Journal of Engineering Sciences
Assiut University
Faculty of Engineering
Vol. 43
No. 6
November 2015
PP. 955 – 968

CO_2 CONCENTRATION REDUCTION VIA AFFORESTATION OF URBAN AREAS

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(Received 1 October 2015; Accepted 5 November 2015)

ABSTRACT

Recently, many environmental problems have emerged in Egypt. The increase in human activities, technological progress, population density and fossil fuel burning, are known to increase harmful emissions and oxides within densely populated urban areas are considered the main pollutants. These factors lead to an unhealthy environment and the phenomenon of heat island and negatively affect the overall health of the human beings, which in turn, reduce the production efficiency.

Hence, it is so important to find the most efficient strategies that can be followed to decrease oxides and harmful emissions. This paper focuses on the role of the green component of plants and trees in the reduction of carbon dioxide emissions, reduce greenhouse gases and improve air quality is studied.

The microclimate simulation software "Envimet" is used for calculating the amount of carbon dioxide emissions within the area of "Alsayed Elbadawi", an ancient area in Tanta, Egypt. The simulation is performed to the current situation of that urban space and after improving it, which comprising this area by planting the green elements and trees. This will manifest the role of the afforestation in improving air quality and reducing oxides concentrations within the area to achieve a clean urban for sustainability.

Keywords: Urban Heat island; greenhouse gases; air quality; carbon dioxide emissions.

1. Introduction

Since the beginnings of the industrial revolution many environmental problems had appeared. The use of fossil fuels in industry and the increase in the transportation activities contributed to the increase in emissions of the air pollutants and harmful emissions in the atmosphere, especially the carbon dioxide. This in turn affects climate change and rising temperatures in addition to many health issues [1]. Therefore, the reduction of such emissions of greenhouse gases has become so important and essential because of its effect on raising the temperature of urban spaces and contamination that is why we are heading towards some of the techniques and strategies to reduce those emissions. These include the design of low energy buildings, and increasing the green spaces within urban areas as a beneficial way for air conditioning [2]. In addition, physical and chemical processes that are useful in deflecting those pollutants and reduce the concentration inside the cities [3] should be studied for improving the environment and achieve air quality.

In spite of having a lot of discussions and attempts to cope with environmental pollution and increased levels of harmful emissions and oxides of Egypt, it is still no clear strategy to deal with this problem in accordance with the steps and mechanisms studied within Egyptian urbanism. In addition, the problem of increased car traffic density is resolved via the expansion of streets at the expense of green elements and trees. That adversely affects the human physical and psychological health. It also affects the human efficiency and productivity. Hence, the most important strategies used globally to deal with those emissions and harmful oxides and try to reduce its concentration within the urban areas are reviewed, with a focus on the role of trees and green infrastructure in the reduction of carbon dioxide emissions and reduce the urban heat island effect in urbanism. That may reduce climate changes and achieve sustainability within the built environment in Egypt.

1.1. Objectives

The aim of this article is to improve the air quality within congested urban areas, by the reduction of oxides and harmful emissions that results from the misuse of the environment in the form of vehicle exhausts, factories and waste, which have a direct impact on the quality of our lives and the safety of our environment. This can be achieved through the use of trees and green elements, which plays an important role in mitigation of those emissions and the reduction of its spread within the urban environment.

1.2. Methodology

This paper studies the sources of oxides and their emissions within urban areas. In addition, it introduces a study for the urban and architectural strategies needed for reduction of these oxides. The effect of plants and trees on oxides concentration reduction especially the CO_2 gas is focused inside urban areas. The tool adopted is simulating a sample urban area using the "Envimet" simulator. The urban area tested is an archaeological residential area in the core of the city of Tanta in Egypt that is called "Alsayed Elbadawi". Two steps do the study: the first is to estimate the CO_2 concentration in the area for the current situation and secondly, the area is planted with trees in all urban spaces and the CO_2 concentration is then re-estimated after treatment with trees. The results is compared in the two cases to find the effect of green elements on reduction of the greenhouse gases especially the CO_2 which considered the most negatively affecting gas on human health in Egyptian urbanism.

2. Oxide emissions, causes, and impact on public health

The different human activities and the misuse of resources in a wrong way had led to the imbalance in environment. This had hurt the environment by releasing contaminations in air, sea and land. Egypt had witnessed during the last decades some of the changes that led to increased emissions and deterioration of air quality in various urban areas:

- Increase the human population and density inside urban areas. Consequently, the movement of cars and buses in urban areas at high densities had increased, as well as the dramatic increase in the consumption of natural resources and generation of different waste types and disposal of it by injurious way to environment and public health for human.
- Expansion of polluting industries. The large industrial boom in Egypt during the last 50 years had led to the rapid expansion of the industry without prior environmental planning in the distribution and location of factories. Particularly, the construction and building materials industries have a severe negative impact on the environment,

as they dramatically increase the polluting emissions and harmful chemical compounds. Therefore, they affect the health of humans and all ecosystems. It is reported that almost 5% of the world's diseases are caused by air pollution.

The air pollutants can be categorized as follows:

- Contaminating gases that include carbon dioxides, CO and CO2, sulphur oxides, nitrogen oxides and hydrogen sulphide gas, ammonia, hydrogen fluoride, etc.
- Particles such as dust, smoke, minerals and pesticide particles of different types of particle air pollutants.
- Radioactive and secondary pollutants such as smog and acid rain.

The most important and influential of these oxides to air quality and temperature is CO_2. The level of carbon dioxide before the Industrial Revolution was about 280 ppm. This value represents the equilibrium of the flows among the atmosphere, oceans and biosphere. This level of carbon dioxide in the atmosphere increased by 141% of its level before the Industrial Revolution in 2011 [4], due primarily to the following activities:

- Complete combustion of organic materials and coal: in various industries that include some stages on the interaction of water with hydrocarbons [5], in addition to the fuel burning engines that are found in automated traffic and cars [3]. The process of burning fossil fuels releases around 26 billion tons of carbon dioxide into the atmosphere each year.
- Breathing animals and organisms, and their decomposition after death.
- Cement production: approximately 5% of the carbon dioxide released by humans into the atmosphere comes from the cement industry.

Figure 1. shows the increase in CO_2 emissions over time from (2001-2025) [6].

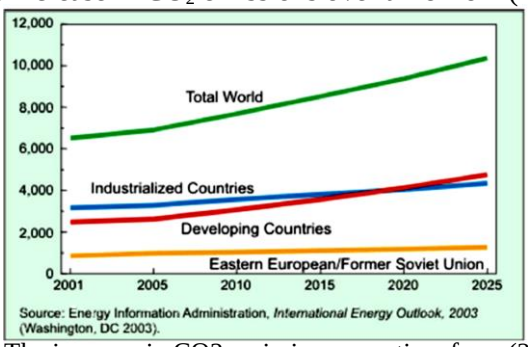

Fig. 1. The increase in CO2 emissions over time from (2001-2025)

High concentration of carbon dioxide and its accumulation in the atmosphere increases the absorption of large amounts of infrared (4). Therefore, air and ground temperatures increase. In addition, it changes the air components and damages the human health.

3. Strategies to deal with CO2 emissions within the construction and try to mitigate

Different directions that can be followed to reduce CO_2 emissions and/or concentration are listed in the following discussion.

3.1.On the level of urban

- **Good urban planning:** planning must be compatible with the environment in accordance with the requirements of the appropriate standards and population

densities of planning that meet the appropriate distribution of services. It should provide spaces and trails that help to get rid of contaminants and netting as well as reduce traffic in clusters different areas to achieve the air quality and reduce air emissions and oxides within urban areas.

- **Transportation:** development of streets and roads and increased reliance on non-polluting public transport, use of environment-friendly engines to reduce emissions, as well as to the possibility of providing special places for bicycles which are clean and fuel-less transportation method.
- **Plants and green areas:** increasing the availability of cultivated gardens and parks create an appropriate domestic environment, reduce the thermal loads and greenhouse gases, and improve air quality.
- **Trees:** trees with dense growth of leaves can provide shading and reduce the temperature as well as they can combat the effects of climate changes, global warming and reduction of oxides.
- **Energy:** the trend towards traditional energy released by burning coal and oil is to change their usage patterns in factories, buildings and power plants, by replacing them by clean renewable sources such as solar and wind energy to reduce air pollution and reduce harmful oxides [7].

3.2. On the level of buildings

- **Good design of the building:** the trend of design and construction management with high efficiency and passive use of solar energy in the design process, as well as for the efficient management of energy use in the building of new techniques reduce air pollution to maximize the role of renewable energies, particularly solar and wind energy.
- **The outer shell of the building:** It should be considered that buildings should be able to achieve self-isolation and have an appropriate orientation. This will reduce the heat leakage through the walls and ceilings from inside or outside the building. Hence, thermal comfort can be achieved through natural air conditioning while reducing the use of industrial appliances that consume a lot of energy and contribute in increased oxides emissions in construction.
- **Lighting and natural ventilation:** It is preferably to rely completely on natural light during the day even in deep places in the building. Artificial light can be used only after sunset. Note that the energy consumed for electricity generation produces large amounts of carbon dioxide. This should be done without neglecting the harmonization between natural lighting and ventilation and an appropriate air movement inside the building to help reduce energy consumption and provide a comfort environment.
- **Building materials:** the industry of building materials is one of the most important and the main reasons in the increase of greenhouse gases and the high proportion of carbon dioxide in the construction. To achieve sustainability and to reduce the negative impacts of the construction process [8], local, natural and compatible materials should be used. Materials that emit Chlorofluorocarbon and other polluting gases should be avoided.
- **Growing plants:** The plants are considered as an important component at the level of urbanization and at the level of the building. It acts as a protector for buildings from thermal loads of Foreign and as a purifier for the air and directing it to inside the building. Plants also increase the biomass that can absorb oxides of carbon from the air and improve it. Hence, the cultivation of plants and trees is one of the important strategies that helps in reduction of oxides and emissions and reduces the global

warming. That is why the research has tended to examine its role and impact in the reduction of those oxides, reduce its construction and improvement of air quality.

4. The role of the green element in the reduction of CO2 construction

Tree planting in the urban areas can mitigate climate changes and improve air quality. Trees and plants absorb carbon dioxide CO_2 in photosynthesis process for the formation of carbohydrates that that is necessary for plant growth. They act as carbon sinks and is considered as an effective way to reduce the global warming and reduce emissions of oxides, pollutants and mitigate urban heat island phenomenon.

In one trial in California in 2006, it is found that planting one million trees reduces carbon dioxide in the atmosphere by 3.5 million tons. In another study, it is found that planting 100,000 trees will reduce CO2 emissions by 1 million tons over the next 35 years that is equivalent to CO2 emissions from 7,000 cars on the road each year [9].

In Florida, United States, the trend is to expand "urban forests" as a strategy to mitigate climate changes. It is found that the trees in Florida in 1990 absorbed 14.4 million metric tons of co2, while in 2005 they absorbed about 6.23 million metric tons. Therefore, a plan of action was adopted there and extends to the year 2025 to increase the vegetation and landscaping to achieve a reduction in emissions and oxides by an amount that is greater than 6.23 million tons and increase the intensity of shading by 30% through planting at least 6.7 million trees per year [10].

Another study in Florida in 2009, reported that increasing green infrastructure by planting trees in streets and parking provided shading and improved air quality. It is deduced that planting trees over 18% of the city area, decreased ground temperature and removed 390 metric tons of pollutants [11].

It is found also that cultivation of trees and plants protects pedestrians from ultraviolet rays (UV). The trees leaves can absorb up to 95% from those harmful rays [12]. Tree planting in USA reduced CO_2 concentrations by 1.5-5% [13].

In Tokyo, Japan, tree-planting experiments showed the same trend of results. Tall trees planting in a high population city led to reduction of surface temperature by 10-15 ^{o}C and CO_2 concentration in over 60% of the area studied which is clear in Figure 2 that shows the concentration of pollutants before and after improvement in summer and winter [14].

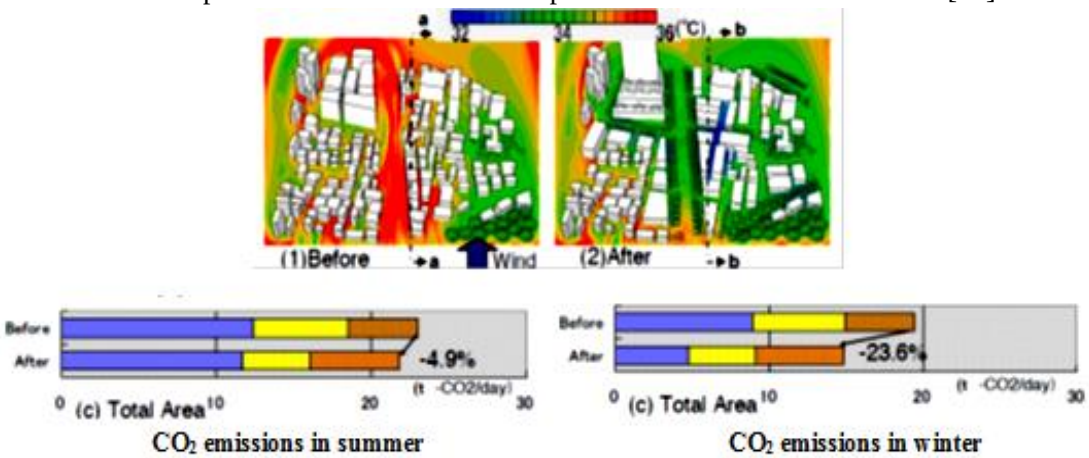

Fig. 2. The CO2 concentration before and after improvement in summer and winter in Tokyo

The most important facts observed in tress is that a tree can store about 6 Kg of Carbon each year. If a forest of trees planted over an area of 4200 m^2 can generate an enough quantity of Oxygen to let 18 persons to breathe every day. This forest can also absorb CO gas that is emitted from a car travelling 42000 Km each year [15].

We can conclude that the trees and the plants they are as the lungs in urbanism for its ability to remove contaminants from the air and control the dust and small particles. It also improves air quality and thereby improves human health and increase its production capacity. For these reasons, the direction of research adopted in this paper is to study the impact of planting trees on carbon dioxide within the area of Alsayed Elbadawi heritage city of Tanta in the Province of Gharbya, Egypt.

5. The case study

5.1. Choosing the area for applying the study

The study area has been chosen to be at the heart of the city of Tanta, Gharbya governorate in Egypt that is Alsayed Elbadawi as depicted in Figure 3. It is an important urban area with valuable heritage. Therefore, it is teeming with visitors form other residential quarters in Tanta and the surrounding cities as well as residents. They come mainly for praying in the famous mosque Alsayed Elbadawi. In addition, this area can considered a commercial area with many shops and high commercial activity all over the streets and canyons leading to the mosque besides the "Elsekka Elgedida" and "Omar Zaffan" streets. It is a high-density urban area with compact fabric as shown in Fig. . Furthermore, vehicles and other activities generate a lot of pollutants as well as noise pollution. Hence, it is important to treat this urban area and obtain a solution to achieve an environment friendly urbanism. The proposed solution is growing vegetation and trees and finds the enhancement achieved in air quality and oxides emissions and concentration.

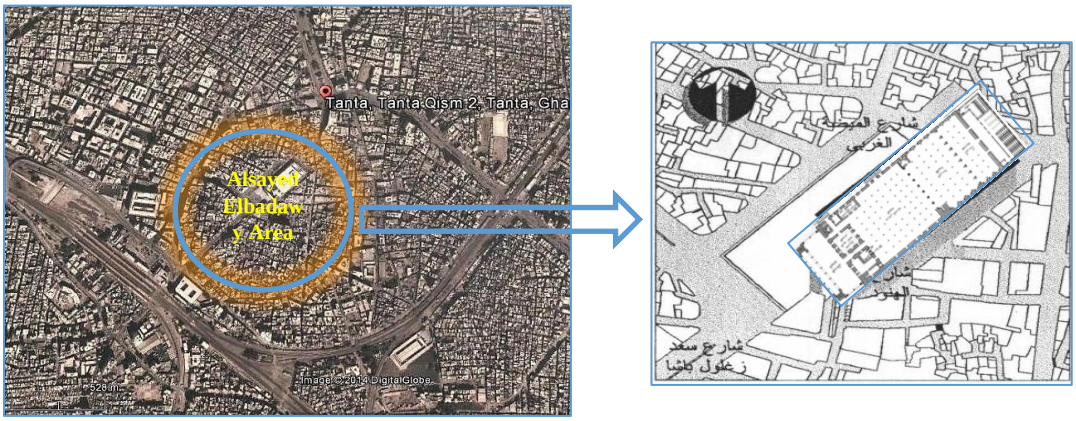

Fig. 3. Case Study Region in Tanta

5.2. Simulation tool description

ENVI-met is a simulation program that is developed by Michael Burse [16].It has various capabilities including 3D micro-climate modeling, calculating and simulating climate in urban areas with a resolution ranging from 0.5 to 10 meters and as low as 10 seconds time intervals. It integrates the laws of thermo-dynamics and fluid-mechanics to calculate micro-climate wind-speed and direction, air temperature, humidity, turbulence,

fluxes of different gases and particles and pollutant dispersion. It enables simulating surface vegetation, building, and atmospheric processes. Moreover, it can be configured and adjust its setting parameters to the geographical area under study. [17].

Fig. 4. Photos of the study area in Alsayed Elbadawi

5.3. Description of the simulated urban area

The simulated region lays geographically at latitude of $30^o\ 47'\ 27''$ North and longitude of $30^o\ 59'\ 53''$ East and at $22m$ above sea level. It is a $150m \times 236m$ with overall area of $35600\ m^2$. Main paths leading to Alsayed ELbadawy mosque are:

- Elsekka Elgedida street extends from North-East to South-West.
- Omar Zaffan street that extends from North-West to South-East.
- The width for these two streets is between $28\ to\ 32\ m$.

Figure 5 shows this area as viewed by satellites using Google Earth.

Fig. 5. the study area in Google Earth

6. The experiment

The experiment includes the simulation of the area under test (Alsayed Elbadawi) on the current situation and after treatment by adding trees.

The trees are added as follows:

- Trees at the two sides of Elsekka Elgedida and Omar Zaffan streets.
- Trees with dense leaves at the island in the middle of the two streets
- Trees with large crowns outside the walls of the mosque to act as shades for the parking of cars

- Tall trees are planted in the square containing the mosque to achieve required shading and air quality enhancement by reducing CO_2 for prayers.
- Adding trees at the entrance and front wall of the mosque to absorb CO_2 and block other pollutants.

The total number of planted trees all over the area is 110 tall trees with distinct crowns, 20 shrubs and a small area of grass. The ratio of the total area of the crowns to the urban area is 15%. Figure 6 shows the urban area in its current state before treating by trees as plotted using the "Envimet Eddi" which facilitates the inputting the design to the simulator.

Figure 7 introduces the same area after enhancing it using the trees. It also indicates selected discrete measurement points (receptors).

The concentration distribution of CO_2 is measured all over the area in the rush period for human activities that extends from 9:00 AM to 3:00 PM. The measurement units is particle per million (ppm).

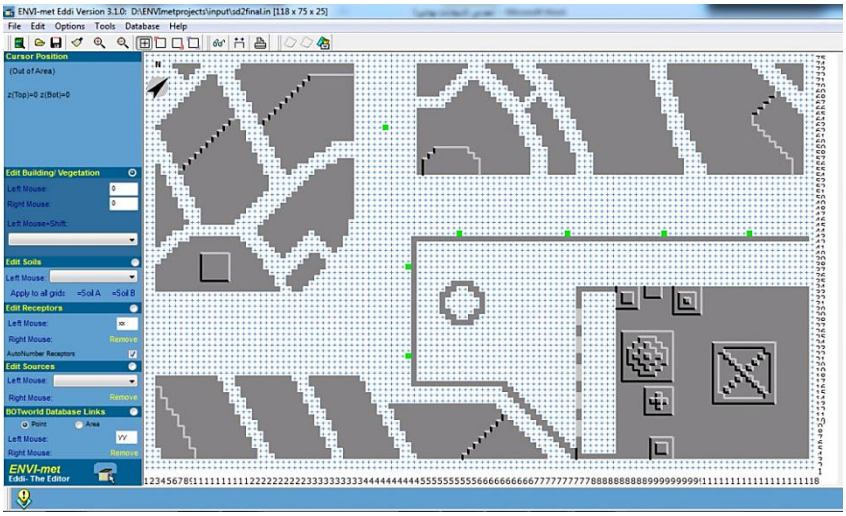

Fig. 6. Alsayed Elbadawi area as plotted the Envimet editor (before tree planting)

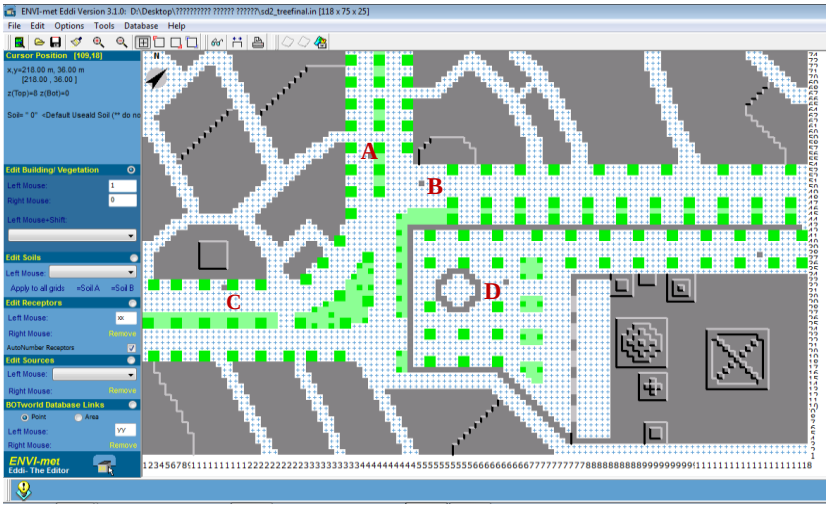

Fig. 7. Alsayed Elbadawi area as plotted the Envimet editor (after tree planting)

Table 1.
The Envimet configuration file

Date, time of simulation	**1-7-2014**
	Start Simulation at Time (HH:MM:SS) = 9
	Total Simulation Time in Hours: = 6
	Save Model State each ? min 60
Boundary conditions	Initial Temperature Atmosphere [K] =301.8
	Relative Humidity in 2m [%] = 59
	Wind Speed in 10 m ab. Ground [m/s] = 3.5
Grid size	118 x 75 x 25; X-Y grid spacing, 2m; Z grid spacing, 2m
Plants	Trees in parking lots: 10m high, dense foliage, distinct crown Street trees: 10m high, distinct crown, dense foliage Grass trip around Mosque : Luzerne 18cm Bushes in front of the mosque : 2m

The main simulation configuration used during dealing with the two cases is summarized in **Error! Reference source not found.**.

7. Results

In this section, the results of simulating the environment in the "Alsayed Elbadawi" area before and after adding trees are discussed. The greenhouse gas CO_2 is monitored all-over the area at high human and traffic activity hours that extends from 9:00 to 15:00. Figure 8 through Figure 14 display the CO_2 gas concentration over the whole area at the mentioned hours.

It is clear in Figure 14 the CO_2 emission and concentration are identical at 9:00 before and after tree planting. The concentration is about 350 ppm in the two cases. This result is due to night cooling hours and low human activities at this hour. Furthermore, it is noticed that CO_2 concentration is the least among all measured concentration by about 5-7 ppm.

By examining Figure 9, we note the difference in concentration become clear for the two cases. At 10:00, the CO_2 concentration before adding trees increased to 356.5 ppm. When adding trees, the concentration becomes as low as 355 ppm with reduction of 1.5 ppm. It is should be noted that a previous study showed that if a 10 million "CO_2 pipette machines" spread all over the earth, they can reduce the concentration by only 5 ppm [18]. This indicates the abilities and noticeable effect of planting trees as a CO_2 sink. Hence, a reduction of CO_2 concentration of 1.5 ppm can be considered as an effective reduction.

The effect of trees becomes clearly noticeable at 11:00 as shown in Figure 10. Trees caused an average CO_2 concentration reduction by 356 ppm as compared to 357 ppm before adding trees.

At 12:00, the average CO_2 concentration increased to 359.5 ppm. The trees reduced it to about 357.5 ppm. Moreover, the area that is affected by reduction of CO_2 concentration due to trees has extended to about 75% of the canyons in total study area. Figure 11 proves that result. In Figure 12, the effect of human activities and traffic that emitting CO_2 has increased the concentration as 360-361.5 ppm.

The CO_2 concentration continues increasing at 14:00. It becomes 361.5-362 ppm if no trees are planted. On the other hand, planting trees causes reduction to 360 ppm. The 14:00 has the highest CO_2 concentration if no trees are found in the area.

Starting from the hour 15:00, the CO_2 concentration begins to decrease as it become 360 ppm if no trees are planted and becomes 359 ppm if trees are planted. Moreover, this reduction spreads over 80% of the canyons in the area.

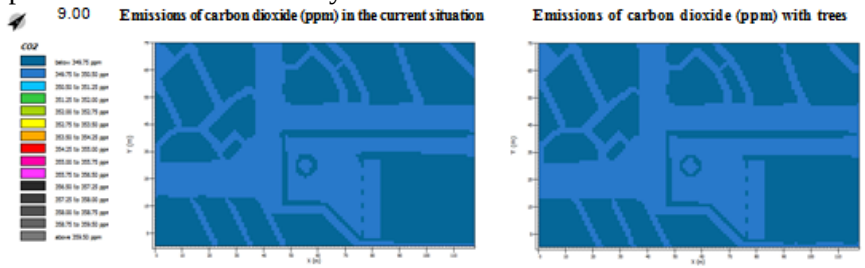

Fig. 8. CO2 concentration (ppm) at (9.00)

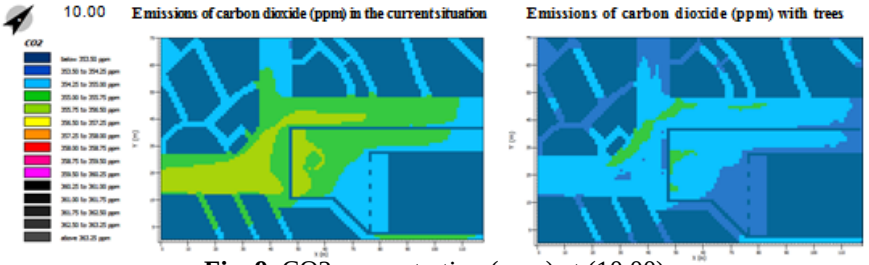

Fig. 9. CO2 concentration (ppm) at (10.00)

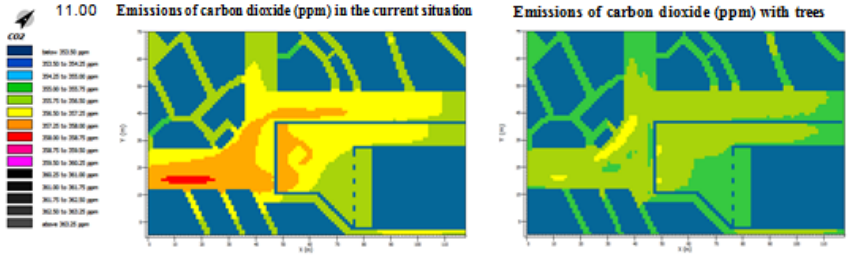

Fig. 10. CO2 concentration (ppm) at (11.00)

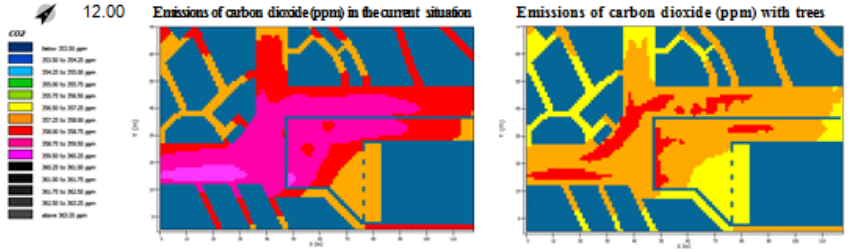

Fig. 11. CO2 concentration (ppm) at (12.00)

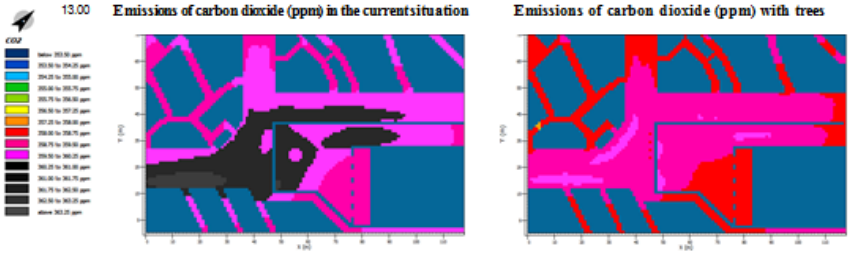

Fig. 12. CO2 concentration (ppm) at (13.00)

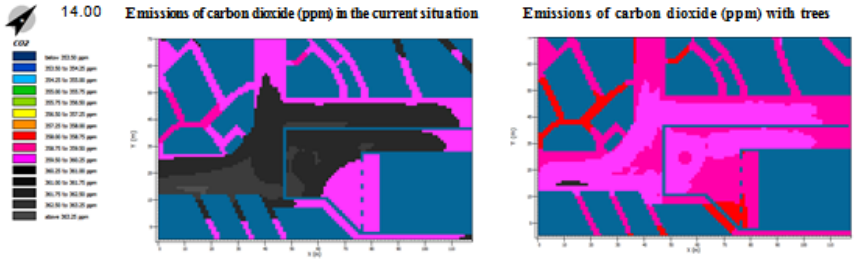

Fig. 13. CO2 concentration (ppm) at (14.00)

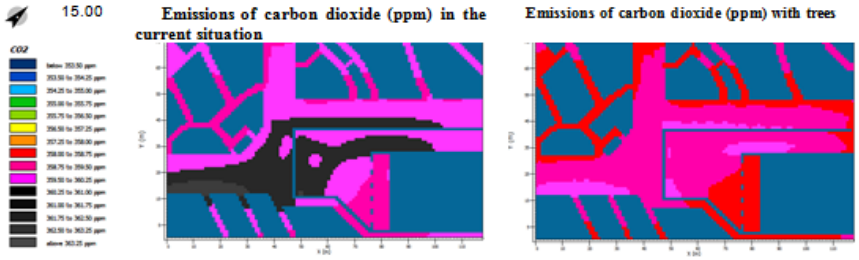

Fig. 14. CO2 concentration (ppm) at (15.00)

The analysis of the measured CO_2 concentration at the specific points (receptors) declared in Figure 7 shows the effect and importance of tree planting on the reduction of CO_2 concentration in the tested region.

As is clear from the analysis point (A) shown in Figure 15.a, which is located in the middle of street Omar Zaffan (north-west to South-east), that the presence of trees on both sides of this road and in the centre of the middle island, reduce the concentration of carbon dioxide clearly during daylight hours. This is clear especially at 12:00, 13:00 and 14:00 because of the high density of traffic. The reduction reaches up to 1.4 ppm, which is a large amount of reduction that positively affects the quality of the air.

The Measurement at point (B) is shown in Figure 15.b. It is an important point, as it is located at the centre of the urban area tested in the extension way of Elsekka Elgedida. The planted trees and green elements greatly affect the concentration of CO_2. The reduction of concentration reaches 1.3 ppm at 12:00 and 13:00. The hour 14:00 has the highest CO_2 concentration, the trees reduces that concentration by 1.2 ppm. Consequently, pollution and temperature is reduced.

At point (C), located at Elsekka Elgedida Street (North-east South-west), the CO_2 concentration is below 360 ppm and below its concentration at the central square. The use of trees has led to reduction amount of 0.8 ppm at this point. The effect of the existence of trees is clear especially at the hours 13:00, 14:00, and 15:00.

The point (D) is located in the inner square of the Alsayed Elbadawi mosque. The rows of trees not only provide shading for prayers but also reduce the CO_2 concentration and provide a better climate compared to the tree-less Inner Square. It also causes a CO_2 concentration reduction during solar shining hours. The reduction reaches its maximum of 1.2 ppm at the hour 12:00 causing a better air quality at this region.

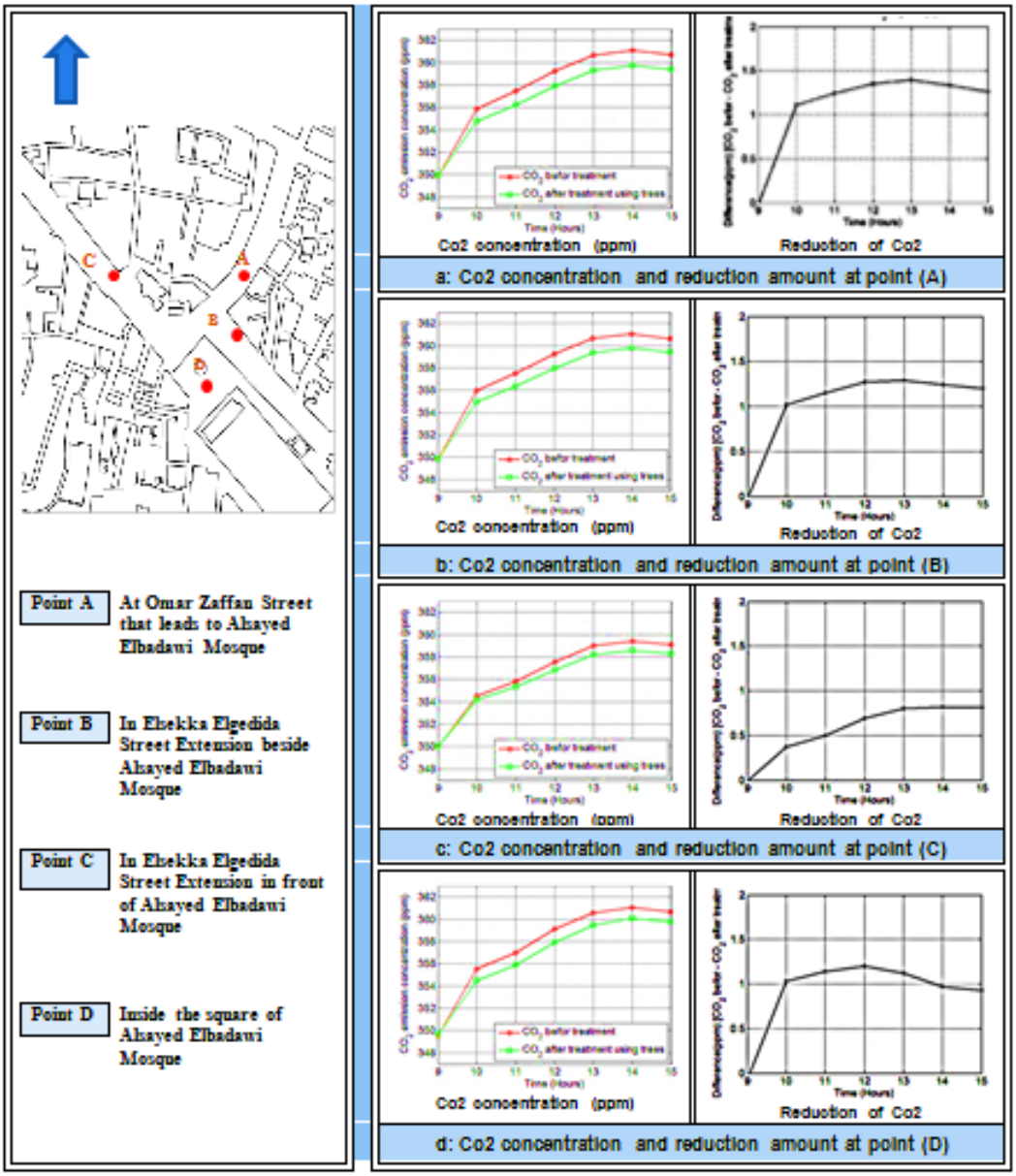

Fig. 15. CO_2 measurement at different receptor points

8. Conclusions

In this paper, a simulation for a high population and human activity heritage area is introduced in two cases: with and without afforestation. The Envimet microclimate modeler is employed for simulating this area and estimating the CO_2 emissions and concentrations all over that urban area. This experiment shows that planting trees with dense leafs within open spaces and along the canyons in a regular and reciprocal manner, disposes CO_2 polluted air. The increase in afforestation ratio to 15% i.e. nine trees per 1000 m^2, leads to a reduction of 1.5 ppm in CO_2 concentration in the air. This becomes evident during the hours having the thermal climax, as the air temperature increases as well as CO_2 concentration. The level of CO_2 in non-

afforested canyons is always higher than its level in the same but afforested canyons throughout all the day as shown in the simulation results. The results clarify the effect of afforestation on the urban environment. It provides a balanced uncontaminated environment with reduced emissions of volatile organic compounds that result from the life activities.

Therefore, afforestation and green elements are important strategy that should be followed to reduce CO2 concentration inside urban areas, mitigate the urban heat island phenomenon, improve air quality, reduce climate changes, decrease energy consumption, and achieve thermal comfort. Comparing different types of trees is the future research target to select the most suitable trees for the study area.

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خفض تركيز CO_2 باستخدام التشجير بالمناطق الحضرية

الملخص العربى:

مؤخرا ظهرت العديد من المشاكل البيئية في مصر حيث الزيادة في الأنشطة البشرية والتقدم التكنولوجي والكثافة السكانية وحرق الوقود الأحفوري، ومن المعروف أن زيادة انبعاثات الأكاسيد الضارة داخل المناطق الحضرية المكتظة بالسكان تعتبر من الملوثات الرئيسية في المناطق الحضرية. كل هذه العوامل تؤدي إلى بيئة غير صحية وظاهرة الجزر الحرارية وتؤثر سلبا على الصحة العامة للبشر وهذا بدوره، يقلل من كفاءة الإنتاج .

وبالتالي فكان هام جدا التوصل للاستراتيجيات الأكثر فعالية التي يمكن اتباعها لتقليل أكاسيد والانبعاثات الضارة بالبيئة. تركز هذه الورقة على دور العنصر الأخضر من النباتات والأشجار في الحد من انبعاثات ثاني أكسيد الكربون، والحد من الغازات المسببة للاحتباس الحراري وتحسين نوعية الهواء

حيث يتم استخدام برنامج المحاكاة "Envimet" لحساب كمية انبعاثات ثاني أكسيد الكربون داخل منطقة "السيد البدوي" وهي منطقة قديمة في مدينة طنطا، مصر. يتم تنفيذ محاكاة للوضع الحالي لذلك الحيز الحضري وبعد تحسينه، والتي تضم هذا المجال من خلال زرع عناصر الخضراء والأشجار. وهذا يعبر عن دور العناصر الخضراء والأشجار في تحسين نوعية الهواء والحد من انبعاثات أكاسيد وداخل المنطقة والشوارع المؤدية لتحقيق نظافة البيئة الحضرية للاستدامة.