

# Particulate Triggers Spread of Covid-19, A Case Study of Industrial Clustered Region of Jharkhand, India

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### PARTICULATES TRIGGERS SPREAD OF COVID-19, JHARKHAND, INDIA

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## ABSTRACT

SARS-CoV-2 named as COVID-19 in talking terms, was first reported in the sea-food market of Wuhan township in China in Dec., 2019. Since then, SARS-CoV-2 has caused panic around the world and has been declared pandemic by WHO on March 11, 2020. The disease took the form of an epidemic in beginning 2020 causing widespread loss of lives and economic slowdown in the form of lockdowns with sudden burst still being reported. The root cause of the disease transmission was assigned to human-to-human contact. Later on, as investigations progressed around the world, the aerosol transmission was reported by many authors. Similar investigation was studied in seven most densely populated district of Jharkhand, India for nearly one month from November 4 to December 4, 2020. The statistical analysis of the data of PM<sub>10</sub>, PM<sub>2.5</sub> and percent Covid cases by state authorities clearly established positive relationships in five of the seven districts with negative relationship in two districts at insignificant levels. Dhanbad, Ranchi, Bokaro, Deoghar, Chaibasa showed positive while Jamshedpur and Hazaribagh showed negative Pearson correlation. One-way ANOVA tests indicated that the P-value is less than the significance level of 0.05. In all the cases, the F value crossed the critical value (F crit) rejecting null hypothesis. Thus, the sample data provide strong enough evidence to conclude that there is relationship between the dust concentration to percent Covid cases occurring at a site with particulate characteristics supporting the cause.



Keywords: Corona virus; Dhanbad; Jharia Coal Field; Particulate matter; SARS-CoV-2

#### I. Introduction

Coronaviruses is a newly discovered strain of SARS-CoV-2 commonly referred as COVID-19. It causes respiratory disorder and has taken a pandemic dimension with reported deaths crossing 2,850,521 and infected more than 131,020,967 around the world. <sup>1</sup> The pandemic is likely to cause more deaths with increased intensity as being seen now. Moreover, Scientists across the world have formulated vaccine to cure the disease. Some vaccine has recently been permitted and is progressing around the globe. Partial success has been observed in many countries. Still, there is sharp upsurge of covid cases in some parts of the world and even in some states of

India. One of the major identified causes are the atmospheric air pollutants which is recently been endorsed by WHO. The present study refers to identify such precursors and their impacts on COVID-19 cases.

#### II. Study site

For identifying the impacts for the contribution of air pollutants, we have selected seven densely populated and Industrial agglomerated cities of Jharkhand dominated by mining industry particularly coal. Out of these, Jharia coalfields (JCF) located in the Dhanbad district is top-most polluted city in India (2019). The newly identified coronavirus, has caused a worldwide pandemic called COVID-19.





#### Corona virus

Coronaviruses belong to a large group of viruses encircled with positive, single stranded RNA. Its classification is as follows:

Order- Nidovirales Family- Coronaviridae Subfamily- Coronavirinae

Twenty-six species are known in this group and have been divided into four genera- Alpha, Beta, Gamma and Delta. Till now alpha and beta strains are pathogenic to humans.<sup>2</sup>

#### Morphology, structure and replication

Coronaviruses is given this name because of crown (solar like) appearance. This appearance is attributed to spike peplomers of the glycoprotein emerging from lipid envelope. <sup>3</sup> There are two major proteins envelopes with a third glycoprotein called haemagglutinin-esterase (HE). The antigen that helps in receptor binding and cell fusion is S-glycoprotein <sup>4</sup> and transmembrane glycoprotein which is responsible for budding, crown formation and virion assembly. <sup>5</sup>

Coronaviruses are highly mutable to new hosts by recombinant technology of its single stranded genetic material. RNA-dependent RNA polymerase (RdRp) facilitates replication of the viral gene. Point to point mutation with other Coronavirus strain is very much reported with inherent error of 1,000,000 per mutation/site/replication of RNA-dependent RNA polymerase.



Fig. 2. Molecular architecture of the SARS-CoV-2 Virus<sup>6</sup>

#### Epidemiology, morbidity and mortality

Corona virus causes inflammation and burning in the upper region of respiratory tract along with similar viruses such as respiratory syncytial virus (RSV), parainfluenza, influenza and rhinoviruses. <sup>3</sup> The symptoms resemble those of common cold and Pneumonia. More than 15-30% all the common cold cases are caused by Coronaviruses. Gastroenteritis, body ache, dizziness, anxiety, fever, common ailments of cold and cough such as sneezing, oozing nose, head ache are the other symptoms Coronaviruses. They can also cause complex diseases in other animals too. <sup>7,8</sup>

#### Facts about 2019-nCoV

At the end of 2019, a new coronavirus was detected in Wuhan sea-food market of China commonly referred as novel corona virus. It was identified as a strain of beta coronavirus with sub-genous sarbecovirus having genomic similarity with SARS-CoVupto 80%.<sup>9-11</sup> Many more strains are being reported with more lethal affect being highly mutable such as British, Brazil and South African strains. Zoonotic transmission to bat and animals were initially known but later human to human transmission was also traced with an incubation period of 2-14 days. The observed symptoms are respiratory illness including cold and cough, mild fever, dyspnoea. Proof have been reported for the imperviousness in the two-pronged ground glass in the CT scan of the Chest. <sup>12</sup> Acute respiratory distress was seen in patients with severe illnesses requiring oxygen in ICU care.

The virus may pose lower threat to the individuals, but have a significant risk at the population level if transmitted easily. Asymptomatic patients are a global alarm. Given its pandemic potential, careful surveillance of nCoV is critical to monitor its future host adaption, viral evolution, infectivity, transmissibility and pathogenicity.<sup>11</sup>

#### Prevention

The Countries around the world are doing vaccination on a war footing to check the menace of Covid 19. But looking at the sudden upsurge of Covid 19 in some parts of the world, some Governments are enforcing stricter norms against nCoV with monetary charge and others. Therefore, physical means like isolation and quarantine are still enforced at the community levels to control the epidemics and Covid infections. <sup>3,13</sup> Asymptomatic patients with 2-14 (mean 4 days) days of incubation are the most potential risks in the case of SARS <sup>14</sup> and from 2-15 days in the case of MERS. <sup>14</sup> Centre for Disease Control and Prevention (CDC) recommends use of airborne infection isolation procedures in the care of all confirmed MERS infections in that country. <sup>16</sup>

#### Materials and methods

The values (Avg. of 24 hr) of  $PM_{2.5}$  and  $PM_{10}$  were collected through the online beta system of <u>www.accuweather.com</u><sup>17</sup>. The no. of covid cases during the period was collected through beta system of https://www.bing.com/covid/local/jharkhand\_india. <sup>18</sup> Sample size of the period was the average of the estimated daily tests conducted available from the state agencies. The data marked as \* is the average of the available data approximated to the nearest decimal as no data was available on that date. No data was attributed on 17<sup>th</sup> and 22<sup>nd</sup> Nov.,2020 due to festive holidays in India (Ref. suppl. file, table 1-5).

#### **Results and discussion**

#### **PM**<sub>10</sub>

The values of  $PM_{10}$  (Fig 3) showed increasing trend from 4<sup>th</sup> Nov. to 4<sup>th</sup> Dec. except between 12-14<sup>th</sup> Nov. This can be attributed to the seasonal fluctuation with temperature and wind flow contributing the most. The top most polluting city contributing to the  $PM_{10}$  particulates is Hazaribagh and the lowest being Jamshedpur. The descending order is Hazaribagh> Chaibasa> Deoghar>Bokaro>Ranchi >Dhanbad >Jamshedpur. This pattern indicates the observed impact of wind flow and temperature.



Fig. 3. Values of  $PM_{10}$  (µgm<sup>-3</sup>) across the selected sites <sup>17</sup>



Fig. 4. Values of PM<sub>2.5</sub> (µg m<sup>-3</sup>) across the selected sites <sup>17</sup>

#### PM<sub>2.5</sub>

The values of PM2.5 (Fig.4) showed increasing trend from 4<sup>th</sup> Nov. to 4<sup>th</sup> Dec., 2020. There was decreasing trend between between 12-14th Nov., 2020. Temperature differential along with moisture and wind direction attributed to this cause. The top most polluting city contributing to the PM2.5 is Hazaribagh and the lowest being during Jamshedpur. The observed descending order the study period was Hazaribagh>Chaibasa>Deoghar>Bokaro>Ranchi>Dhanbad>Jamshedpur.Thescenario indicates seasonal gust with temperature, moisture and wind pattern playing the important role. It can be seen from the pattern of both the particulate sizes that the normal distribution trend amongst the selected sites remained almost the same during the monitoring period. There might be some fluctuation due to location of the sampling stations.

#### Covid cases (%) and particulate concentration

Except to metrological factors such as temperature, wind speed and direction, relative humidity whose affect is largely noticed on the emission and transport of dust particulates, the positive relationship is clearly observed between the dust concentration and covid cases (%) from 6<sup>th</sup> November onwards of the monitoring schedule (Fig 5). The relationship between particulate concentration and covid cases (%) is more explained by the statistical analysis. Lately many authors have advocated the role of air pollution in spread of Covid cases. Aerosol and surface contamination in quarantine centres was reported by Santarpia et al. (2020)<sup>20</sup> in Nebraska Medical Centre. Out of 13 samples collected, all the samples reported positive results of nCoV infection supporting the evidence that air particulates are a potential source of transmission of nCoV. Similar findings were reported by Liu et al. (2020)<sup>21</sup> in two Wuhan hospitals for SARS-CoV-2. The aerodynamic size analysis of RNA indicated that there was more concentrated occurrence on bathroom aerosol rather than isolation wards and patient rooms.

Setti et al. (2020)<sup>22</sup> reported similar findings on SARS-CoV-2. The studies reported by Harvard School of Public Health <sup>23</sup> also supported strong association between particulate concentration and the mortality rate due to Covid 19. Italian Society of Environmental Medicine <sup>24</sup> came to similar observation with Covid cases and particulate matter ( $PM_{10}$  and  $PM_{2.5}$ ) in Northern Italy with specific climatic conditions.



Fig. 5. Covid cases (%) (calculation based on no. of covid cases and sample size)

Anthropogenic activity has led to the increase in particulate concentration preferably <2.5 $\mu$  called fine particulates in the ambient atmosphere. The nano particulates (1 to 100 nanometres in size) are still more dangerous because of their surface area and penetrating ability deep into the lungs. Ample proofs indicate that the size of the most of the viruses including nCoV possesses great affinity to this size range inflaming the alveoli of the lungs disrupting O<sub>2</sub> exchange in the haemoglobin. The blood has 100 times more affinity to CO<sub>2</sub> rather than to O<sub>2</sub>. Thus, the concentration of carboxy haemoglobin increases in the blood causing fatigue and breathlessness and ultimately death. A sudden collapse in most of the Covid patients can be attributed to this cause. Interaction of the primary aerosol with other pollutants such as volatile organic compounds (VOC's), SO<sub>2</sub>, O<sub>3</sub>, NOx, CO, NH<sub>3</sub> along with toxic heavy metals such Hg, Cr, Cd, As, Pb etc. <sup>25</sup> and viruses forms secondary and tertiary compounds in the presence of moisture. These reactions are mostly temperature dependent as has been observed in most of the Covid epidemic centres around the world. An environmental genomics study <sup>26</sup> of the smog in Beijing, China indicated presence (0.1%) of numerous pathogens including viruses in PM<sub>10</sub> and PM<sub>2.5</sub> particulates (Fig 6). Their concentration in the particulates is directly proportional to the ambient pollution load and rise in the Covid cases of the region. Increased viral concentration causes severe inflammation in the lungs <sup>26</sup> leading to sudden collapse.



Fig 6. Percent representation of various organisms in PM<sub>10</sub> and PM<sub>2.5</sub> in the Bejing, China <sup>26</sup>

#### **Particle characteristics**

#### Absorption and adhesion

Viruses and other microber Viruses and other microbes get stick to the particles through their binding properties such as absorption and adhesion. Microbe-particle complex formation is reported by Wei et al., 2020.<sup>27</sup> These complexes were observed in H5N1 (avian influenza virus) <sup>28</sup>, RSV. <sup>26</sup> Bianconi et al. (2020) <sup>29</sup> related Covid cases and deaths to past exposure to aerosol particulates (PM<sub>10</sub> and PM<sub>2.5</sub>). Regression analysis depicted strong positive relationship between particulates (PM<sub>10</sub> and PM<sub>2.5</sub>) and Covid cases and deaths reported in the Italian city of Lombardi and Veneto. <sup>29</sup> Air pollution links to Covid cases and deaths were also established by Frontera et al. (2020).<sup>30</sup> Wang et al. (2020)<sup>31</sup> reported SARS-CoV-2 transmission through Flügge droplets. Particles <5 µm can remain for a long time and can spread to longer distances. <sup>32</sup> Most important aspect is exposed surface area to weight ratio that permits larger adsorption per unit weight. As the particle size becomes more and more smaller the exposure surface per unit mass increases thereby increasing adsorption efficiency creating acute toxicity in the cell. <sup>33</sup>

#### Particle Size

The particles of solid and/or liquid nature that remain suspended in the atmosphere for at least 1 hr with minimum stability are called aerosols (Fig 7).<sup>34</sup> It is considered as the most important part of particle character seeing its behaviour. It affects removal process, residence time and scattering hindering visibility. Their origin is traced to natural or anthropogenic sources ranging from few nanometres to several microns. Smaller and finer particles undergo coalition and adhesion with several chemical reactions to form bigger particles of secondary and tertiary nature from <10<sup>-3</sup> to 100 µm.<sup>35</sup> The particles greater than few hundred microns are not considered aerosols as they settle very fast.<sup>34</sup> These aerosols, though present in lower amount, play an important role in physicochemical reactions of the atmosphere such as electrical conductivity, scattering of the solar radiation, compression of water vapor over nuclei forming fog and smog. The climatic alterations may support specific microbial population to grow. The details of the reactions of the particle size chemistry are depicted in Fig 7.<sup>34</sup>

The diameter in PM<sub>10</sub> particulates in the industrial agglomeration of Jharkhand specially in coal mining areas varies from 0.0525-0.598  $\mu$ m. <sup>36</sup> This particle size is even smaller than 1  $\mu$ m and is carried away to longer distances by wind due to its lighter weight. They tend to coalesce with liquid and gaseous aerosol along with viruses and bacteria to form complex secondary and tertiary aerosols. Recent studies citing air particulates as the precursor of bacterial transmission have been reported by many authors. <sup>37</sup> Reports indicate that these are highly dependent on size and concentration of the particulates. Particle size and their count are an important parameter accelerating viral and bacterial coalescence. Lighter and smaller aerosol particles (<0.1  $\mu$ m) coalesce much faster than the larger ones. <sup>33</sup>

The aerosol and its behaviour in the environment with relative humidity and moisture was described by Hanel in 1976 (Fig 9). <sup>38</sup> Particle properties such as reactivity, solubility, charging capacity, polarity/or hydrophobicity, aspect ratio, binding state, and the interactive potential with other tissues generating reactive oxygen affect the level of particle toxicity. <sup>33</sup>

Industrial dust particulates are generated through anthropogenic means like (i) vehicular transportation and road dust (ii) industrial processes like coal and fuel burning (iii) coal based ancillary industries (iv) metallurgical processing (v) waste burning. These particulates serve as a potential precursor for virus transmission through binding forces described herein. Over the last decade, particulates <2.5  $\mu$ m are more emphasised due to larger surface area and its penetration ability. Elemental carbon released during coal burning are very tiny (<2  $\mu$ m) coalesce rapidly even during burning. The processes of physicochemical nature occurring during burning of pulverized coal (70  $\mu$ m) was depicted by Okazaki, 1993<sup>39</sup> (Fig 8). Two pathways (Fig 8) are broadly followed - (i) swelling and (ii) shrinking. In the first case, numerous particles from 0.5 to 30  $\mu$ m are generated through fragmentation and swelling. In the second case, numerous particles ranging from 0.02 to 0.2  $\mu$ m are generated through vaporisation-condensation-nucleation-coagulation-coalescence processes of shrinking. The process may also generate particulates of 10-90  $\mu$ m size through clustering, expansion and slaking. Therefore, very high gas to particle formation occurs. This gives a wide scope of microbial association which has been proved by many authors.

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Fig 7. Size range of aerosols in the atmosphere & their role in atmospheric physics & chemistry <sup>34</sup>



Fig 8. Sketch of an aerosol particle for dry air (left) and humid air (RH=75-80%) (right), with soluble (acid, seasalt, ammonium sulphate) and insoluble (carbonaceous, mineral dust, organics) substances suspended inside the moist particle steadily increasing by condensation until the formation of a water droplet with soluble salts, acids, organic compounds etc. <sup>38</sup>

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Fig 9. Particle formation during combustion of pulverized coal through different combinations of swelling, shrinking, fragmentation, vaporization, condensation, nucleation, coagulation, expansion, quenching, and disintegration processes.<sup>39</sup>

#### Particulate characteristics of JCF region

SEM images of coarse particulates ( $PM_{10}$ ) of coal mining area indicates formation of complex aggregates consisting unburnt carbon and metal associates (Fig 10). They settle very easily being larger (>10 µm) and heavier. SEM images of  $PM_{2.5}$  particulates reveal completeness of the properties of burning having spherical shapes. The unburnt carbon in the form of soot with embedded fly ash particles are spongy and glassy in nature. <sup>40</sup> It contains carbon rich soot aggregate with spherical as fly ash and elongated as mineral (metal silicates). Sources indicate the possibility of unburnt carbon from coal ignition which may harbor deadly microbes including viruses (Fig. 10b). Particles of the coal mining area of JCF possesses (i) aluminosilicates with diverse components (ii) carbonaceous matter (iii) metallics with iron oxides such as magnetite, hematite, and maghemite (iv) lime particles (v) minerals with quartz and mullite (vi) formless particles with irregular shapes, black or brownish in color. Remarkable changes from irregular fractured to compact and spherical shapes is observed (Fig 10) with decreasing size and scattering ratio in the soot. <sup>41</sup> The organic carbon present in the particulates with polycyclic aromatic hydrocarbons (PAH) may harbor microbes possessing mutagenic properties. <sup>35</sup> The non-coal mining sites ( $PM_{2.5}$ ) contain fluffy soot aggregate containing carbon and metallics with high % of silica, a potential source of silicosis. Sources indicate construction activities. The finer particles (<2.5µm) obstruct CO<sub>2</sub> and O<sub>2</sub> exchange in alveoli causing breathlessness and death.



Fig 10. SEM images of coal mine area (a) PM<sub>10</sub> (b) PM<sub>2.5</sub>& non-coal mine area (c) PM<sub>10</sub> (d) PM<sub>2.5</sub>



Fig 11. EDX images of coal mine area (a) PM<sub>10</sub> (b) PM<sub>2.5</sub>& non-coal mine area (c) PM<sub>10</sub> (d) PM<sub>2.5</sub>

High content of Si and AI with varying percentage of Mg, K, Fe, S and Co are present in aluminosilicates.

It consists of kaolinite, illite, montmorillonite and feldspar, which are typical terrigenous minerals. The consistent occurrence of Fe/Cu with Al/Si/O indicates particle origin from a localized material by weathering of a geological structure unique in nature. The prominent elements present in the PM<sub>10</sub> particulates of the coal mining area of JCF are C, O, Na, Mg, Al, Si, S, Cl, K, Ca while the prominent elements present in non-coal mining area contains C, O, Na, Al, Ca, Si, S, Cl, K, Mg, Fe and Ti. Elemental composition reveals presence of many elements viz., Si, Al, K, Fe, Ca and C in appreciable quantity. This indicates origin from non-natural sources. Vehicular burning of fossil fuels, industrial sources and thermal power plants in the vicinity of the site are the potential sources. The origin of TiO<sub>2</sub> can be traced to paints, papers and plastics.<sup>42</sup>

EDX spectra of various elements (both PM<sub>10</sub> and PM<sub>2.5</sub>) at selected locations indicates high concentration of C, O and Si followed by Fe, Al, Ca, Mg, K and Cl (Fig 11). The sites dominated by mining operations shows high C-concentrations with trace of S and K. These particles are typical of C-domination showing spherical, amorphous and typically non aggregated shape.

Non-mining sites showed irregular shaped particles in all size variations. This is attributed to vehicular fossil-fuel combustion. Other dominant elements are- Si, Al, Fe, Mg, Ca & K. They mostly originate from soil, crustal dust and anthropogenic sources. Si associated with Al, Na, Ca, Mg, Fe and K has been thought to indicate the presence of mineral, clay and feldspar particles.

The presence of Fe and  $Al_2SiO_3$  in dust (PM<sub>10</sub> and PM<sub>2.5</sub>) mineral constitutes mostly inorganic elements. XRD analysis indicates presence of quartz (SiO2) and dolomite [CaMg (CO<sub>3</sub>)<sub>2</sub>] in the dust samples of almost all the area of JCF. <sup>34</sup> This indicates the contribution of regional particulates to the overall dust of the area. Ca rich particles indicates the presence of CaCO<sub>3</sub> in calcite phase.

The reported trace elements in the dust ( $PM_{10}$  and  $PM_{2.5}$ ) comprises of Pb, Ni, Cu, Mn, Fe. They have been observed at significant concentration levels. The level of As (Arsenic) is below detectable limit.<sup>36</sup>

#### Health effects of particle size

Particulates are emitted to the ambient air through a lot of activities which can be either natural or anthropogenic. The natural sources are biogenic sources and are non-anthropogenic such as windblown dust from soil surface or sand and wildfire etc. The anthropogenic sources are agriculture, mining, civil construction such as road, buildings etc. These particles when combine with other particulates and gases in the ambient air such as VOC, ammonia, SOx and NOx form secondary and tertiary aerosol of primary, secondary or tertiary nature. Health effects are manifested but is primarily directed towards pulmonary function. The particle size <1 $\mu$  directly enters alveoli to interrupt CO  $\subset O_2$  exchange (Fig 12) causing breathlessness and death. Other effects include:

- Increase in bronchial irritation and asthma
- Frequent heart attacks
- Increased blood pressure
- High level of sugar
- Environmental damage

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The environmental damage include:

- Acid rain
- Lowering soil nutrition and crop production
- Decrease in biodiversity



Fig 12. Effect of dust inhalation with different particle size in human lung <sup>43</sup>

#### Statistical analysis

The bivariate test was taken in the form of Pearson's correlation and ANOVA (one-way) tests to prove the effect of particulates on Covid cases. The relationship was described using linear mapping such as Pearson correlation. It was found that out of the seven cities for  $PM_{10}$ , five showed moderate to high positive correlation while two cities of Jamshedpur and Hazaribagh showed negative correlation at insignificant levels (<0.05) (Table 6, Fig 13). Ranchi showed the highest positive correlation of 0.40. The reason can be attributed to three factors- population density, dust pollution, and weather conditions with moisture and wind direction. Dhanbad, Bokaro, Deoghar and Chaibasa showed moderate correlation of 0.25, 0.11, 0.14 and 0.14.

Location	PM <sub>10</sub>	PM <sub>2.5</sub>
Jamshedpur	-0.02051	-0.02801
Dhanbad	0.247474	0.198208
Ranchi	0.395063	0.368577
Bokaro	0.109909	0.120024
Deoghar	0.135509	0.116604
Chaibasa	0.137967	0.127443
Hazaribagh	-0.04234	-0.07767

Table 6. Pearson correlation between  $PM_{10}$  and  $PM_{2.5}$  with Covid Cases (%) in seven most densely populated cities of Jharkhand



Fig 13. Pearson correlation between  $PM_{10}$  and  $PM_{2.5}$  with Covid Cases (%) in seven most densely populated cities of Jharkhand

Similarly, for  $PM_{2.5}$ , five cities showed moderate positive correlation while two cities showed negative correlation with statistically insignificant (<0.05) for Jamshedpur and significant for Hazaribagh (>0.05) (Table 6, Fig 13). Thus, in both the particle size analysis the relationship analysis showed significant attributes showing particulate as the potential carrier of the nCoV.

#### **One-way ANOVA test**

Table 7 represents the detail analysis of the ANOVA test. The p-value varies from minimum of 1.98E-40 for Chaibasa to maximum of 8.63E-32 for Jamshedpur. The P-value in all the cases is less than the significance level of 0.05 rejecting the null hypothesis suggesting the means are different with statistically proven relationship. In all the cases, the F value crosses the critical value (F crit) rejecting null hypothesis. Thus, the sample data provide strong enough evidence to conclude that there is relationship between the dust concentration to percent of Covid cases occurring at a site.

Site	F	P-value	F crit
Jamshedpur	188.60478	8.63E-32	3.105157
Dhanbad	266.84656	4.048E-37	3.105157
Ranchi	254.72916	2.174E-36	3.105157
Bokaro	213.82931	1.103E-33	3.105157
Deoghar	262.74828	1.245E-36	3.106507
Chaibasa	328.30060	1.982E-40	3.105157
Hazaribagh	192.08525	4.6E-32	3.105157

Table 7. One-way ANOVA test

#### III. Conclusion

The investigation of the available data set of particulates of  $PM_{10}$  and  $PM_{2.5}$  over a period of nearly one month (29 days) in post monsoon and beginning of winter season of the selected sites provide strong evidence for the particulate aerosol as the mode of transmission. Though not specific evidence is available but statistical correlation in linear and ANOVA tests proves beyond doubt that the aerosol particle can be a prime mode of transmission of the nCoV besides other investigations described world over for the spread of COVID 19.

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#### **Competing interests**

The authors declare they have no competing interests

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