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# Letters to the Editor

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## MIXING HEIGHTS, WIND SPEEDS AND VENTILATION COEFFICIENTS AT SOME SITES IN EGYPT

1. The use of mixing height which measure the height to which air pollutants will mix in the atmosphere was developed by Holzworth (1962). The monthly mean maximum mixing height was maped by Holzworth (1964) for the contiguous United States. For calculating the morning mixing height, a method was presented by Holzworth (1967). From the meteorological points of view, the ventilation coefficient, which is the product of mixing height and mean wind speed through the mixing layer, can be taken as the resultant of both vertical and horizontal mixing of pollutants, Vittal Murty *et al.* (1980) have estimated the monthly mean afternoon and early morning mixing heights for eleven radiosonde stations in India. The morning and afternoon ventilation coefficients have been also estimated.

The present study is based on data at three radiosonde stations Matruh (Lat. 31° 20′ N, Long. 27° 13′ E, and altitude of 25 m), Helwan (Lat. 29°52′ N, Long. 31° 20′ E, and altitude of 139.3 m) and Aswan (Lat. 23° 58′ N, Long. 32° 47′ E, and altitude of 191.1 m) in Egypt. Monthly means of mixing heights, average wind speeds through the mixing layer and the ventilation coefficients were calculated and discussed. Daily values of the radiosonde ascent at 00 GMT (02 LST) and 12 GMT (14 LST) for the period (1976-1979), obtained from the Meteorological Authority of Egypt have been used. The mixing height was obtained directly from the temperature profiles according to Wuerch *et al.* (1972). This method will be mentioned here as direct method. The mixing height was calculated also using Holzworth (1972) method which will be nominated here as ZH method.

2.1. *Mixing height* — In Table 1, it is seen that the ratios of morning monthly mean mixing heights of the direct method and the ZH method are mostly higher than one. The standard deviation of morning mixing heights estimated by the direct method is larger than that estimated by the ZH method, indicating a comparatively larger amount of day to day variation of the mixing heights estimated by the direct method. A possible explanation for this is due to the fact that the procedure of ZH method ignores the details of thermal structure of the mixing layer.

At afternoon, Table 2 shows the same parameters for the three sites. For Helwan and Aswan (inland sites) the ratios of mixing heights of the direct method and ZH method are mostly less than one, while for Matruh (coastal site) is mostly greater than one. The standard deviation of the mixing heights estimated by the direct method is larger than that estimated by ZH method except for April at Matruh and Helwan, and through the period from April to October at Aswan. This may be due to the larger variations of the daily maximum surface temperature in that period. From the above comparisons it can be seen that it is desirable to use the direct method in the case of available morning and around mid-day radiosonde data. For this reason, data of Tables 1 and 2 for the monthly mean mixing height calculated by the direct method was represented in Fig. 1(a). From the figure it can be seen that the afternoon mixing heights are the highest in May for inland stations (Helwan and Aswan). This may be due to the effect of the heat waves which characterise this month. At Matruh (coastal station) the maximum value is observed in November and this is due to the effect of the Mediterranean secondary depressions in winter season. The lowest mixing height at Helwan and Aswan are in December and January respectively. This may be due to the percentage frequency of the inversions in the lower troposphere is higher in winter (Table 3). Generally, afternoon mixing height increases from the north to south of Egypt, especially in May.

The morning mixing heights are highest in November at Matruh and Helwan, and in August at Aswan. The lowest value was in May for both Matruh and Helwan, and in December at Aswan.

The range (difference between the afternoon and morning mixing heights) has been found to be well marked [Fig. 1(a)] where it is a maximum in May at Helwan and Aswan, and a minimum in December and January for both Helwan and Aswan respectively. However, for Matruh the range is a maximum in February and a minimum in July. From Table 3, it may be seen that occurrence of ground based inversions is very high at 00 GMT all over the year, except in May at Aswan. This shows the effect of the ground based inversions on the mixing layer at Aswan during morning. Generally, the effect of the ground based inversions during morning on the mixing height is not clear at both Matruh and Helwan in winter, and this may be due to the attack of the secondary depressions from time to time.

2.2. *Wind speed* — Average wind speeds through morning and afternoon mixing heights (thereafter referred to as wind speeds) are shown in Fig. 1(b). Like mixing heights, wind speeds are greater in afternoon than in the morning, except at Helwan in August, this is due to a locality reasons. The annual variations in the morning curve is similar to that in the afternoon, at

**TABLE 1**

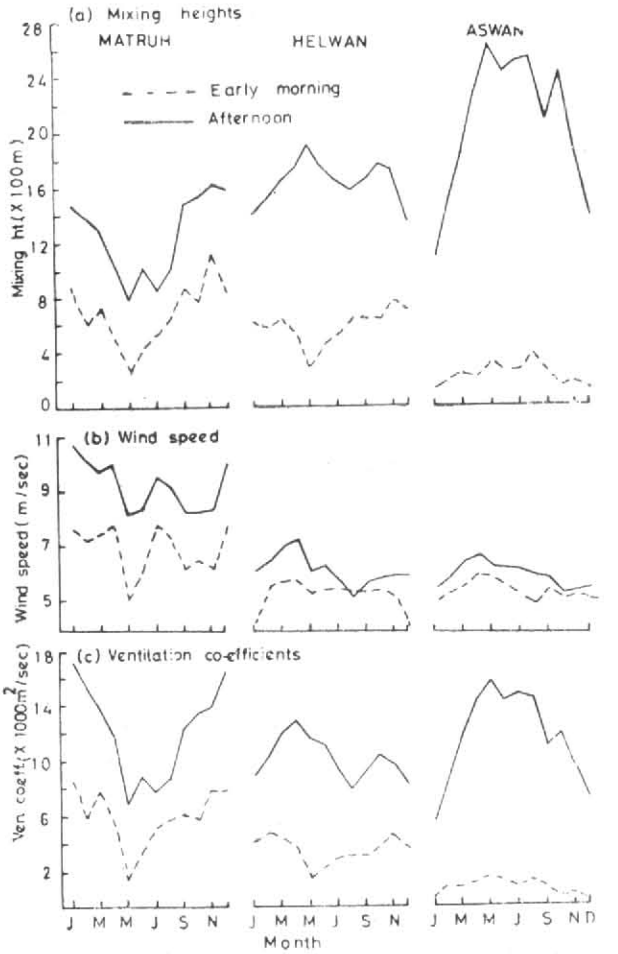
**Comparison of early morning (minimum) monthly mean mixing heights for the period 1976-1979 at Matruh, Helwan and Aswan stations in Egypt**

| Month | Matruh | | | | | Helwan | | | | | Aswan | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Direct method | | ZH method | | Ratio of Ht. | Direct method | | ZH method | | Ratio of Ht. | Direct method | | ZH method | | Ratio of Ht. |
| | Ht. (m) | Std. Dev. (m) | Ht. (m) | Std. Dev. (m) | | Ht. (m) | Std. Dev. (m) | Ht. (m) | Std. Dev. (m) | | Ht. (m) | Std. Dev. (m) | Ht. (m) | Std. Dev. (m) | |
| Jan | 864 | 979 | 439 | 547 | 1.97 | 614 | 812 | 349 | 239 | 1.76 | 133 | 167 | 139 | 168 | 0.96 |
| Feb | 622 | 571 | 465 | 511 | 1.34 | 576 | 748 | 405 | 397 | 1.42 | 204 | 362 | 143 | 142 | 1.43 |
| Mar | 740 | 804 | 547 | 510 | 1.35 | 635 | 768 | 459 | 355 | 1.38 | 216 | 392 | 166 | 230 | 1.30 |
| Apr | 504 | 671 | 562 | 577 | 0.90 | 518 | 731 | 454 | 380 | 1.14 | 208 | 424 | 159 | 191 | 1.31 |
| May | 269 | 296 | 396 | 331 | 0.68 | 296 | 413 | 350 | 247 | 0.84 | 315 | 613 | 313 | 324 | 1.01 |
| Jun | 457 | 578 | 416 | 393 | 1.10 | 441 | 519 | 497 | 318 | 0.89 | 249 | 552 | 167 | 114 | 1.49 |
| Jul | 553 | 648 | 510 | 410 | 1.08 | 527 | 629 | 460 | 234 | 1.14 | 271 | 584 | 236 | 218 | 1.15 |
| Aug | 665 | 637 | 589 | 417 | 1.13 | 646 | 632 | 535 | 260 | 1.21 | 376 | 773 | 221 | 143 | 1.70 |
| Sep | 877 | 844 | 696 | 542 | 1.26 | 638 | 589 | 524 | 303 | 1.22 | 250 | 505 | 174 | 116 | 1.44 |
| Oct | 776 | 746 | 616 | 566 | 1.26 | 636 | 704 | 427 | 453 | 1.49 | 145 | 317 | 135 | 90 | 1.07 |
| Nov | 1124 | 958 | 611 | 575 | 1.84 | 773 | 854 | 466 | 419 | 1.66 | 177 | 353 | 144 | 102 | 1.23 |
| Dec | 838 | 866 | 526 | 540 | 1.59 | 701 | 817 | 396 | 343 | 1.77 | 128 | 220 | 128 | 72 | 1.00 |

**TABLE 2**

**Comparison of afternoon (maximum) monthly mean mixing heights for the period 1976-1979 at Matruh, Helwan and Aswan stations in Egypt**

| Month | Matruh | | | | | Helwan | | | | | Aswan | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Direct method | | ZH method | | Ratio of Ht. | Direct method | | ZH method | | Ratio of Ht. | Direct method | | ZH method | | Ratio of Ht. |
| | Ht. (m) | Std. Dev. (m) | Ht. (m) | Std. Dev. (m) | | Ht. (m) | Std. Dev. (m) | Ht. (m) | Std. Dev. (m) | | Ht. (m) | Std. Dev. (m) | Ht. (m) | Std. Dev. (m) | |
| Jan | 1493 | 834 | 1345 | 613 | 1.11 | 1407 | 725 | 1451 | 440 | 0.97 | 1083 | 561 | 1239 | 347 | 0.87 |
| Feb | 1404 | 830 | 1284 | 600 | 1.09 | 1520 | 704 | 1574 | 549 | 0.95 | 1505 | 763 | 1673 | 627 | 0.90 |
| Mar | 1309 | 860 | 1218 | 653 | 1.07 | 1642 | 801 | 1870 | 650 | 0.88 | 1831 | 794 | 2014 | 727 | 0.91 |
| Apr | 1049 | 953 | 1257 | 977 | 0.83 | 1735 | 857 | 2045 | 1182 | 0.85 | 2280 | 817 | 2757 | 1224 | 0.83 |
| May | 786 | 928 | 970 | 775 | 0.81 | 1900 | 960 | 1989 | 936 | 0.96 | 2619 | 689 | 3406 | 1144 | 0.77 |
| Jun | 1015 | 1127 | 942 | 850 | 1.08 | 1742 | 942 | 1949 | 695 | 0.89 | 2417 | 726 | 3390 | 1346 | 0.71 |
| Jul | 863 | 896 | 833 | 399 | 1.04 | 1644 | 800 | 1821 | 476 | 0.90 | 2498 | 599 | 3099 | 1027 | 0.81 |
| Aug | 1025 | 857 | 968 | 404 | 1.06 | 1584 | 677 | 1720 | 461 | 0.92 | 2514 | 540 | 2949 | 887 | 0.85 |
| Sep | 1484 | 1037 | 1230 | 685 | 1.21 | 1667 | 830 | 1694 | 489 | 0.98 | 2075 | 853 | 2480 | 1152 | 0.84 |
| Oct | 1525 | 1008 | 1186 | 607 | 1.28 | 1759 | 808 | 1685 | 642 | 1.04 | 2412 | 828 | 2930 | 1287 | 0.82 |
| Nov | 1628 | 868 | 1336 | 580 | 1.21 | 1709 | 802 | 1632 | 595 | 1.05 | 1848 | 811 | 1750 | 698 | 1.06 |
| Dec | 1591 | 781 | 1320 | 572 | 1.20 | 1358 | 659 | 1418 | 530 | 0.96 | 1368 | 660 | 1237 | 355 | 1.10 |




Figs. 1 (a-c). Monthly mean : (a) mixing height, (b) values of the average wind speed through the mixing layer, and (c) ventilation coefficients

all sites, except at Helwan in the period from July to December [Fig. 1(b)]. At Aswan, the difference between afternoon and morning wind speeds is smaller than at both Matruh and Helwan, except from July through September at Helwan.

2.3. *Ventilation coefficient* — Fig. 1(c) shows the variation of ventilation coefficients from month to month. The afternoon ventilation coefficient at Matruh is maximum in January and minimum in May. For Helwan the maximum value occurs in April and the minimum value in August. At Aswan, it is increased rapidly from lowest value in January to maximum value in May. The morning ventilation coefficient for Matruh is minimum in May and maximum in January. For Helwan, it has a maximum value in February and a minimum value in May. At Aswan, irregularity between lower value in December and higher value in May was found. The range is maximum in February at Matruh, this is mainly due to the association of larger mixing heights with higher wind speeds. For both Helwan and Aswan the range is maximum in May. The minimum range is observed in July at Matruh, in December at Helwan, and in January at Aswan.

TABLE 3

**Relative frequency of ground based inversions (F. Inv.) at time 00 and 12 GMT for the period 1976-1979 at Matruh, Helwan and Aswan stations in Egypt**

| Month | Matruh F. Inv. | | Helwan F. Inv. | | Aswan F. Inv. | |
|---|---|---|---|---|---|---|
| | 00 GMT | 12 GMT | 00 GMT | 12 GMT | 00 GMT | 12 GMT |
| Jan | 0.44 | 0.03 | 0.38 | 0.01 | 0.94 | 0.00 |
| Feb | 0.44 | 0.04 | 0.41 | 0.02 | 0.85 | 0.01 |
| Mar | 0.30 | 0.05 | 0.25 | 0.02 | 0.84 | 0.00 |
| Apr | 0.33 | 0.11 | 0.37 | 0.03 | 0.82 | 0.01 |
| May | 0.32 | 0.05 | 0.46 | 0.02 | 0.58 | 0.00 |
| Jun | 0.32 | 0.05 | 0.24 | 0.04 | 0.78 | 0.00 |
| Jul | 0.18 | 0.07 | 0.16 | 0.03 | 0.77 | 0.00 |
| Aug | 0.12 | 0.02 | 0.09 | 0.01 | 0.75 | 0.00 |
| Sep | 0.19 | 0.00 | 0.20 | 0.03 | 0.78 | 0.00 |
| Oct | 0.22 | 0.01 | 0.28 | 0.04 | 0.88 | 0.01 |
| Nov | 0.30 | 0.02 | 0.31 | 0.01 | 0.89 | 0.00 |
| Dec | 0.32 | 0.02 | 0.35 | 0.01 | 0.98 | 0.00 |

3. *Conclusions* — In concluding the above discussions the present study is considered as the first work for calculating the mixing heights, wind speeds, and ventilation coefficients at the selected sites in Egypt. From the analysis of the mixing heights, it is concluded that Matruh and Helwan regions are pollution prone areas in May during early morning. Aswan region can have high pollution potential during early morning and low pollution potential at afternoon all over the year. The wind speeds have a pronounced effect on the ventilation coefficient especially in winter and autumn, at Matruh region. The analysis of the ventilation coefficients indicate that meteorological conditions during afternoon are most favourable for rapid dispersion of pollutants in winter and autumn over Matruh region, in both April and October over Helwan, and in May over Aswan. Finally this conclusions can be taken as a base of the planning of the emission schedule at Matruh, Helwan and Aswan regions in Egypt.

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