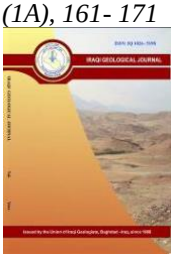
Iraqi Geological Journal

Journal homepage: https://www.igj-iraq.org



Effect Dynamic Stability of Atmospheric Boundary Layer on Plume Downward Flux Emitted from Daura Refinery Stacks

Ahmed F. Hassoon[1,*] and Sama K. Al-Dabbagh[2]

[1] Department of Atmospheric Sciences, College of Science, Mustansiriyah University, Baghdad, Iraq
[2] Atmospheric Sciences, College of Sciences, Mustansirya University, Baghdad, Iraq
* **Correspondence**: ahmed.fattah79.atmsc@uomustansiriyah.edu.iq

Received:
18 May 2022

Accepted:
21 September 2022

Published:
31 January 2023

Abstract

The vertical motion of air that enhances or restricts the atmospheric turbulence through atmospheric boundary layer is known as "atmospheric stability", in which any movement of atmospheric components such as water vapor, aerosols, etc. are affected by the atmospheric stability. The aim of this research is to test the effect of atmospheric boundary layer stability on the amount of downward aersols flux at 10um (PM_{10}) emission from stacks of Daura refinery, and estimated of deposition dust aerosols PM_{10} amount in area around the Daura refinery. In this study, hourly atmospheric stability based on similar theory of Monin-Obukhov length is calculated from archived data of the European Center for Medium Range Weather Forecast, and deposition velocity (V_d) for PM_{10} that is emitted from stacks Daura Refinery is calculated using the stability parameter (L). PM_{10} concentration is estimated according to the Gaussian model, which is used along with deposition velocity at this partical size in order to produce downward sedimentation flux (F_p) at distances 1000, 5000 and 10000 m from stack point sources emission. Results show that areas located to the south and southeast of the refinery receive large amounts of deposited flux values through stable weather conditions, where the accumulated PM_{10} amounts during one month have recorded 1.5 million µg /m^2.s in January at a distance of 1000 m from refinery center stacks, while this amount reaches 532 million µg/m^2.s during July due to the high emission rates resulting from burning fuel oil during July. The percentages of PM_{10} sedimentation decreased with the distance from the refinery to 1712 and 322839 µg /m^2.s at a distance 10 km from the refinery in January and July, respectively. According to this method, the accumulated amount of PM_{10} in square meters can be estimated at any time, if atmospheric stability conditions and the domain of wind direction are known.

Keywords: Stability Classes; Flux deposition; Particulate matter; Daura Refinery

1. Introduction

Atmospheric stability is defined as the response of air parcels to vertical motion, which largely depends on the vartical variations of wind speed and temperature, such that these elements are considered indicators used to calculate atmospheric stability conditions (Anad et al., 2019). There is no physical law that specifically determines atmospheric stability, but there is a wide range of schemes, such as Pasquill, Richardson number, Monin-Obukhov, etc. (Albdiri, 2018). The contamination of the atmosphere by pollutants has serious impacts on different sectors, and their deposition is affected by

DOI: 10.46717/igj.56.1A.12ms-2023-1-24

many factors. For instance, dry deposition in urban areas depends on particle properties, concentrations, local conditions of air-to-surface flux, and surface characteristics such that smooth surfaces compared to rough surfaces have lower deposition rates per unit area (Giardina et al., 2019). The transport of some chemical compounds, such sulfur oxides, nitrogen and ammonium, base cations and heavy metals, is responsible for many urban air pollution problems (e.g., visibility reduction, respiratory diseases, etc.). The deposition rate depends on the size of particles; where coarse particles are rapidly settled by sedimentation or impaction processes, while, Brownian diffusion is effective for small particles (Jacob, 1999). Due to urban and industrial activities, the formation of pollutants is quite inevitable, and they are deposited on human beings, surfaces of plants such as trees and crops, buildings and wate rbodies (Dolske, 1995), where the dry deposition of pollutants on water surfaces will cause a degradation in water quality and may spoil the aquatic ecosystems, while wet deposition is active during the rain (Mohan, 2016).There are many studies directed at deposition velocity, one of which comprises a comparison between many models used to study the rate of deposition and the use of a proposed model that covers a wider range of conditions, replacing complicated calculations of atmospheric stability and friction velocity with a simpler algorithms that includes the usage of meteorological data such as wind speed (Abbasi et al., 2018). Dry deposition flux is calculated via several methods, and the relationship between dry deposition flux and particle concentration has been reviewed in a comprehensive study (Mohan, 2016). A similar study was made, but for stacks brick production factories to study the effect of stack emission on the occurrence of high voltage insulators flashover in Diwanyah Governorate in Iraq, and to test the effect of some meteorological data on dispersion and deposition rates of PM_{10}, in which Gaussian dispersion model is adopted to simulate local air pollution with distance. The results show that the atmospheric stability conditions have a major role in determining the deposition rate of PM_{10}; the study found that the thickness of the deposited layer changes when the atmospheric stability changes from a moderately unstable conditions to a strongly unstable conditions (changing stability classes from class B to stable conditions class F) (Albdiri, 2018). Another study is made to design a mathematical model, operating at different stability conditions to calculate the deposition velocity of particulates over Baghdad City by using wind speed and temperature data near the earth's surface at 20 m height, and the results show a direct relationship between deposition velocity and friction velocity, but the relation is opposite for wind speed (Saad, 2012). This study aims to determine the effect of atmospheric stability by using the similarity theory of Monin-Obukhov and Pasquill Turner stability on deposition downward flux for PM_{10} at different distances resulting from emitted plume stacks from the Daura refinery, according to the domain of wind direction, and finally to calculate the amount of deposited dust in the specified area in this domain direction.

2. Location of the Study Area

Al-Daura Refinery is one of the main refineries in Iraq, located in Al-Daura region, about a few kilometers from the city center in the southeastern suburb of Baghdad, near the Tigris River, with an area of approximately 205 Hectares (1620m x 860m) as shown in Fig.1a, bounded on the north and the west by Karada city, one of the largest cities in Baghdad province, while it is bounded on the east by a highway, and on the south by the refinery workers households (Hamiza et al. , 2021). Fig. 1a, b show the location of the Daura refinery relative Baghdad province and Baghdad center. Daura refinery operates twenty-four hours per day, processing large quantities of crude oil and producing about 210,000 barrels per day (Anad et al., 2022; Anad et al., 2019).

Most of the atmospheric data are obtained from the European Center for Medium-Range Weather Forecasts (ECMWF). This center is considered a research institute and operational service, producing global numerical weather predictions and other data for members and other states and communities. ECMWF considers one of the largest supercomputer facilities and meteorological data archives in the

world. Grid data is used over Baghdad center with grid clarity of 0.125x0.125 degrees, and the nearest grid point to Daura refinery is 33.28ºN lat. and 44.25ºE, data from this point are considered a refinery point station for atmospheric data. Fig. 1 (a and b) shows the distribution of ECMWF grid stations over the Baghdad map, and the station near to refinery region, respectively.

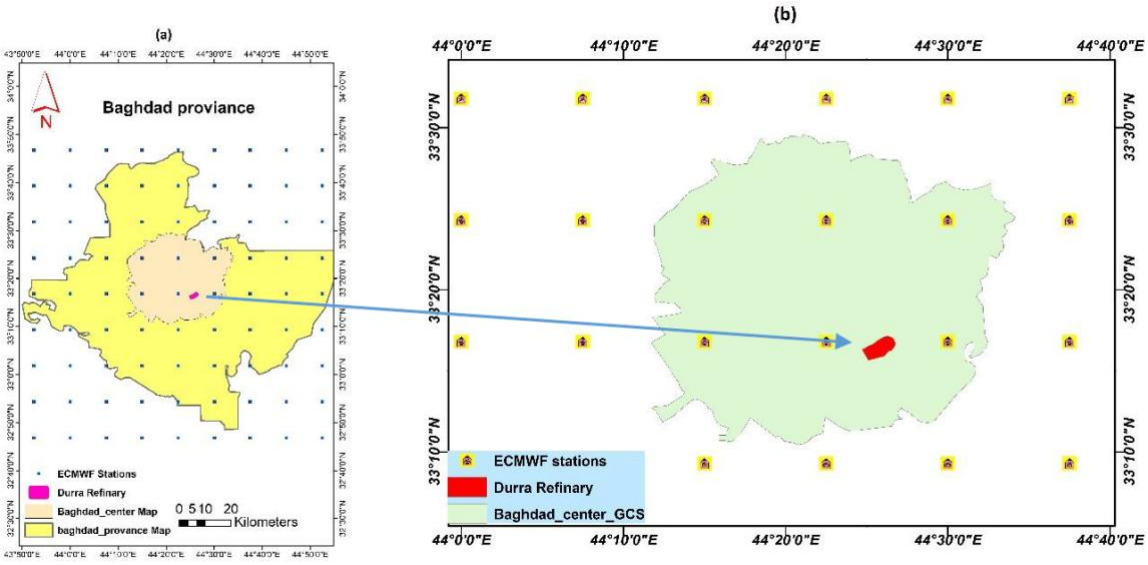


Fig 1. Location study, (a) Baghdad province and Baghdad center map; (b) Baghdad center located Daura refinery and nearest grid data of ECMWF.

Hourly data at 00, 03, 06, 09, 12, 15, 18, and 21 for some atmospheric parameters, including sensible heat flux H, air temperature above the surface T, eastward and northward shear stress τx, and τy, wind speed compounds, and wind direction at altitude 10 m, from this point and for January (as the winter season) and July (as the summer season), were used to estimate the atmospheric stability condition by Obukhov length and Pasquill Turner stability classes using references standard tables. These atmospheric data and stability parameter index, in addition to amount of fuel burned inside the refinery in 2019 during the January and July, are considered in the Gussain model to estimate PM10 concentration and finally determine the flux deposition amount for PM10.

3. Materials and Methods

3.1. Monin-Obukhov Length Stability Indices

The hypothesis of Monin–Obukhov similarity state that any mean flow or turbulence quantity in the surface layer, when normalized by an appropriate scaling parameter, must be a unique function of z/L only, where L is Obu-khov length calculated byHassoon and Tawfiq (2019).

$$L = \frac{-\rho c_p u_*^3 \bar{\theta}}{kgH} \qquad (1)$$

Where g is the gravitational acceleration (m.s^{-2}), ρ_{air} is air density (1.2kg m^{-3}), c_p is the specific heat at a constant pressure (1004 J K^{-1} kg^{-1}), $\bar{\theta}$ is the mean potential temperature between two levels (°K), and u_* is the friction velocity (m s^{-1}), where friction velocity and sensible heat flux must be estimated to determine L according to equation 1, and vice versa.

3.2. Friction Velocity

The friction velocity (also known as the shear-stress velocity), is a measure of the wind shearing stress on the surface below. Friction velocity is less accurate, but commonly estimated from more routine meteorological measurements of wind speed and temperature at multiple levels (Czernecki et al., 2017). It is derived from the similarity theory of the atmospheric boundary layer proposed by Monin and Obukhov (Mrokowska et al., 2015) and can be estimated from the following equation (Castellví and Cavero, 2020):

$$u_* = \sqrt{\frac{\tau_i}{\rho}} \qquad (2)$$

Where τ_i : is shear stress in northward (y-axis), or eastward (x-axis) directions, i: refers to x-axis or y-axis, and the average shear stress can be substituted in the following equation (Hassoon and Tawfiq, 2019):

$$\tau_{x,y} = \sqrt{(\tau_x)^2 + (\tau_y)^2} \qquad (3)$$

3.3. Turner Pasquill stability Classes

Different techniques are used for stability determination, but there is some complexity in measuring some parameters to calculate stability, such as heat flux from a surface or friction speed, etc., thus, some schemes were developed to facilitate the classification of atmospheric stability conditions, such as the Pasquill scheme. Pasquill (1961) proposed a discrete classification scheme of atmospheric stability which was modified later by Turner (1969) (Mohan and Siddiqui, 1998). The scheme depends on atmospheric observations near the surface at 10 m, such as wind, solar radiation, and cloudiness. There are mainly six atmospheric stability classes labeled as (A) extremely unstable, (B) unstable, (C) slightly unstable, (D) neutral, (E) slightly stable, and (F) extremely stable. Later, class G is involved to represent low wind speed at nighttime conditions (stable conditions) (Chapman, 2017) (Table 1).

Table 1. Pasquill-Gifford Scheme (Turner, 1969)

Wind speed (m/s) at 10m	Day			Night	
	Incoming solar radiation			cloudiness	
	strong	Moderate	slight	>=4/8	<=3/8
<2	A	A-B	B		
2-3	A-B	B	C	E	F
3-5	B	B-C	C	D	E
5-6	C	C-D	D	D	D
>6	C	D	D	D	D

Obukhov's length can be determined from Pasquill's scheme, (Martínez, 2019) see Table 2.

Table 2. Monin Obukhov's and Pasquill-Gifford's Stability conditions schemes

Stability condition	Monin – Obukhov	Pasquill - Gifford
Extremely unstable	$-100 < L < 0$	A
Unstable	$-10^5 < L < -100$	B
Slightly unstable	$\|L\| > 10^5$	C
Neutral	$10 < L < 10$	D
Slightly	$10 < L < 10^5$	E
Extremely Stable	$0 < L < 10$	F

3.4. Gaussian Model

The Gaussian plume dispersion model is obtained from the analytical solution of the simplified diffusion equation, which is mostly used in regulatory dispersion models. It describes a continuous point source release in origin in a uniform (homogeneous) turbulent flow. The final form of the Gaussian plume equation is for an unrestricted elevated plume as given in the following equation (4) (Anad et al., 2022; Albdiri, 2018):

$$C(x,y,z) = \frac{Q}{2\pi u_{av.}\sigma_y \sigma_z}\exp\left(-\frac{y^2}{2\sigma_y}\right)\left(\exp\left(-\frac{(z-H_p)^2}{2\sigma_z^2}\right)+\exp\left(-\frac{(z+H)}{2\sigma_z^2}\right)\right) \quad (4)$$

Where C: is the point of concentration at the receptor (μg/m^3), x, y, z: is the ground level coordinates of the receptor relative to the source with wind direction (m), and H_p: is the effective release height of emissions (m), Q: is the mass flow rate of a given pollutant from a source located at constant location (μg/s), $\bar{u_p}$ is the wind speed (m/s), σ_y and σ_z: is the standard deviation of plume concentration distribution in y and z plane (m) where they are calculated according to stability by Pasqual and Turner classes (Albdiri, 2018; Shubbar et al., 2019). The estimation of mass flow rate (emission rate) for any location depends on the methods of the recent research with change from the amount of fuel burned (Hamiza et al., 2021, Anad et al., 2019 and Anad et al., 2022).

3.5. Particulate Matter

Particulate matter (PM_{10}) recieved growing attention from researchers due to their impacts on human health. The exposure to high concentrations of PM_{10} increases mortality rates and more cases of respiratory and cardiovascular diseases. The concentration of PM_{10} changes according to interrelated, environmental and anthropogenic factors. For example, the occurrence of temperature inversion can enhance the accumulation of particulate matter in the surface boundary layer (Czernecki et al., 2017).

3.6 Gravitational Settling Velocity

In cases of dust deposition, which is a coarse aerosol, the velocity of gravitational settling is significant, and it can be calculated through the equilibrium between gravitational force and drag force, neglecting the buoyancy force (due to the larger density of particle compared to the density of air). If the Stokes law is established (Re < 0.01), the settling velocity can be calculated from the following equation (Abbasi et al., 2018):

$$V_g = \frac{\rho_p g D^2}{18\mu} \quad (5)$$

Where, ρ_p: particale density (2 g/cm^3), μ:the absolute viscosity of air (~1.81x10^{-4} g⁄cm.s), g: the gravitational acceleration (9.8 m/s^2).

3.7 Particulate Matter Deposition Flux

The dry deposition velocity V_d depends on several factors: the height above the ground surface (altitude), the surface topographic conditions, as well as the behavior of turbulence in the atmosphere. The general approach used in this calculation is the deposition velocity equation that depends on the explicit resistance methods, including parameterizations of Brownian diffusion, inertial impact, and gravitational settling. The deposition velocity is written as the inverse of the sum of resistances (referred to as R_a and R_d in equation 6) to pollutant transfer, R_a and R_d are defined as aerodynamic resistance and land surface resistance, respectively) through various layers, plus gravitational settling as in the following equation (Fang et al., 2010; Szep et al., 2016).

$$V_d = V_g + \left[\frac{1}{R_a + R_d + (R_a R_d V_g)}\right] \quad (6)$$

Where:

$$R_a = \frac{1}{k\, u_*}\left[\ln\left(\frac{z}{z_0}\right) + 4.7\ \frac{z}{L}\right] \quad (7)$$

$$R_d = \frac{1}{(Sc^{-2/3} + 10^{-3/st})u_*} \quad (8)$$

$$Sc = \frac{\nu_a}{D_b} \quad (9)$$

$$St = \left(\frac{V_g}{g}\right)\left(\frac{u_*^2}{\nu_a}\right) \quad (10)$$

where Sc: is Schmidt number that is defined as the ratio of momentum diffusivity (viscosity) and mass diffusivity (dimensionless) (Bergman et al., 2011), St: is stokes number (dimensionless), ν_a: is kinematic viscosity of air (~0.15 cm^2/s), and D_b: is the Brownian diffusivity (cm^2/s) of the pollutant in air.

4. Results and Discussion

4.1. Atmospheric Stability classes at nighttime

Atmospheric stability is considerably important in calculating of the concentration particulate matter (PM_{10}), and its deposition velocity. In this study, two approaches are applied to determine the stability based on the ECMWF gridded data at a point near the Daura refinery. The first approach includes the calculation of Monin-Obukhov length according to equation 1, and the friction velocity in equation 1 is calculated from equations 2 and 3. The used data comprise the sensible heat flux, instantaneous shear stress and air temperature near the Earth surface. Fig. 2, shows the behavior of friction velocity in the area near Daura refinery in the January and July every 3 hours from 00 to 21; the friction velocity in July is greater than that in January in most observations due to great turbulence and unstable atmosphere as a result of convection. Large values of friction velocity are proportional to unstable conditions, according to the theory of Monin-Obukhov in equation 1.

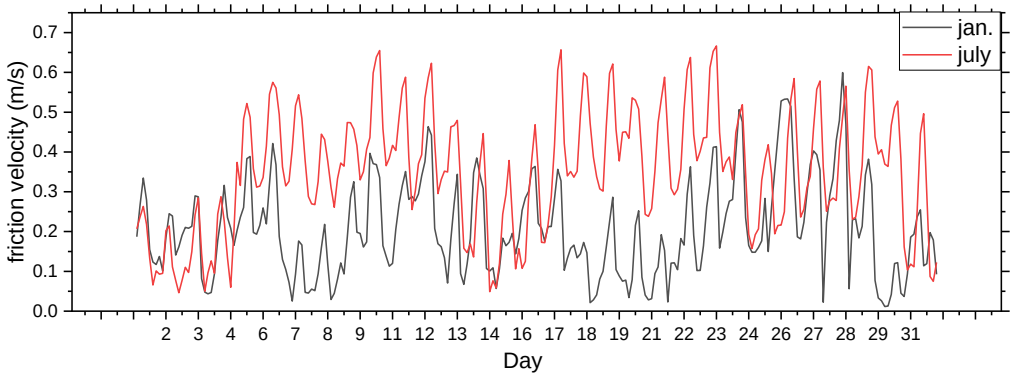


Fig 2. Friction velocity in January and July months observed for each 3 hours in area around Daura refinery calculated from ECMWF data, 2019

This stability parameter also depends on surface sensible heat flux. Fig. 3a shows the difference between the observed instantaneous sensible heat flux in July and January, where it has negative values in most observations; this refers to the effect of the positive sign. Because there is an open area, that does

not effect on large values of positive flux, although there are large values of air temperature in July (Fig. 3b). This method of stability is used to find the gravity velocity of the PM_{10} according to equation 5.

The second approach is the stability classes, which depend on the first approach and on Table 2 that correlated to the Monin-Obukhov length (L). The Pasquill Turner stability classes are constructed of three classes: A, B, and C, which are considered as unstable; D class as neutral, and E, and F as stable. These classes were used in the Gaussian model to calculate the concentration of PM_{10} at different distances by using equation 4.

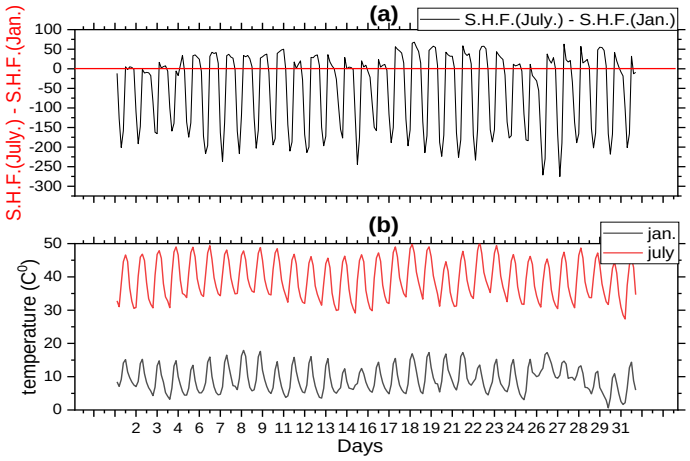


Fig. 3. Show (a) Sensible heat flux differences between January and July hour month; (b) air temperature in January and July month

Table 3. Relationship between number of frequency stability classes of January and July and average stability Monin-Obukhov length

July				January			
Class	**Freq. No.**	**Percent**	**L(av.)**	**Class**	**Freq. No.**	**Percent**	**L(av.)**
A	10	6.451613	-4.5769	A	35	22.72727	-4.0328
B	36	23.22581	-54.729	B	78	50.64935	-33.444
C	16	10.32258	-133.614	C	10	6.493506	-148.687
E	79	50.96774	61.553	D	1	0.649351	37.615
F	14	9.032258	6.46963	E	21	13.63636	87.6607
				F	9	5.844156	5.20489
Total	155			Total	154		

4.2 Emission PM_{10} from stacks Daura Refinery

The Daura refinery operates twenty-four hours per day, with two types of fuel burned inside the refinery units. According to the issued reports from the environment department in the refinery, the latter has twelve units, consuming fuel oil and fuel gas as an operating fuel. Nearly 46606.1 m^3 and 64171115 m^3 of fuel oil and fuel gas, respectively, were burned through January, while nearly 31436.1 m^3 and 9290554 m^3 of fuel oil and fuel gas were burned in January and July, respectively, in 2019. Knowing these amounts of fuel is very important to estimating the emission rate of PM_{10} from stack outlets (Table 4).

Table 4. Fuel oil and fuel gas burned in refinery units also emission rate of PM_{10} resulted from burning at January and July 2019.

Months	Fuel Oil (m^3)	Emission Rate (mg/s)	Fuel Gas (m^3)	Emission Rate (mg/s)
Jan.	46606.1	41692.15	6417115	767.421
July	31436.1	28121.61	9290554	1111.1371

Atmospheric data such as wind speed, direction, and other parameters from ECMWF used to estimate atmospheric stability, according to the Pasquill Turner stability scheme, while atmospheric stability classes are used to calculate PM_{10} concentration above the surface according to the Gussain model, equation 4. Fig. 5 shows the many circle lines around the refinery center point that represent the distance of particulate pollutants, reaching also the direction of wind speed domain in January and July plotted by GIS program.

According to equation 4, PM_{10} dispersed from refinery stacks can be estimated according to the Gaussain model and depending on data from the ECMWF. The emission rate is necessary to determine PM_{10} concentration at different distances assuming homogenous turbulence. The emission rate is governed by fuel oil and fuel gas supplied to the refinery during the study period. Gaussian model estimates PM_{10} concentration over the surface at a different distance from the refinery center (Fig. 5), but it does not represent the amount of deposit particles.

4.3. Evaluation Flux Deposition at Stable Conditions

The boundary layer structure is different throughout daytime and nighttime according to stability, such that in the daytime it is constructed from the surface layer and mixed layer, while at nighttime it is constructed from the stability inversion layer and residual layer. This arrangement of the stacked layer is different for the winter season than for the summer season. This study is an attempt to evaluate aerosol deposition amounts in the regions around the Daura refinery according to the distance from the stacks source. The calculation passed through two stages: the first stage was to evaluate flux deposition for aerosol particles with a diameter of 10 um. The equations from 5 to 10 were used to calculate flux deposition depending on atmospheric stability in the surface layer. The important parts of the first stage included gravity deposition, velocity deposition and stability parameter Obukhov length. The second stage is to determine aerosol concentration at 10 μm according to the Gaussian model for dispersion in equation 4. This model needs many parameters, such as wind speed at the stack exit height, atmospheric stability classes, and diffusion coefficients, in addition to emission rate. Knowledge of aerosol deposition velocity and aerosols concentration at 10 μm is necessary to determine downward the flux deposition, where flux is defined as the transport of any aersols amount per unit area per unit time, the amount here refers to the PM_{10} calculated by the Gaussian model, and it depends on the amount of burned fuel inside refinery units released by 35 stack located inside the refinery by plume derived by exit velocity of 23.45m/s. Two types of experimented data represent different weather conditions in January and July which perhaps represents extreme weather condition, it is very important to reflect stability conditions in the boundary layer through these study periods.

4.4. Spatial Distribution of Flux Deposition According to Wind Direction Domain

This study is not concerned only about the downward flux of PM_{10} pollutant amount released from Daura stacks from the known surface boundary layer, friction velocity, stability classes and Monin abu khov length, but it also takes into account how to determine the accumulation amount of PM_{10} resulting from burning products at different locations around the refinery through average periods of the day, month and year, thus the domain of wind direction at there time periods must be known (Fig. 4).

The Gaussian model can be utilized to give downward deposition concentration of pollutant with distance from point sources. Fig. 5 shows three circles for distances of 1000, 5000, and 10000 m from the refinery center, each circle considered the amount of deposition rate. The refinery needs 24 hours to complete the daily operation, which will take time for deposition to determine the thickness of accumulated dust.

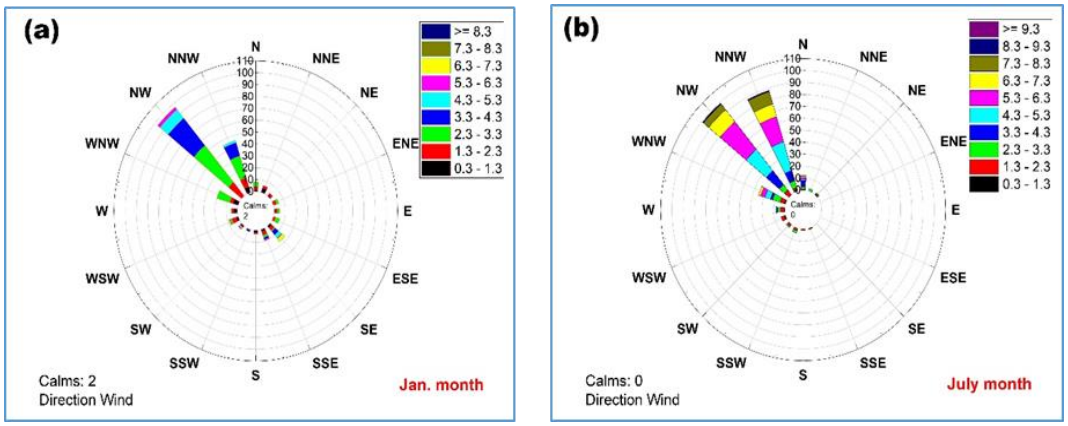


Fig. 4. Blowing domain from wind speed and direction over Durra refinery by windrose in (a) January; (b) July

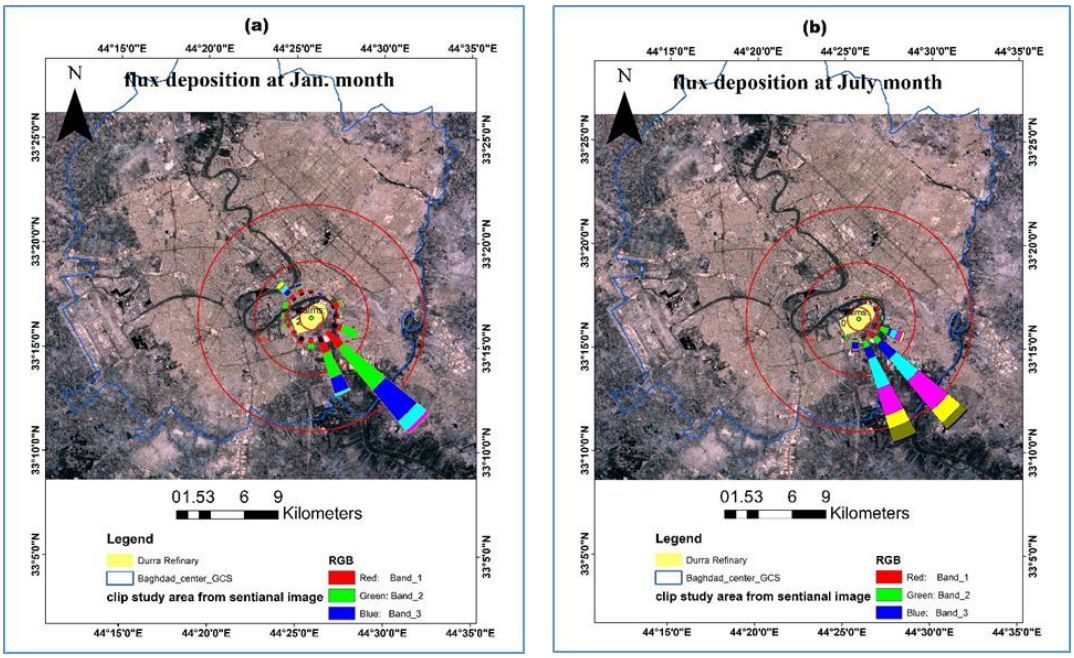


Fig. 5. spatial distribution of average downward flux deposition aerosols emitted from refinery stacks reaching distances of 1km, 5km, and 10km (three red circles) according to blowing domain to wind speed in (a) January; (b) July

The figure also shows the flux deposition for different conditions (January and July). According to the wind direction domain, most amounts of accumulated dust can be specified at any location. The importance of this study is in determining whether the center of regions have a large deposition amounts of aerosols that are loaded into the atmosphere, which is considered a prediction that can be introduced for those interested in knowing the lines of deposition flux.

Table 5. Average amount of the flux deposition according to blowing domain of wind direction and distance from stack refinery through stable atmospheric conditions and average time

Month	Distance	g/m^2.sec	g/m^2.hour	g/m^2.day	g/m^2.month
Jan.	1 km	$6.24*10^{-10}$	$2.25*10^{-5}$	$5.39*10^{-5}$	0.001617
	5 km	$4.5*10^{-12}$	$1.62*10^{-8}$	$3.89*10^{-7}$	$1.17*10^{-5}$
	10 km	$6.606*10^{-13}$	$2.378*10^{-9}$	$5.71*10^{-8}$	$1.71*10^{-6}$
July	1 km	$2.06*10^{-7}$	0.00074	0.017765	0.53296
	5 km	$9.04*10^{-10}$	$3.25*10^{-6}$	$7.81*10^{-5}$	0.002343
	10 km	$1.25*10^{-10}$	$4.48*10^{-7}$	$1.08*10^{-5}$	0.000323

5. Conclusions

Flux is a vector amount describing the magnitude and direction of the flow of a substance or property, measured in units amount per unit area per unit time. In this study, pollutant aerosol flux at 10 um (PM10) emitted from refinery stacks calculated in this study resulted from burning of oil crude in operation systems. When pm10 is emitted from the Daura refinery stacks it will be deposit after some duration through it movement and deposited (accumulated) in the area surrounding the Daura refinery according to domain wind direction. Atmospheric stability effected on flux transformed and deposition PM10 concentration. In this study, atmospheric stability at different behavior climate months was estimated with two methods, its Monin–Obukhov similarity theory length and Turner stability classes, first method uses z/L as stability index depends on data of wind speed, friction velocity, deposition velocity, shear stress, air temperature, sensible heat flux, obtained or calculated using ECMWF archive data for grid point stations near to refinery location, and second one used to calculeate PM10 concentration by used gussain model.

This study focuses on the deposition flux of PM10 concentration because this particulate matter has large size and is deposited in a large amounts around the refinery and causes side effects on humans. There are also many additional parameters used to determine flux deposition in addition to stability, such as emission flow rate from refinery stacks, effective stack height, and other elements related to the environment, such as wind speed, and air temperature. Results of deposition flux with the domain of wind direction are considered very important indices for air pollutants, since aerosol emissions seem to be the most serious problem in the area, considering suspended particles are at high levels and exceed local and international standards, in addition to the calculation of the dust deposition amount with times and distances for specified time and distance around the refinery. The areas located to the south and southeast of the refinery received large amounts of deposited flux values per squre meters through stable weather conditions. The accumulated PM10 amounts during one month have recorded 1.5 million μg /m^2.s in January at a distance of 1000 m from refinery center stacks, while this amount reaches 532 million μg/m^2.s during July due to the high emission rates resulting from burning fuel oil during July. The percentages of PM10 sedimentation decreased with the distance from the refinery to 1712 and 322839 μg /m^2.s at a distance of 10 km from the refinery in January and July, respectively. According to this method, the accumulated amount of PM10 per squares meter can be estimated at any time, if atmospheric stability conditions and the domain of wind direction are known.

Acknowledgements

The authors would like to thank the the reviewers and the editors of this manuscript, Mustansiriyah University and College of Science, Department of Atmospheric Sciences for providing the chance to implement this work and the use of ERA5 datasets as stated in the Copernicus C3S/CAMS License agreement.

References

Abbasi, A., Malayeri, M.R., Setodeh, P., 2018. A revamped model of dust storm dry deposition. Journal of Earth Science & Climatic Change, 9(8) 1000486.

Albdiri, A.D.Z., 2018. Effect of atmospheric stability conditions on the dispersion and deposition rates of particulate matter on the surface of high voltage insulators. Journal of Engineering and Applied Sciences, 13, 10323–10333.

Anad A.M., Al-Jiboori, M.H., Hassoon, H.A., 2019. Simulation effect of stability classes on SO_2 concentration in dura refinery and neighboring regions. Mustansiriyah Journal of Science, 30(3), 1–8.

Anad, A.M., Hassoon, A.F., Al-Jiboori, M.H., 2022. Assessment of air pollution around Durra Refinery (Baghdad) from emission NO_2 Gas at April month. Baghdad Science Journal, 19(3), 515-527.

Bergman, T.L., Incropera, F.P., DeWitt, D.P., Lavine, A.S., 2011. Fundamentals of heat and mass transfer. John Wiley & Sons.

Castellví, F., Medina, E.T., Cavero, J., 2020. Surface eddy fluxes and friction velocity estimates taking measurements at the canopy top. Agricultural Water Management, 241, 106358.

Chapman, H., 2017. Performance Test of the Pasquill Stability Classification Scheme. MSc. Thesis, University of Wisconsin-Milwaukee.

Czernecki, B., Półrolniczak, M., Kolendowicz, L., Marosz, M., Kendzierski, S., Pilguj, N., 2017. Influence of the atmospheric conditions on PM10 concentrations in Poznań, Poland. Journal of Atmospheric Chemistry, 74, 115–139.

Dolske, D.A., 1995. Deposition of atmospheric pollutants to monuments, statues, and buildings. Science of the total environment, 167, 15–31.

Fang, G.C., Yang, I.L., Liu, C.K., 2010. Estimation of atmospheric particulates and dry deposition particulate-bound mercury Hg (p) in Sha-Lu, Taiwan. Aerosol and Air Quality Research, 10, 403–413.

Giardina, M., Donateo, A., Buffa, P., Contini, D., Cervone, A., Lombardo, C., Rocchi, F., 2019. Atmospheric dry deposition processes of particles on urban and suburban surfaces: Modelling and validation works. Atmospheric Environment, 214, 116857.

Hamiza, A., Hassoon, A.F., Shubbar, R.M., 2021. Evaluation of air pollution dispersion in al-daura refinery after used desulfurization techniques. Iraqi Geological Journal, 54, 43–56.

Hassoon, A.F., Tawfiq, M.K., 2019. Determined Abu-Khov Length Over Baghdad City. Journal of Engineering and Sustainable Development, 23(3), 99-113. DOI:10.31272/jeasd.23.3.8

Jacob, D.J., 1999. Introduction to atmospheric chemistry. In: Introduction to Atmospheric Chemistry. Princeton University Press: p.

Mohan, M.S., 2016. An overview of particulate dry deposition: measuring methods, deposition velocity and controlling factors. International journal of environmental science and technology, 13, 387–402.

Martínez, D.S., 2019. Effects of Atmospheric Stability Conditions on the Pollutants Dispersion Near Roads Using CFD. MSc. Thesis, Instituto Tecnológico y de Estudios Superiores de Monterrey.

Mohan, M., Siddiqui, T.A., 1998. Analysis of various schemes for the estimation of atmospheric stability classification. Atmospheric Environment, 32, 3775–3781.

Mrokowska, M.M., Rowiński, P.M., Kalinowska, M.B. 2015. Evaluation of friction velocity in unsteady flow experiments. Journal of Hydraulic Research, 53, 659–669. https://doi.org/10.1080/00221686.2015.1072853

Saad Hassan, H., 2012. Empirical relation to estimate particle deposition velocity over Baghdad City. MSc. thesis, College of Science Al-Mustansiriya University.

Shubbar, R.M., Lee, D.I., Gzar, H.A., Rood, A.S., 2019. Modeling air dispersion of pollutants emitted from the Daura Oil Refinery, Baghdad-Iraq using the CALPUFF modeling system. Journal of Environmental Informatics Letters, 2, 28–39.

Szep, R., Keresztes, R., Deak, G., Toba, F., Ghimpusan, M., 2016. The dry deposition of the PM10 and PM2. 5 to the vegetation and its health effect in the ciuc basin. Revista de Chimie, 67, 639–644.