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CASE STUDY

Greenhouse gasses emission in the highly urbanized city using GIS- based analysis

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ABSTRACT

BACKGROUND AND OBJECTIVES: As the population grows on the earth, transport and industrial sector have become the main parameters whose emissions increase pollutants like greenhouse gasses that have a snowballing impact on urban air quality and life in the area. This study aims to analyze the emission of greenhouse gases in the highly urbanized city of Karachi through Geographic information technique.

METHODS: This study used Inverse distance weighted technique of Geographic information system to highlight the emission of greenhouse gases in ten different sites of Karachi, Pakistan. Target areas include, Baloch colony, Clifton, Civic center, Garden police headquarter, II Chundrigar, Karimabad, Korangi, Nazimabad, SITE area and SUPARCO.

FINDINGS: Results showed that Baloch colony, Korangi, Nazimabad, SITE area and Garden police headquarter lies in the highly polluted areas among these ten sites of Karachi city. Karimabad with moderate pollution, II Chundriger and SUPARCO with low pollution rate and Clifton had very low pollution.

CONCLUSION: As all of the observed ten sites of the city have dense population with heavy traffic and industrial pollution, there is a need to take serious steps towards areas indicated in this study to safeguard the people from the effects of GHG emission. With the help of this study the general population and all concerned authorities with highly polluted areas, can be familiarized so that efficient and different ways to overcome the pollution, like plantation, can be applied.

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INTRODUCTION

Both Developed and developing countries are faced with the pollution crisis (Niaz *et al.,* 2015). Annually, urban passenger transportation in USA, China and India, causes 670, 200 and 70 megatons CO_2 emission respectively (Sajjad *et al.,* 2010). In Karachi, due to rapid increase in the rate of population, pollution of water, soil and air in the city has also increased. (Afzal *et al.,* 2005). It has been demonstrated that urbanization and rapid population growth has created different adverse effects into the environment. (Arsalan *et al.,* 2010). Regular growth in transportation sector which is among the major sources of air pollution, accounted for 14.3% of the world and 25.73% of Pakistan greenhouse gas (CO_2) emission as of 2010 (Duduta *et al.,* 2010). Gaseous composition of clean, dry air by volume, is 78% nitrogen, 21% oxygen, inert gases 1.0% and CO_2 up to 0.1% to 0.3% (Wikipedia (2014). But disturbance in the gaseous mixture of earth's air may give rise to many health related consequences in humans (Afzal *et al.,* 2005). In 2018, human, animal and plant diseases were reported to have developed due to the pollutants found in water and air (Neethirajan *et al.,* 2018). Moreover, a number of allergic reactions were developed as a consequence of fungal spores present in the air (Sanches *et al.,* 1999). From the atmosphere of Karachi, different fungal species were isolated such as *Aspergillus, Saccharomyces cerevisae, Cladosporium, Alternaria* and *Penicillium* Afzal *et al.,* (2004) which are the causative agents of many opportunistic infections. Whereas, a number of respiratory illnesses and skin infections were also reported to develop in Karachi, due to the contamination of both air and water (Arsalan *et al.,* 2010). Air pollution may arise by both anthropogenic and non-anthropogenic activities. Natural proceedings like volcanic activity, wildfires and sand/ dust storms are included as non-anthropogenic activities (Hutton, 2011). While industrialization and transportation are the two main sources of anthropogenic activities which are responsible for the increase in levels of Sulphur, carbon, nitrogen, lead, ozone and other hazardous contaminants into the environment. *Sulphur dioxide* is one of the manmade air pollutants which is causing extensive spreading and damage. The combustion of fossil fuel, coke ovens, metal smelting, wood and pulp production, petroleum refining and brick manufacture are the major source of the sulphur dioxide (Katsouyani, 1995). High short-term level of SO_2 may increase disturbance in lung function, respiratory diseases and mobility rates in children and adult (Mentz *et al.,* 2018). Furthermore, various epidemiological studies have shown that variation in exposure to major air pollutants on daily basis, such as ozone, particulate matter and SO_2 are related with health defects ranging from increased hospital admissions and mortality to subtle change in lung function at low to very low concentration (McClellan *et al.,* 2009). *Carbon monoxide* is almost entirely a manmade pollutant. The incomplete burning of fuel produces carbon monoxide. At concentration of 100 ppm or more it is the most hazardous to humans, if experienced over a period of several hours (Sax *et al.,* 2020). Most people experience headache and dizziness at 100 ppm. Cigarette smoke contains 400 to 450 ppm of CO. Death may occur after a short period of time (few minutes) when the CO concentration exceeds 750 ppm, while people may experience less consciousness at 250 to 500 ppm. Approximately about one million tons of CO is released into the atmosphere each year, half of which is due to human activities. In photochemical reaction 90% of CO is consumed in the air and produces ozone (Katsouyani, 1995). Moreover, automobiles contribute to manmade global CO emission by more than 80%, with a smaller amount resulting from other combustion processes (Zhong *et al.,* 2017). Ozone is generated more significantly, as a result of chemical reactions involving the absorption of solar radiation by *nitrogen dioxide (NO_2)* in the presence of volatile organic compounds (VOCs) and carbon monoxide. In Los Angeles, the environmental impact of photo-chemically derived ozone was first studied during smog in 1950 (Kundu *et al.,* 2010). *Nitrogen oxides* are extremely reactive gases and are formed when Nitrogen in fuel or combustion air is heated in the presence of oxygen to temperatures above 650 C. The initial product, nitric oxide (NO) is oxidized further in the atmosphere to nitrogen dioxide (NO_2), which is an active compound in the formation of photochemical smog. Because of low emission heights, Vehicular emissions are of particular significance. 70% of NO_2 concentration is found in ambient air environmental pollutants (Sindha, 2018; Lippmann, 2020). Mixing ratios of GHG in Atmosphere, e.g. CO_2 have increased by a

factor of 1.4, compared to pre-industrial times (Hartmann *et al.,* 2013). Developed countries' CO_2 emissions can be accurately estimated due to the available fossil fuel consumption data (Bréon *et al.,* 2015). The rising trends of increasing emission of *Carbon dioxide* are significant, the CO_2 emission rate is not only rapid but without any considerable down fall it is representing a positive and regular trend throughout the computed time. In 2006 emission of CO_2 in atmosphere has reached up to 151 million metric tons that was, in 1980, 39 million metric tons. This 287% increase in CO_2 during 1980 to 2006 is the result of energy consumption and mass urbanization in Karachi (Sajjad *et al.,* 2010). Additionally, high energy consumption and demand was also increased due to industrialization and over population throughout the world (World Development Indicators 2016). This high energy consumption and demand indicates the threatening fact that reserves of all conventional forms of energy (e.g. natural gas, coal, oil etc.) are fast depleting, causing atmospheric pollution and global warming particularly due to CO_2 emission (World Development Indicators 2016; IPCC 2014). Currently less than 3% of earth's terrestrial surface is covered by urban areas (Liu et al., 2014), while it accommodates more than half of the population of the world, with growing trends (UN, 2018). From urban areas, many studies have performed on the estimation of GHG emissions (e.g. CO_2, CH_4 etc.). Air quality assessment demonstrate that natural gas and landfills are the two major sources of CH_4 emission in the United State (Plant *et al.,* 2019; Ren *et al.,* 2018; Cambaliza *et al.,* 2015). These gases are taking part in the global warming by causing outgoing infrared radiation absorption. The aim of Paris Agreement is, with comparison to pre-industrial levels, to maintain the global temperature rise below 2°C (UNFCCC, 2015). In present study, GHG emission which is badly affecting the earth's temperature in the form of CO, CO_2, NO and SO_2 were analyzed and represented through GIS. GIS techniques have been used in recent years to study issues regarding pollution. GIS is an efficient computer mapping software, within a geographic platform that allows enormous information to be analyzed and understood (Vine *et al.,* 1997; Kulldorff, 1999). GIS is an incorporated system of components which consisting real world information that has been summarized and represented into non-spatial and spatial features of digital database, that in combination with effective software, and together with the proficient judgment of the GIS analyst, find the solutions to spatial queries and problems. Utilization of GIS include disease diffusion analysis, risk assessments, exposure modeling, environmental analyses and investigations of various other environmental and health issues (Schulz *et al.,* 2002; Briggs *et al.,* 2000; Becker *et al.,* 1998; Kulldorff *et al.,* 1997; Bullen *et al.,* 1996; Chakraborty and Armstrong, 1995). This study may provide information to the planners and concerned authorities in order to make informed decisions in the city and improve the environmental conditions. The current study has been carried out in 2018 to highlight the emission of CO, CO_2, NO and SO_2 in ten different sites of Karachi. The basic intention of this study is to represent GHG emission in highly urbanized city of Pakistan.

MATERIALS AND METHODS

Study area and objectives

Karachi is the financial city of Pakistan, and in recent years it is growing rapidly in terms of financial importance. In its west the Indus River flows and it is adjacent to the Arabian Sea. Karachi has an urbanized area of 1,300 km^2 over its total area of 3,600 km^2 (Qureshi, 2010). 16 million people live in the city, while approximately 95% of population resides in urbanized areas (Khan *et al.,* 2010; Mehdi *et al.,* 2011). The study area constitutes of ten different GHG Emission Sites (ES) in Karachi City i.e., Baloch colony, Clifton, Civic center, Garden police HQ, II Chundrigar, Karimabad, Korangi, Nazimabad, SITE area and SUPARCO. These ten ES reflect the massive environmental area of Karachi, such as its planned and unplanned residential localities, industrial and commercial areas, proximity to Arabian Sea, and the Malir River carrying waste water. Fig. 1 illustrates the ES of study area. These ES were basically taken as geographic analysis unit. In this study, these ES point's GHG emission data of Kazi (2014) was used to develop GIS based maps. This research has been performed using Geographic Information System (GIS) techniques based on the following main objectives.

- To represent the emission of greenhouse gases (GHG) in the study area.
- To target the polluted areas (PA) of the study area due to the combine effect of GHG.

Flow of data processing

Statistical data may be analyzed to extract valuable thematic information of the earth's surface. Then this raw data is changed into information. There is lot of information extraction techniques but Inverse distance weighted (IDW) is one of the most practiced methods. In this study four gases such as CO, CO_2, NO and SO_2 are used as GHG emission in study area. IDW technique was used to represent the pattern (Figs. 2, 3, 4, and 5) of these four gases in ArcGIS software while the Table 1 is showing the range of observed gasses. The GHG emission pattern of ES is derived to analyze environmental quality. Then finally to find the polluted area (PA) of these four emission patterns are combined in ArcGIS.

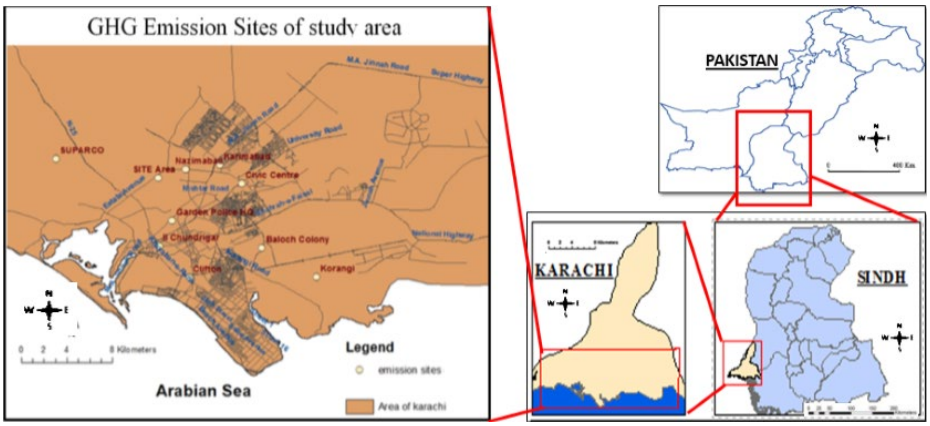

Fig. 1: Emission Sites (ES) of Karachi

Table 1: GHG emission range of study area (Kazi, 2014)

S.No.	GHG parameter	Values	Ref.
1	Carbon dioxide (CO_2)	457.726 ppm to 286.98 ppm	Fig. 2
2	Carbon monoxide (CO)	3.91997 ppm to 2.95 ppm	Fig. 3
3	Nitrogen oxide (NO)	80.4022 ppb to 20.2712 ppb	Fig. 4
4	Sulphur dioxide (SO_2)	35.1593 ppb to 15.6904 ppb	Fig. 5

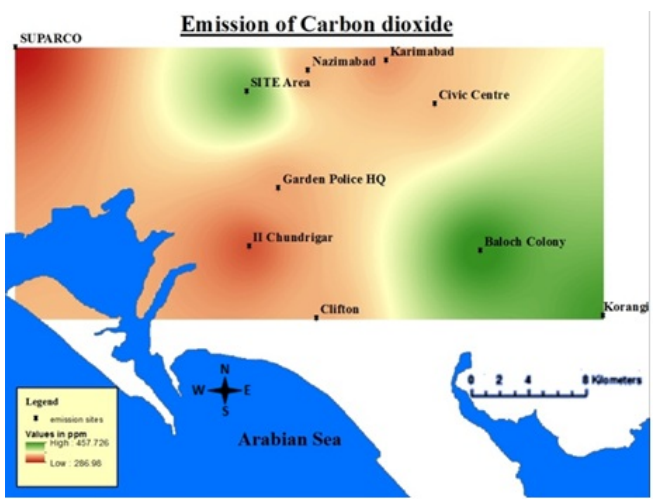

Fig. 2: CO_2 emission

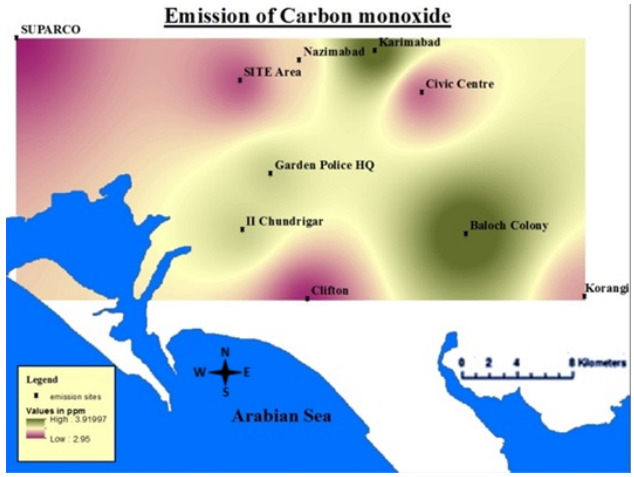

Fig. 3: CO emission

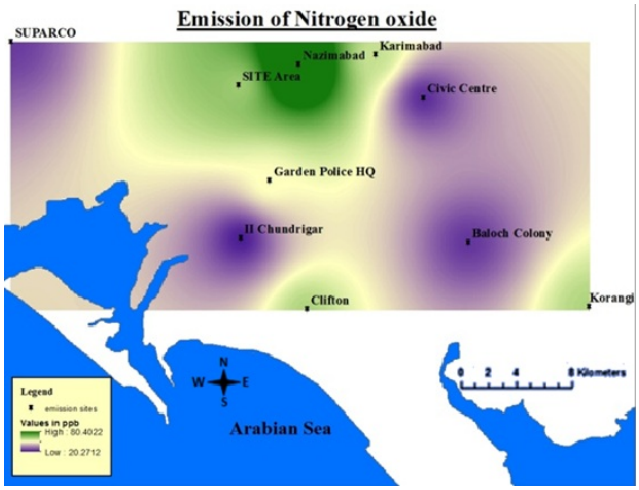

Fig. 4: NO emission

RESULTS AND DISCUSSION

As literature says that the previous studies have been done to estimate the GHG emission, finding the trend of GHG, many others analyzed the effect of GHG on the environment (Sun *et al.,* 2018) or discussed the diseases caused by its emission for the specific area or at country level (Crippa *et al.,* 2018), researchers also have performed the comparative study of GHG emission (Brown *et al.,* 2017) while this study is entirely different from previous researches because it's focus is to create awareness among the common people with the help of PA highlighted in the pictorial or mapped form so that they may understand the significance of this issue and take safety measures and work towards finding a solution for the pollution in Karachi city. Pollution of this mega city is increasing day by day due to the various factors which include traffic and industrial growth. In this study, PA results (Fig. 6) which is the combined emission effect of CO_2, CO, NO and SO_2 which were also individually mapped in Fig. 2, 3, 4, and 5 respectively. All ten ES are highly populated, industrialized and have dense traffic. PA categorized the PA into five different categorizes, namely, very high, high, moderate, low and very low. According to the PA category, rate of pollution in Baloch Colony is very high. Garden police HQ, Korangi, Nazimabad and SITE area lie in high PA. Karimabad has moderate, II Chundriger and SUPARCO has low pollution rate

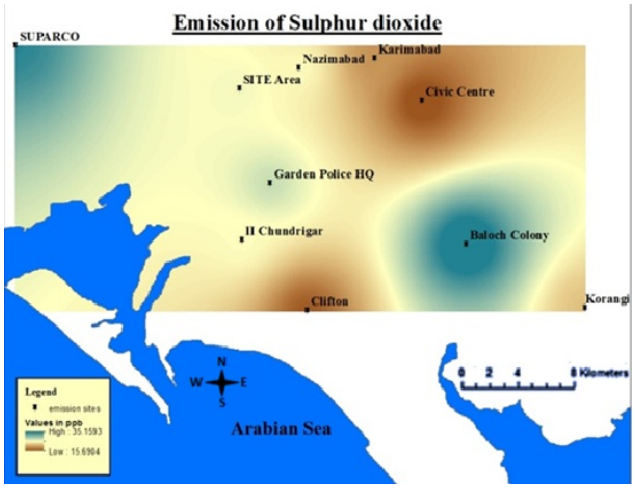

Fig. 5: SO_2 emission

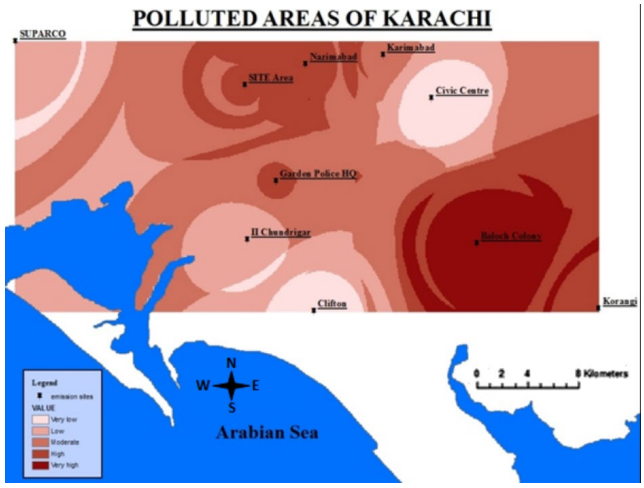

Fig. 6: Final result of PA in Karachi

however, Clifton has very low pollution. As Karachi is one of the most urbanized city of Pakistan where rate of population is increasing rapidly and along with it the industrialization and traffic burden of the city is also increasing which ultimately induces the air pollution, especially the emission of GHG into the environment. High GHG levels may cause hazardous effects on human health such as, inhaling these toxic contaminants may cause different infections dermal and lungs infections.

CONCLUSION

In conclusion, air quality was disrupted by the presence of a number of hazardous contaminants, the present study shows the concentrations of CO, CO_2, NO and SO_2 that were analyzed and then highlighted the PA of Karachi, Pakistan through GIS. This study declared that GHG emission were high in the densely populated areas of Karachi or where traffic burden was high. Moreover, in the industrial areas of Karachi GHG emission were also high and it makes the air quality objectionable and potentially dangerous. Increase of air pollution at this rate will have great consequences on all life in that area, from lung and skin diseases in humans to complications in plant and animal life. The study highlights these areas so that concerned authorities and the general population in these highly polluted areas can be educated about the disastrous amounts of GHG emissions. If concerned

authorities and general population are made aware then proper steps can be taken towards improving the quality of air in these ES by adopting proper strategies and with careful planning. Such strategies may include, plantation which is one of the best options for controlling the air pollution and purifying the pollutant dense air. Furthermore, use of biofuels in the vehicles and industries will not only reduce the air contaminants but it also helps to overcome the energy crises. Many steps can also be taken on individual level by the general population which will contribute to reducing air pollution or preventing it from increasing in the PA. Limiting the usage of personal transport and walking, taking a bicycle, opting to carpool or using public transport are a few ways by which pollution can be minimized. With time the health of engines in all vehicles deteriorates which increases the amount of harmful emissions that are released. With proper and timely maintenance, we can decrease the amount of GHG emissions by the transport sector. The general population can also urge all concerned authorities to take proper steps towards decreasing GHG emissions by boycotting companies that fail to maintain low GHG emissions and starting petitions.

AUTHOR CONTRIBUTIONS

S. Arsalan Performed the literature review, experimental design and GIS work, compiled the data, I. Alishbah, K. Areeba and S.R. Erum prepared the manuscript text, and manuscript edition. I. Fizza, F. Zainab and S.R. Saima helped in the literature review and GIS working.

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CONFLICT OF INTEREST

The author declares that there is no conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy have been completely observed by the authors.

ABBREVIATIONS

ES	Emission sites
GHG	Greenhouse gases
GIS	Geographic information system
PA	Polluted areas
CO_2	Carbon dioxide
CO	Carbon monoxide
NO	Nitric oxide
SO_2	Sulphur dioxide

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