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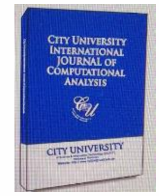

Correlation along with scaling behavior of particulate matter, prevailing high in Pakistan, India, and China

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A B S T R A C T

Due to unchecked anthropogenic activities coupled with growing competition for industrialization, the quantity of particulate matter is growing hard. Global surveys describing the air quality and other environmental parameters have shown great concern due to the particulate matter over the states of various countries more specifically Pakistan, India, and China. It is significantly concluded that the concentration of fine particulate matter is on an increasing track. However, the involvement of maximum anthropogenic activities has accelerated it to great extent. Among Pakistan, India, and China, China is showing the highest concentration of fine particulate matter and the major reason behind this phenomenon is the great development of industries and countless running vehicles on the road. Therefore, our study has provided a clear depiction of alarming threats along with their positive as well as negative correlations that are supportive of developing policies to control the situation and devise environment-friendly measures.

1 Introduction

Particulate matter also known as aerosols is the most rudimentary attribute atmosphere. According to a report it has been observed that particulate matter plays a controlling role in the visibility index as well as the nature of precipitation. Furthermore, it has been reported that particulate matter implies a critical impact on the health of common people along with the overall climate conditions of any state [1-4]. Due to unchecked anthropogenic activities coupled with growing competition for industrialization, the quantity of particulate matter is growing hard. Global surveys describing the air quality and other environmental parameters have shown great concern due to the particulate matter over the states of various countries more specifically Pakistan, India, and China [5-8]. In the present era, all the subject matter countries including Pakistan, India, and China have shown tremendous success in the field of industrialization and revolutionary progress in developing new cities.

Particulate matter exists in different sizes depending upon the size and other properties related to it. However, it has been reported that the finest size particulate matter whose size is less than 2.5 μm is the most trouble-causing particle [9-12] Thus, fine matriculate matter due to ever-increasing concentration in Pakistan, India, and China has become the most alarming threat in the present era. However, every researcher who has highlighted this awful threat has involved the data of one city, or state [1-4]. Contrary to this, none of the literature is helpful for explaining the correlation among the particulate matter of various states such as Pakistan, India, and China.

Many researchers have explained the physic-chemical properties of particulate matter of various sizes. Similarly, some researchers have depicted the distribution as well as the available concentration of particulate matter in the atmosphere in various states [5-8, 13, 14]. Following the same footsteps others have explained the varying concentration of particulate matter due to changes or variations in the prevailing climate or season [9-11, 15]. In addition, some researchers have observed the chronological variation in the concentration of particulate matter over the various sites. Likewise, some researchers have included particulate matter as the critical component for clearing and describing the air quality of some specific sites [1-4]. Furthermore, it was also observed that the concentration of particulate matter remains varying with the variation in the site, time, depth, and many other factors.

Therefore, keeping in view the above-mentioned facts and present scenario it is an obligatory aspect to find out the correlation in the particulate matter of various states rather than cities of some specific country. Various theories such as component analysis as well as complex network theory are significantly being used in the current era to analyse as well as enlighten the atmospheric properties of some specific regions [5-8, 13, 14]. However, the research gap that no one has put the spotlight on to describe the correlation, in particular neighboring various neighboring countries is an important aspect that is being highlighted through this study.

2 Research Methodology

For the data management, we used the data given by the "The Ministry of Environmental Protection of Pakistan", "The Ministry of Environmental Protection of India" and "The Ministry of Environmental Protection of China". Furthermore, we took the data for the years 2016 and 2017 explaining the hourly concentration of fine particulate matter. For this purpose, 1234 sites were selected from the three countries including Pakistan, India, and China. As the prevailing seasonal condition in selected countries is divided into 4 including winter, spring, summer, and autumn, we arranged the data according to this aspect.

For the representation of the time variation, we declared it as "T" while the concerned site (suppose i) we represented it as $X_i(T)$. Here X represents the sequence of series from 1, 2, and so on. However, for consideration of the average, it was considered as "$T=1$ $X_i(T)$, there is a fluctuation series $\delta X_i(T) = X_i(T) - X_i$". Furthermore, for declaring site 1 as the i and last site as the j, for the calculation of the cross-correlation as:

$$C_{ij}(\tau) = \frac{\delta X_i(t) \bullet -\delta X_i(t+\tau)}{\sqrt{(\delta X_i(t))^2 \bullet (\delta X_i(t+\tau))^2}}$$

Here "τ" represents the "time lag", moreover, on the basis of chronological sequences, a relation of "$C_{ij}(-\tau) = C_{ij}(\tau)$" can be developed. Furthermore, for the calculation of cross correlation on the basis of time duration "$(-t_{\max}, t_{\max})$" we have used the relationship as "$C_{ij}(t \geq 0)$ along with "$C_{ij}(\tau \geq 0)$". In addition to this, the estimation of the largest absolute value for the "$C_{ij}(\tau)$" as well as time duration for τ^*ij are used for developing the correlation "i" among various sites (such as i and j). However, here "i" represents the starting point or the first site while "j" as the last site having relation $\tau^*ij > 0$ while the reverse will be obtained for reversing the direction.

Additionally, with the help of the probability distribution function also known as "$\rho(C)$", we represented the number of nodes as the "N" while their correlation was calculated as $\frac{(N-1)N}{2}$. Similarly, following the theory of network to remove the barrier of noise from the development of exact correlation of fine particulate matter, a new correlation, named threshold correlation "Δ" was used. Thus, for the calculation of the adjacent matrix in the selected network along with the threshold following function was used:

$$A_{ij} = \begin{Bmatrix} 1-\delta_{ij}, & |C_{ij}| > \Delta, \\ 0-\delta_{ij}, & |C_{ij}| \leq \Delta, \end{Bmatrix}.$$

Here, Kronecker's delta $\delta_{ij} = 0$ while $i \neq j$.

Similarly, degree $K_i^C = \sum_{j=1}^{N} A_{ij}$ was being used for the calculation of the importance of the various sites (such as i).

Furthermore, the weighted degree was also used for the calculation of the details of the degree. Thus, the following function was used for the calculation of the weighted degree:

$$K_i^C = \sum_{j=1}^{N} A_{ij} |C_{ij}|$$

3 Results

Our results showed that the mean value of the fine particulate matter for four seasons in Pakistan (winter = 65.1 μgm^{-3}, spring = 38.7 μgm^{-3}, summer = 24.9 μgm^{-3} and autumn = 26.2 μgm^{-3}), India (winter = 70.1 μgm^{-3}, spring = 42.7 μgm^{-3}, summer = 29.9 μgm^{-3} and autumn = 31.2 μgm^{-3}) and China (winter = 76.7 μgm^{-3}, spring = 48.2 μgm^{-3}, summer = 38.2 μgm^{-3} and autumn = 48.2 μgm^{-3}). The major reason behind the highest mean value of fine particulate matter in China followed by India and Pakistan is the increased industrialization as well as the numerous quantities of vehicles on the road. Furthermore, among the four seasons maximum concentration of fine particulate matter was observed during the winter due to extensive use of fuel and other warming material coupled with the supportive climatic conditions for the distribution of fine particulate matter. Mean values of the fine particulate matters are mentioned below in the following figures 1, 2, and 3.

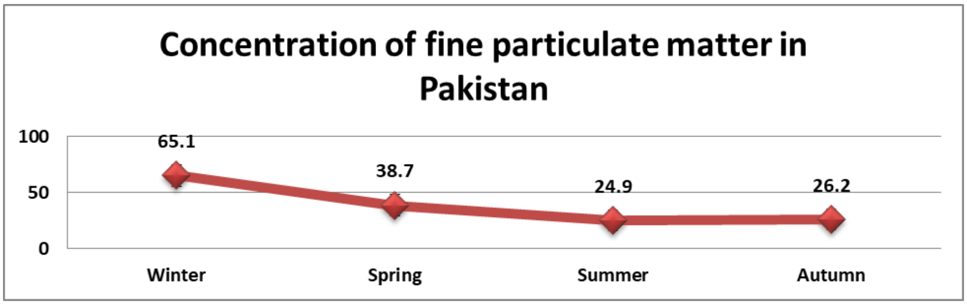

Fig: 1. Concentration of fine particulate matter in Pakistan

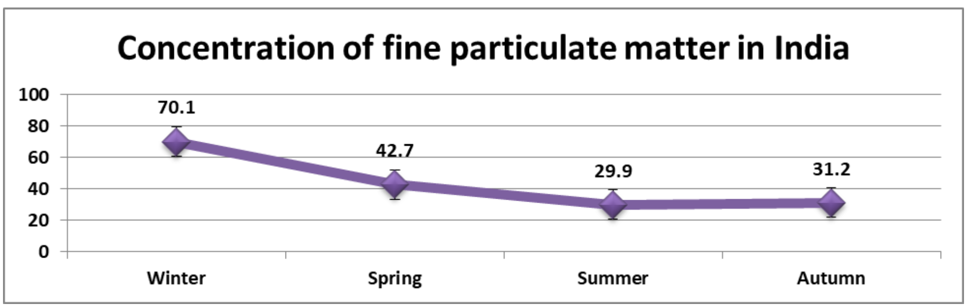

Fig: 2. Concentration of fine particulate matter in Pakistan

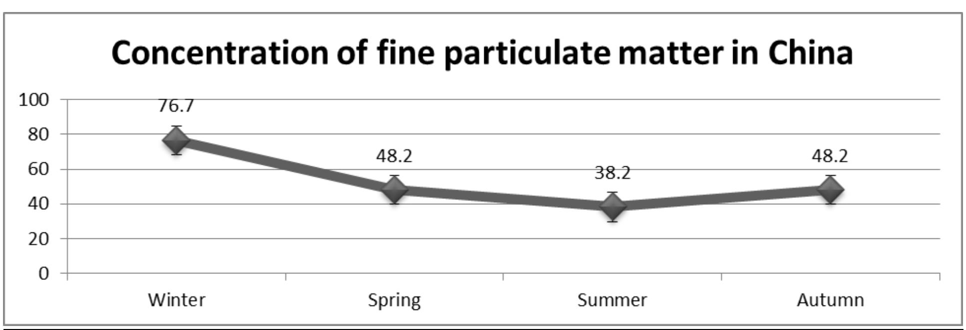

Fig: 3. Concentration of fine particulate matter in Pakistan

Similarly, with the above-mentioned formulae we calculated the positive as well as negative correlation among the fine particulate matter of Pakistan, India, and China. Results depicted that a positive correlation among the various seasons in Pakistan was observed as winter (88%) > autumn (77%) > spring (71%) > summer (48%), in India as winter (91%) > autumn (80%) > spring (74%) > summer (51%) and in China as winter (98%) > autumn (87%) > spring (81%) > summer (58%). Details of the positive correlation among the fine particulate matter of Pakistan, India, and China are clear from the following graphs:

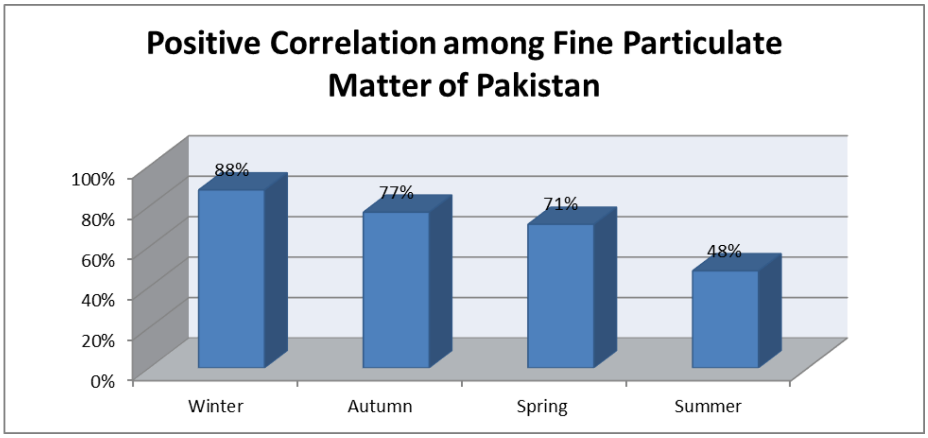

Fig: 4. Positive Correlation among Fine Particulate Matter of Pakistan

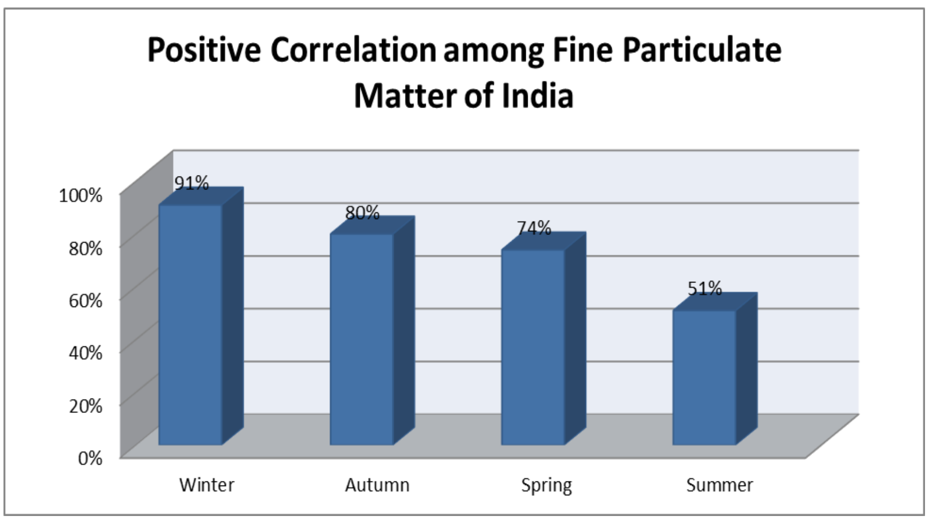

Fig: 5. Positive Correlation among Fine Particulate Matter of India

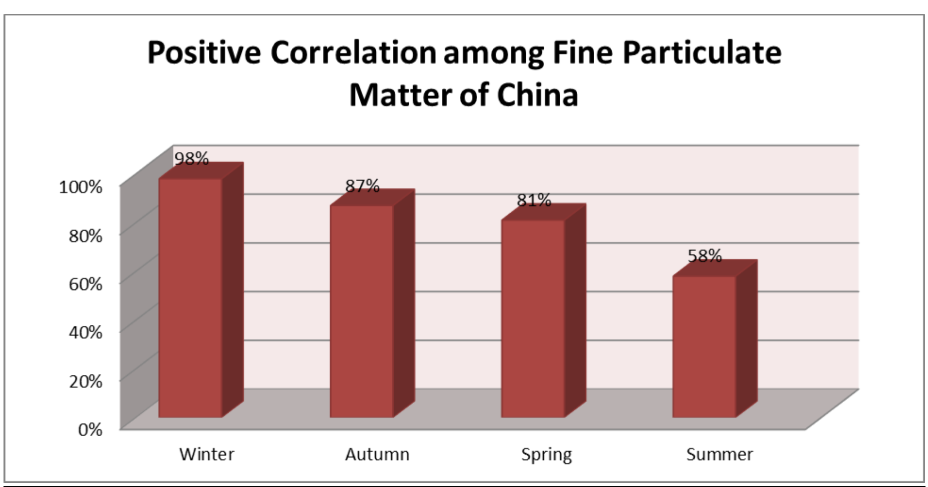

Fig: 6. Positive Correlation among Fine Particulate Matter of China

Similarly, negative correlations was also calculated as in Pakistan it was observed as summer (41%) > spring (19%) > autumn (13%) > winter (2%), in India as summer (43%) > spring (21%) > autumn (15%) > winter (4%) and in China as summer (47%) > spring (25%) > autumn (19%) > winter (8%). Details of the negative correlation among the fine particulate matter of Pakistan, India, and China are clear from the following graphs:

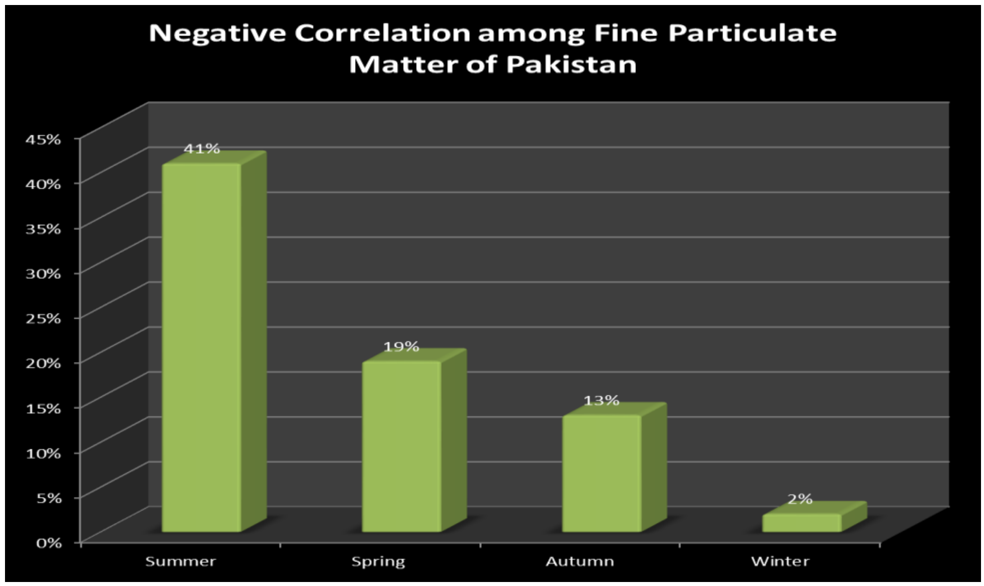

Fig: 7. Negative Correlation among Fine Particulate Matter of Pakistan

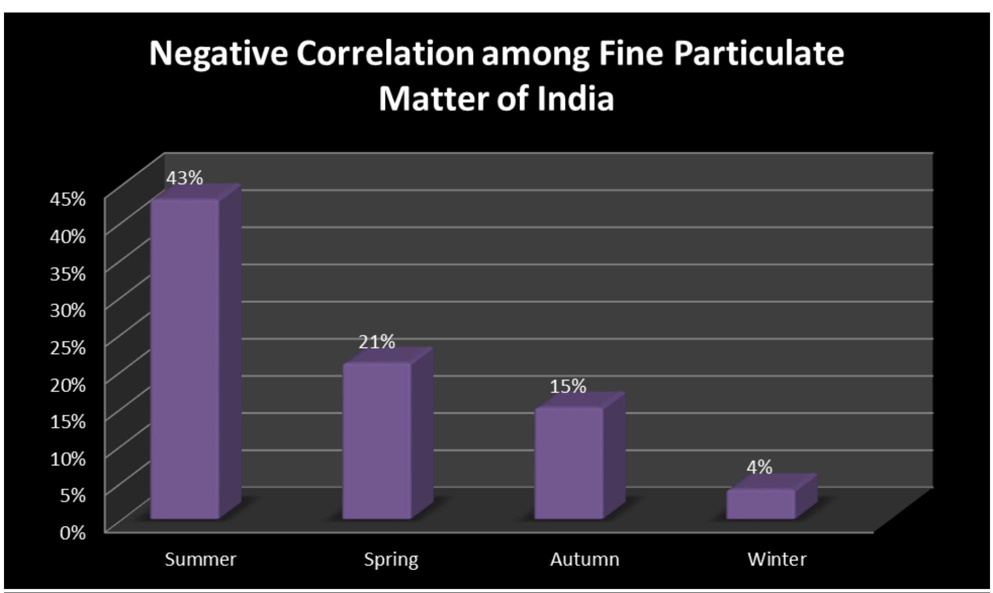

Fig: 8. Negative Correlation among Fine Particulate Matter of India

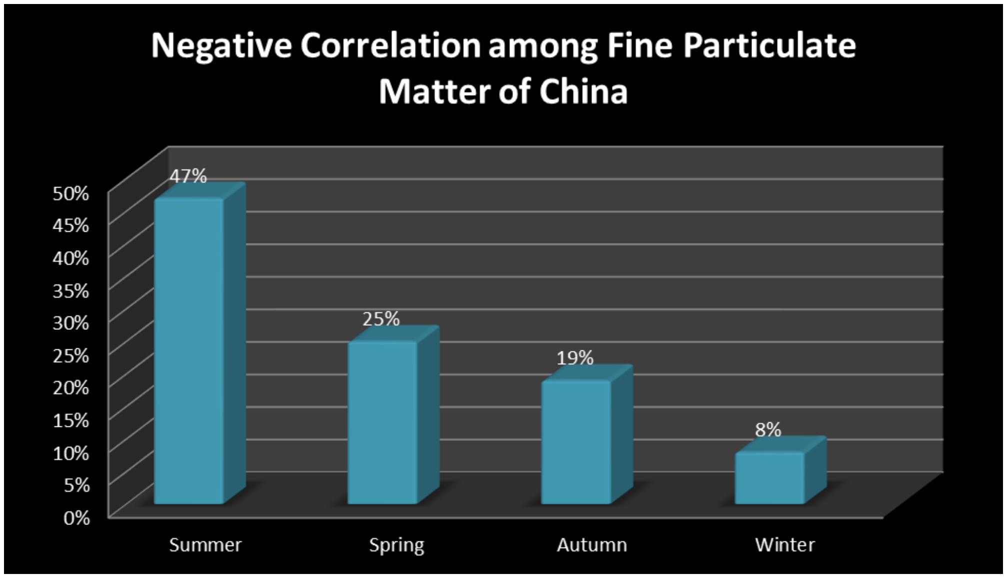

Fig: 9. Negative Correlation among Fine Particulate Matter of China

4 Conclusion

It is significantly concluded that concentration of fine particulate matter is on increasing track. However, involvement of maximum anthropogenic activities has accelerated it up to great extent. Among Pakistan, India, and China, China is showing the highest concentration of fine particulate matter and the major reason behind this phenomenon is the great development of industries and countless running vehicles on the road. Therefore, our study have provided the clear depiction of alarming threat along with its positive as well as negative correlation that are supportive for developing the policies to control the situation and devise the environment friendly measures. For the solution of the fractional model, the new transformation is authentic. By applying this transformation it is easier to obtain the solution of the fractional model.

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