases. The management system is must be abled to collect the required data in real-time off line-time through pollution monitoring sensors and weather stations. Besides, the paper focuses on finding best mathematical forecasting models for fitting original data for (CO_2) gas. Therefore, two approaches (Statistical and simulation) are implemented and evaluated the three models for predicating the level of (CO_2) level. Three regression models were implemented and compared (Linear, Exponential and Polynomial) in the simulation phase. Table 1 illustrates the results for the three models based the two factors (Accuracy and Complexity). However, the results of Polynomial and Exponential models for predicting the original data of CO_2 gas are achieved best fitting. Therefore, the researcher needs to choose a high accuracy fitting (Polynomial and Exponential models) or less complexity (Linear model). Based on the results of these models, an efficient alarm system can be built for sending a suitable caution messages when the level of predicated gas is more than the standard levels. The future work can focus on implementing more models for other greenhouse gases like (CH_4, NOx and N_2O). Besides, soft computing techniques can be proposed to implement new models and compare the results with other works.

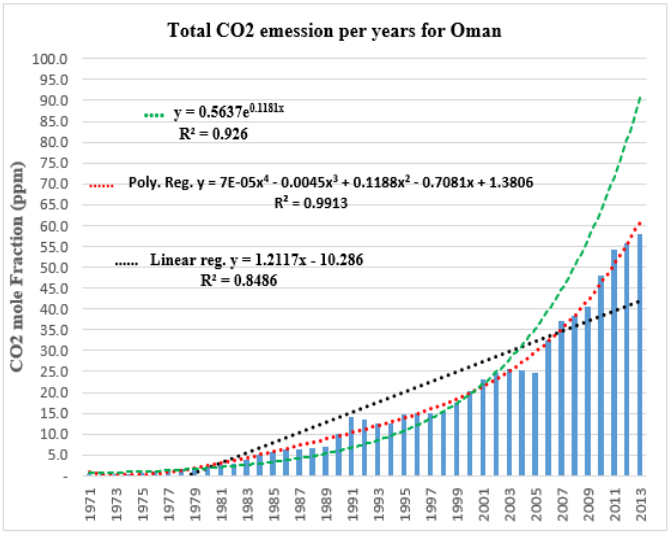


Figure 4: The CO_2 Emission Rate for Oman Mole Fraction Based on Data Generated by IEA.

Table 1. The Comparison Result of Proposed Regression Models

	R^2-Linear	R^2-Polynomial	R^2-Exponential	Best Accuracy	Less Complexity	Differences (Best-Less)
CO2	0.848	0.998	0.995	Polynomial R^2=0.998	Linear R^2=0.848	0.15

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