Statistical investigation of relationship between spread of coronavirus disease (COVID-19) and environmental factors based on study of four mostly affected places of China and five mostly affected places of Italy

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Abstract: COVID-19 is a new type of coronavirus disease which is caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). It originated in China in the month of December 2019 and quickly started to spread within the country. On 31st December 2019, it was first reported to country office of World Health Organization (WHO) in China. Since then, it has spread to most of the countries around the globe. However, there has been a recent rise in trend in believing that it would go away during summer days, which has not yet been properly investigated. In this paper, relationship of daily number of confirmed cases of COVID-19 with three environmental factors, viz. maximum relative humidity (RH_{max}), maximum temperature (T_{max}) and highest wind speed (WS_{max}), considering the incubation period, have been investigated statistically, for four of the most affected places of China, viz. Beijing, Chongqing, Shanghai, Wuhan and five of the most affected places of Italy, viz. Bergamo, Cremona, Lodi, Milano. It has been found that the relationship with maximum relative humidity and highest wind is mostly negligible, whereas relationship with maximum temperature is ranging between negligible to moderate.

Keywords: Coronavirus, COVID-19, Environmental factors

Introduction: Over the years, many different viruses of coronavirus family have surfaced and disrupted life of a lot of people. In 2002, a new disease called Severe Acute Respiratory Syndrome (SARS) started from Guangdong province of China. In 2003 it was found that, the disease is caused by SARS coronavirus (SARS-CoV) and it quickly became an epidemic,

affecting life of more than 8000 people in 26 different countries [1]. In 2012, another disease called called Middle East Respiratory Syndrome (MERS), caused by MERS coronavirus (MERS-CoV), started from Saudi Arabia, became an epidemic and spread to 27 countries [2]. In the later part of 2019, an outbreak of pneumonia of unknown cause started appearing in Wuhan, China and was reported to the Country Office of WHO in China on 31st December 2019. On 30th January 2020, it was declared as Public Health Emergency of International Concern. On 11th February 2020, WHO named the disease as coronavirus disease (COVID-19) and the virus causing the disease as severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) [3]. On 11th March 2020, WHO declared COVID-19 as pandemic [4] and by 16th March 2020, the virus has spread to 156 countries/regions [5].

From 19th January 2020 onwards, there has been hearsay about relationship between coronavirus and summer [6]. However, there has been a sharp rise in interest shown by people all around the world, in the relationship, as shown by Google Trend [6], after President of the United States of America, who is currently one of the most influential person in the world [7], tweeted that the virus might be gone with warmer weather [8]. If such claims are not properly investigated then it might end up being rumour and ultimately hinder the disease control process [9], which has not yet been done widely.

One of the terms to describe severity of any infectious disease is effective reproduction number (R) [10]. Wang et al., tried to develop an equation to estimate the value of R with respect to the value of Temperature (T) and relative humidity (RH) [11], but they developed the equation based on data only from Chinese cities and applied that for places outside China. However, the environment and their effect are different at different places of the globe and the effect of incubation period has also not been considered while developing the equation. Incubation period of COVID-19 has been investigated by Baum et al. and it has been found that the median incubation period is approximately 5 days [12]. In the current paper, the

relationship of daily number of confirmed COVID-19 cases, which has been assumed to be reflecting how contagious the disease is, from four of the most affected places of China and five of the most affected places of Italy has been investigated with RH_{max}, T_{max} and WS_{max}. The environmental factors, that have been considered, are that of 5 days back from the date of reporting the case, to consider the effect of incubation period.

Methodology: Since 21st January, WHO has been publishing daily situation report on COVID-19 [13]. The data for the Chinese places has been collected from these reports and has been summarised in Table 1. All the weather data, reported in Table 1, have been collected from Weather Underground [14]

Table 1: Details of considered places from China

Date	Place	Number of additional confirmed cases in last 24 hours	RH_{max} (%)	T_{max} (°F)	WS_{max} (mph)
20-01-2020	Beijing	3	65	35	4
21-01-2020	Beijing	0	74	36	4
22-01-2020	Beijing	5	75	37	4
02-02-2020	Beijing	27	75	41	4
03-02-2020	Beijing	29	86	46	7
04-02-2020	Beijing	16	80	43	9
05-02-2020	Beijing	25	74	44	4
06-02-2020	Beijing	21	33	40	7
07-02-2020	Beijing	23	89	34	7
08-02-2020	Beijing	18	49	36	11
09-02-2020	Beijing	11	61	34	13
10-02-2020	Beijing	11	83	24	7
11-02-2020	Beijing	5	87	24	7

12-02-2020	Beijing	10	83	35	2
13-02-2020	Beijing	14	89	44	4
14-02-2020	Beijing	6	82	42	7
15-02-2020	Beijing	3	90	52	2
16-02-2020	Beijing	5	87	49	4
17-02-2020	Beijing	1	90	51	2
18-02-2020	Beijing	6	93	44	7
19-02-2020	Beijing	6	94	44	18
20-02-2020	Beijing	2	37	31	13
21-02-2020	Beijing	1	33	38	13
22-02-2020	Beijing	3	52	41	11
23-02-2020	Beijing	0	74	49	7
24-02-2020	Beijing	0	83	46	7
25-02-2020	Beijing	1	80	40	4
26-02-2020	Beijing	0	93	47	7
27-02-2020	Beijing	10	29	48	9
28-02-2020	Beijing	0	55	48	4
29-02-2020	Beijing	1	71	48	7
01-03-2020	Beijing	2	47	48	4
02-03-2020	Beijing	1	5	46	9
03-03-2020	Beijing	0	51	41	7
04-03-2020	Beijing	3	72	45	4
05-03-2020	Beijing	1	95	38	4
06-03-2020	Beijing	4	96	50	11
07-03-2020	Beijing	4	67	47	9
08-03-2020	Beijing	2	91	45	13
09-03-2020	Beijing	0	34	43	9
10-03-2020	Beijing	1	44	47	11
11-03-2020	Beijing	6	72	50	7
12-03-2020	Beijing	0	89	58	7

13-03-2020	Beijing	1	94	42	4
14-03-2020	Beijing	1	94	52	7
20-01-2020	Chongqing	0	81	48	11
21-01-2020	Chongqing	1	87	48	4
22-01-2020	Chongqing	4	93	52	11
02-02-2020	Chongqing	24	81	54	7
03-02-2020	Chongqing	38	93	57	9
04-02-2020	Chongqing	37	87	52	9
05-02-2020	Chongqing	29	93	50	9
06-02-2020	Chongqing	23	87	48	9
07-02-2020	Chongqing	22	93	48	7
08-02-2020	Chongqing	15	93	50	7
09-02-2020	Chongqing	20	93	54	9
10-02-2020	Chongqing	22	87	54	11
11-02-2020	Chongqing	18	100	50	9
12-02-2020	Chongqing	19	100	54	9
13-02-2020	Chongqing	13	94	55	4
14-02-2020	Chongqing	11	100	55	7
15-02-2020	Chongqing	8	94	55	7
16-02-2020	Chongqing	7	87	59	7
17-02-2020	Chongqing	7	93	66	9
18-02-2020	Chongqing	2	76	66	9
19-02-2020	Chongqing	2	82	64	9
20-02-2020	Chongqing	5	93	54	11
21-02-2020	Chongqing	7	93	54	7
22-02-2020	Chongqing	5	81	55	7
23-02-2020	Chongqing	1	71	52	9
24-02-2020	Chongqing	2	93	55	9
25-02-2020	Chongqing	1	93	50	11
26-02-2020	Chongqing	0	93	54	9

27-02-2020	Chongqing	0	87	55	9
28-02-2020	Chongqing	0	100	52	9
29-02-2020	Chongqing	0	100	55	7
01-03-2020	Chongqing	0	94	59	9
02-03-2020	Chongqing	0	94	59	13
03-03-2020	Chongqing	0	94	57	7
04-03-2020	Chongqing	0	94	64	7
05-03-2020	Chongqing	0	100	64	9
06-03-2020	Chongqing	0	100	66	7
07-03-2020	Chongqing	0	94	61	16
08-03-2020	Chongqing	0	100	52	11
09-03-2020	Chongqing	0	94	55	7
10-03-2020	Chongqing	0	93	57	13
11-03-2020	Chongqing	0	82	63	9
12-03-2020	Chongqing	0	94	68	13
13-03-2020	Chongqing	0	77	61	13
14-03-2020	Chongqing	0	82	63	11
20-01-2020	Shanghai	1	93	48	11
21-01-2020	Shanghai	1	93	45	13
22-01-2020	Shanghai	7	93	45	13
02-02-2020	Shanghai	24	87	45	13
03-02-2020	Shanghai	16	76	50	20
04-02-2020	Shanghai	15	75	46	18
05-02-2020	Shanghai	25	80	50	13
06-02-2020	Shanghai	21	93	57	9
07-02-2020	Shanghai	15	81	57	11
08-02-2020	Shanghai	12	93	52	16
09-02-2020	Shanghai	11	87	57	11
10-02-2020	Shanghai	3	93	52	16
11-02-2020	Shanghai	7	93	45	16

12-02-2020	Shanghai	4	93	48	11
13-02-2020	Shanghai	7	81	50	11
14-02-2020	Shanghai	5	93	54	11
15-02-2020	Shanghai	8	93	63	13
16-02-2020	Shanghai	2	100	54	16
17-02-2020	Shanghai	3	100	63	9
18-02-2020	Shanghai	2	100	61	16
19-02-2020	Shanghai	0	100	64	13
20-02-2020	Shanghai	0	100	57	22
21-02-2020	Shanghai	1	93	43	22
22-02-2020	Shanghai	0	60	50	22
23-02-2020	Shanghai	1	65	54	11
24-02-2020	Shanghai	0	81	55	13
25-02-2020	Shanghai	0	87	61	11
26-02-2020	Shanghai	1	93	64	16
27-02-2020	Shanghai	1	82	64	16
28-02-2020	Shanghai	0	71	59	16
29-02-2020	Shanghai	0	82	72	13
01-03-2020	Shanghai	0	88	79	18
02-03-2020	Shanghai	0	87	52	16
03-03-2020	Shanghai	1	76	57	13
04-03-2020	Shanghai	0	94	55	18
05-03-2020	Shanghai	0	100	54	9
06-03-2020	Shanghai	1	94	52	16
07-03-2020	Shanghai	3	87	52	13
08-03-2020	Shanghai	0	76	55	9
09-03-2020	Shanghai	0	71	54	18
10-03-2020	Shanghai	0	65	54	11
11-03-2020	Shanghai	2	88	59	16
12-03-2020	Shanghai	0	94	63	13

13-03-2020	Shanghai	2	93	63	20
14-03-2020	Shanghai	4	100	57	16
20-01-2020	Wuhan	60	100	39	11
21-01-2020	Wuhan	12	87	37	9
22-01-2020	Wuhan	105	93	41	4
26-01-2020	Wuhan	323	87	41	11
27-01-2020	Wuhan	371	100	45	7
28-01-2020	Wuhan	1291	100	48	9
29-01-2020	Wuhan	840	100	46	11
30-01-2020	Wuhan	1032	93	43	9
31-01-2020	Wuhan	1220	93	39	9
01-02-2020	Wuhan	1347	87	41	9
02-02-2020	Wuhan	1921	93	46	7
03-02-2020	Wuhan	2103	100	54	9
04-02-2020	Wuhan	2345	100	57	7
05-02-2020	Wuhan	3156	81	57	9
06-02-2020	Wuhan	2987	70	57	11
07-02-2020	Wuhan	2447	87	54	7
08-02-2020	Wuhan	2841	100	57	7
09-02-2020	Wuhan	2147	87	59	7
10-02-2020	Wuhan	2531	87	61	13
11-02-2020	Wuhan	2097	93	45	11
12-02-2020	Wuhan	1638	93	43	9
13-02-2020	Wuhan	1508	87	48	7
14-02-2020	Wuhan	4823	100	57	7
15-02-2020	Wuhan	2420	93	52	7
16-02-2020	Wuhan	1843	93	54	7
17-02-2020	Wuhan	1933	94	57	7
18-02-2020	Wuhan	1807	94	64	13
19-02-2020	Wuhan	1693	100	61	20

20-02-2020	Wuhan	349	100	46	20
21-02-2020	Wuhan	631	93	46	7
22-02-2020	Wuhan	366	93	54	7
23-02-2020	Wuhan	630	87	57	9
24-02-2020	Wuhan	398	66	59	7
25-02-2020	Wuhan	499	81	64	11
26-02-2020	Wuhan	401	87	59	9
27-02-2020	Wuhan	409	100	63	9
28-02-2020	Wuhan	318	67	68	9
29-02-2020	Wuhan	423	73	75	13
01-03-2020	Wuhan	570	94	72	13
02-03-2020	Wuhan	196	100	59	13
03-03-2020	Wuhan	114	100	52	11
04-03-2020	Wuhan	115	100	45	9
05-03-2020	Wuhan	134	100	54	7
06-03-2020	Wuhan	126	100	55	13
07-03-2020	Wuhan	74	87	50	11
08-03-2020	Wuhan	41	93	48	4
09-03-2020	Wuhan	36	76	59	7
10-03-2020	Wuhan	17	81	61	9
11-03-2020	Wuhan	13	88	57	9
12-03-2020	Wuhan	8	88	66	9
13-03-2020	Wuhan	5	100	64	13
14-03-2020	Wuhan	4	100	57	13

Similarly, the data for Italy has been collected from the official GitHub repository of Department of Civil Protection, Italy [15] and the summary is presented in Table 2 along with weather data which is obtained from Weather Underground [14].

Table 2: Details of considered places from Italy

Date	Place	Number of additional confirmed cases in last 24 hours	RH_{max} (%)	T_{max} (°F)	WS_{max} (mph)
24-02-2020	Bergamo	0	93	57	17
25-02-2020	Bergamo	18	70	55	8
26-02-2020	Bergamo	2	75	55	7
27-02-2020	Bergamo	52	81	55	8
28-02-2020	Bergamo	31	87	61	14
29-02-2020	Bergamo	7	93	61	10
01-03-2020	Bergamo	99	93	57	9
02-03-2020	Bergamo	34	100	55	24
03-03-2020	Bergamo	129	57	52	9
04-03-2020	Bergamo	51	65	57	21
05-03-2020	Bergamo	114	87	52	8
06-03-2020	Bergamo	86	100	46	9
07-03-2020	Bergamo	138	100	48	13
08-03-2020	Bergamo	236	100	54	10
09-03-2020	Bergamo	248	87	54	8
10-03-2020	Bergamo	227	100	50	9
11-03-2020	Bergamo	343	100	48	8
12-03-2020	Bergamo	321	93	59	9
13-03-2020	Bergamo	232	76	55	8
24-02-2020	Brescia	0	93	57	17

25-02-2020	Brescia	0	70	55	8
26-02-2020	Brescia	2	75	55	7
27-02-2020	Brescia	8	81	55	8
28-02-2020	Brescia	3	87	61	14
29-02-2020	Brescia	1	100	59	20
01-03-2020	Brescia	35	93	55	7
02-03-2020	Brescia	11	100	59	25
03-03-2020	Brescia	26	69	54	15
04-03-2020	Brescia	41	65	61	18
05-03-2020	Brescia	28	71	52	9
06-03-2020	Brescia	27	100	46	9
07-03-2020	Brescia	231	100	46	24
08-03-2020	Brescia	88	100	48	15
09-03-2020	Brescia	238	93	55	9
10-03-2020	Brescia	51	93	52	15
11-03-2020	Brescia	561	100	50	16
12-03-2020	Brescia	247	100	59	9
13-03-2020	Brescia	186	93	57	10
24-02-2020	Cremona	0	100	57	17
25-02-2020	Cremona	53	70	57	9
26-02-2020	Cremona	4	81	59	8
27-02-2020	Cremona	34	81	57	7
28-02-2020	Cremona	32	93	61	18
29-02-2020	Cremona	13	100	59	14
01-03-2020	Cremona	78	100	54	6

02-03-2020	Cremona	9	100	61	29
03-03-2020	Cremona	64	64	54	12
04-03-2020	Cremona	46	61	59	18
05-03-2020	Cremona	73	66	54	8
06-03-2020	Cremona	46	100	46	8
07-03-2020	Cremona	110	100	52	20
08-03-2020	Cremona	103	100	50	10
09-03-2020	Cremona	251	93	55	8
10-03-2020	Cremona	41	93	52	16
11-03-2020	Cremona	104	93	52	17
12-03-2020	Cremona	241	93	59	12
13-03-2020	Cremona	42	81	57	8
24-02-2020	Lodi	0	100	57	8
25-02-2020	Lodi	125	76	57	7
26-02-2020	Lodi	3	93	61	9
27-02-2020	Lodi	31	93	57	7
28-02-2020	Lodi	23	87	59	13
29-02-2020	Lodi	55	82	66	13
01-03-2020	Lodi	107	93	57	5
02-03-2020	Lodi	40	100	57	20
03-03-2020	Lodi	98	65	54	9
04-03-2020	Lodi	77	65	61	14
05-03-2020	Lodi	99	93	50	9
06-03-2020	Lodi	81	100	46	6
07-03-2020	Lodi	72	100	48	18

08-03-2020	Lodi	42	100	54	13
09-03-2020	Lodi	75	100	55	10
10-03-2020	Lodi	35	93	50	10
11-03-2020	Lodi	72	93	52	9
12-03-2020	Lodi	88	100	61	12
13-03-2020	Lodi	10	100	57	6
24-02-2020	Milano	0	100	57	8
25-02-2020	Milano	8	76	57	7
26-02-2020	Milano	0	93	61	9
27-02-2020	Milano	7	93	57	7
28-02-2020	Milano	14	87	59	13
29-02-2020	Milano	1	82	66	13
01-03-2020	Milano	16	93	57	5
02-03-2020	Milano	12	100	57	20
03-03-2020	Milano	35	65	54	9
04-03-2020	Milano	52	65	61	14
05-03-2020	Milano	52	93	50	9
06-03-2020	Milano	70	100	46	6
07-03-2020	Milano	94	100	48	18
08-03-2020	Milano	45	100	54	13
09-03-2020	Milano	100	100	55	10
10-03-2020	Milano	86	93	50	10
11-03-2020	Milano	333	93	52	9
12-03-2020	Milano	221	100	61	12
13-03-2020	Milano	161	100	57	6

Once the data has been collected, then to find out how well the daily number of newly confirmed cases of COVID-19 relates to RH_{max}, T_{max} and WS_{max}, at first the daily number of cases is plotted against each one of the considered environmental factor and visually inspected, then Pearson's correlation coefficient (r) for each such pair has been calculated [16] using MATLAB (R2019b). After that, the each of the values are interpreted according to the rule of thumb mentioned by Mukaka [17].

To further strengthen the finding, hypothesis test has also been done on them using 95% confidence interval. Null hypothesis, for each such pair, being that the environmental factors do not influence the spread of disease. But, while testing hypothesis, the results are not interpreted depending only on the p-values, as cautioned by Wasserstein et al. [18]. Instead Bayes Factor (BF), for each one of them is calculated using the expression $-\frac{1}{ep\ln(p)}$ [19] and then the relationship is once again interpreted based on the value of BF as mentioned in the classification scheme by Jamil et al. [20].

Results and discussion: From figure 1 – 27, it can be seen that the influence of environmental factors is neither that strong nor that can be outrightly rejected.

The value and interpretation of Pearson's correlation coefficient and Bayes Factor is listed in Table 3.

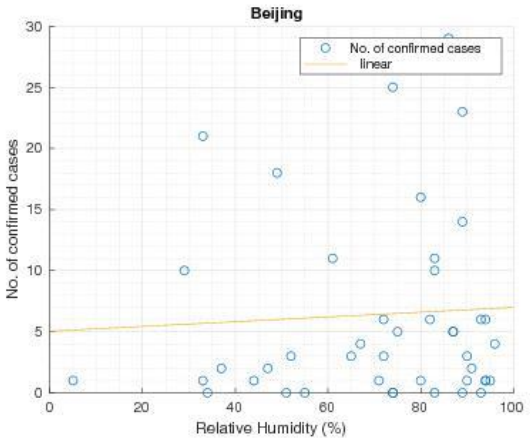

Figure 1: Effect of maximum relative humidity in Beijing

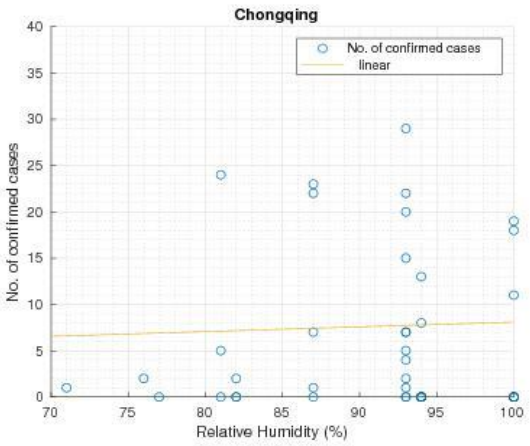

Figure 2: Effect of maximum relative humidity in Chongqing

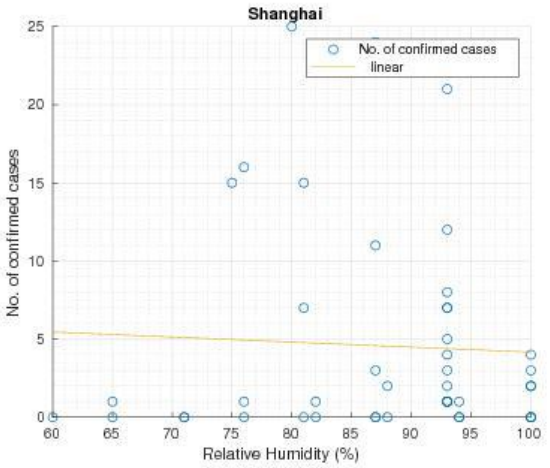

Figure 3: Effect of maximum relative humidity in Shanghai

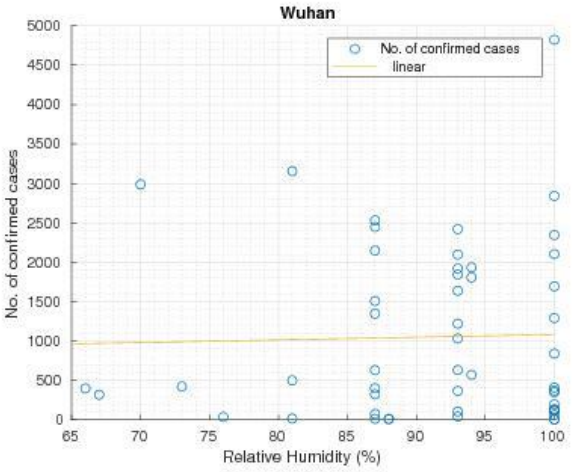

Figure 4: Effect of maximum relative humidity in Wuhan

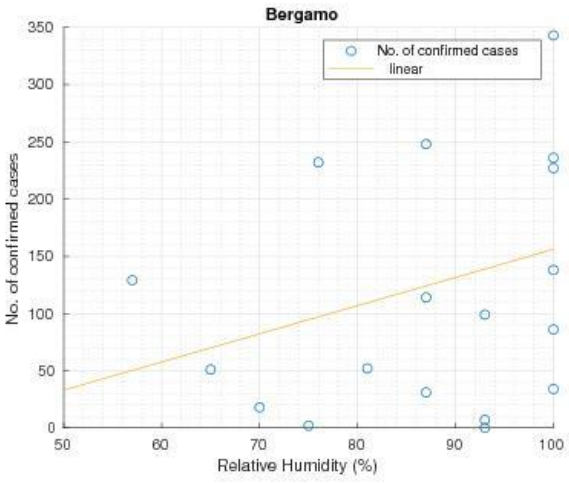

Figure 5: Effect of maximum relative humidity in Bergamo

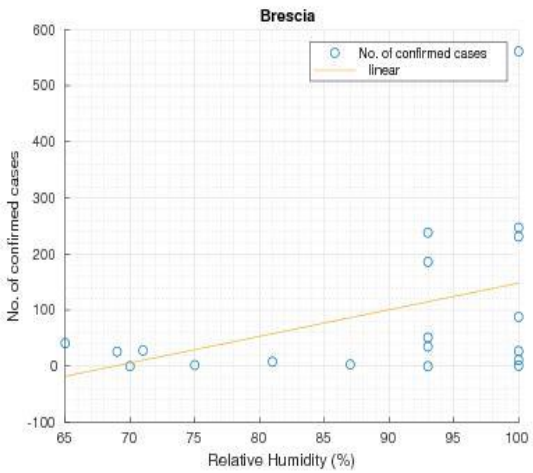

Figure 6: Effect of maximum relative humidity in Brescia

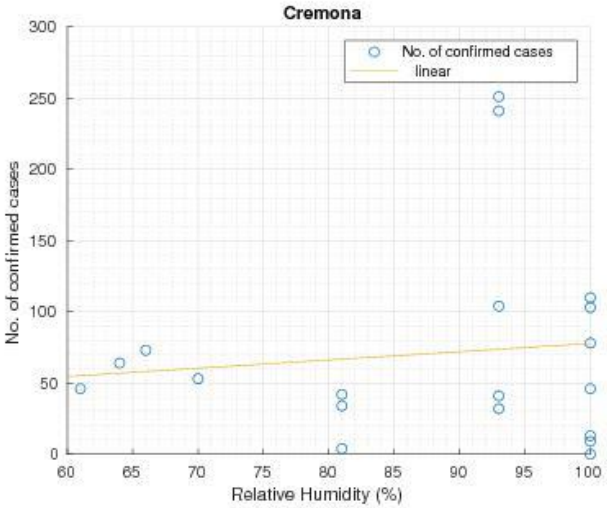

Figure 7: Effect of maximum relative humidity in Cremona

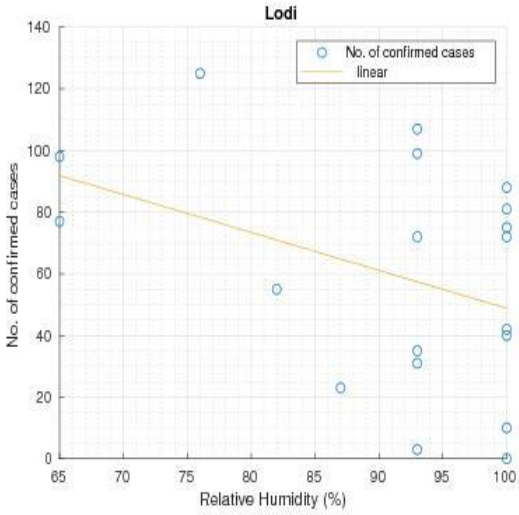

Figure 8: Effect of maximum relative humidity in Lodi

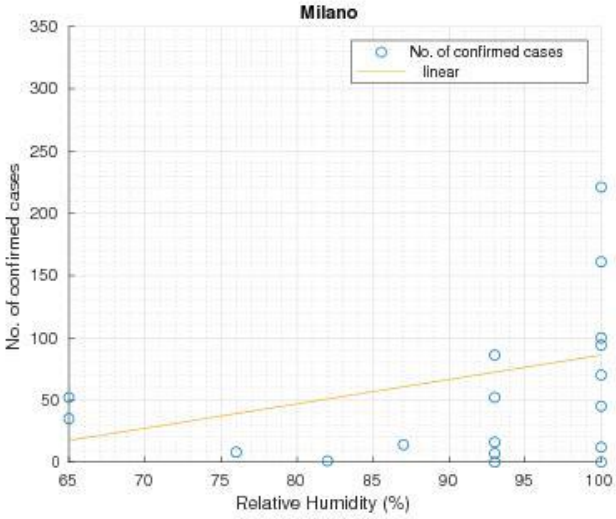

Figure 9: Effect of maximum relative humidity in Milano

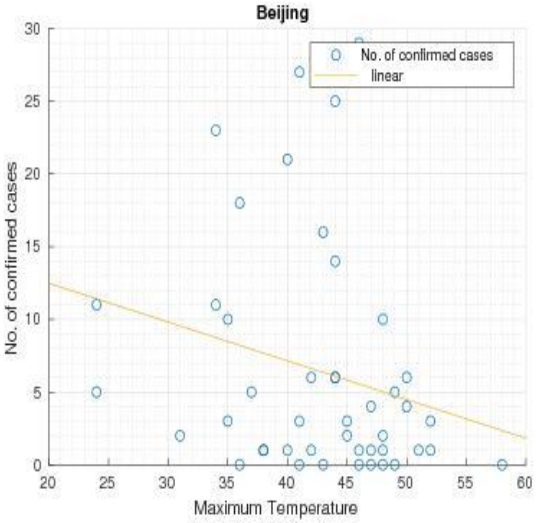

Figure 10: Effect of maximum temperature in Beijing

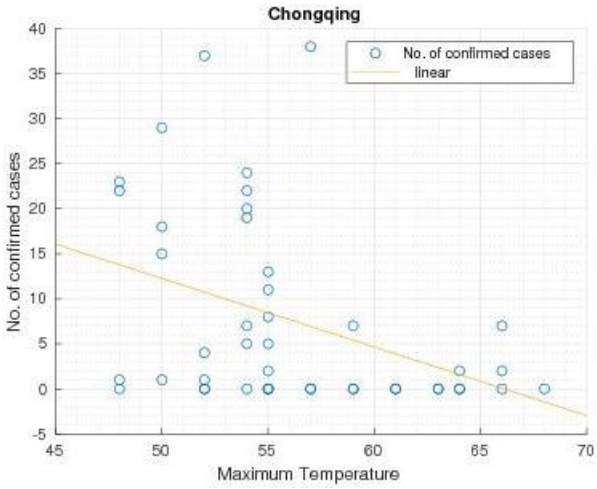

Figure 11: Effect of maximum temperature in Chongqing

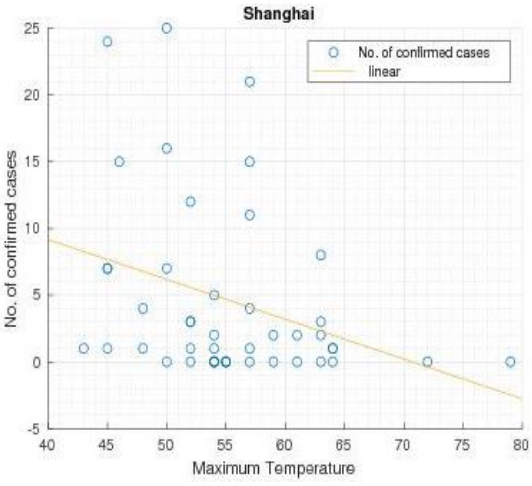

Figure 12: Effect of maximum temperature in Shanghai

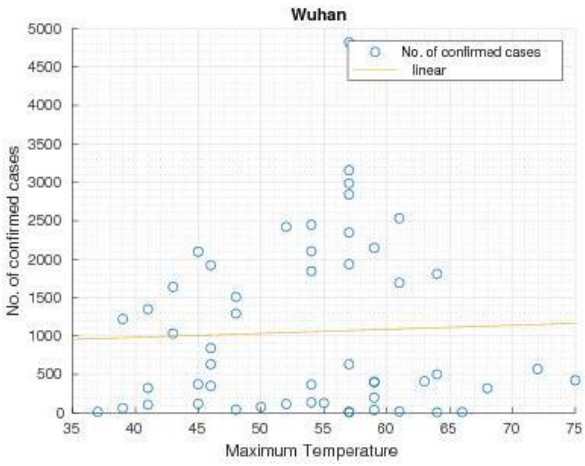

Figure 13: Effect of maximum temperature in Wuhan

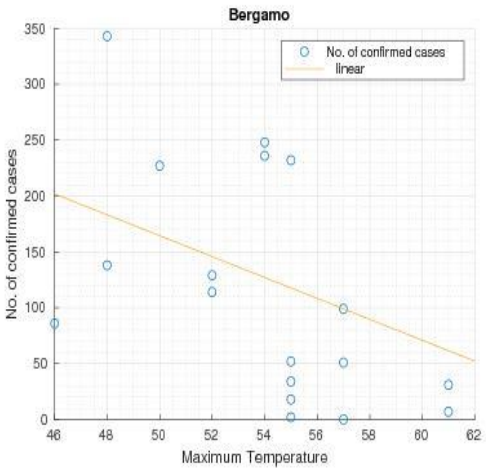

Figure 14: Effect of maximum temperature in Bergamo

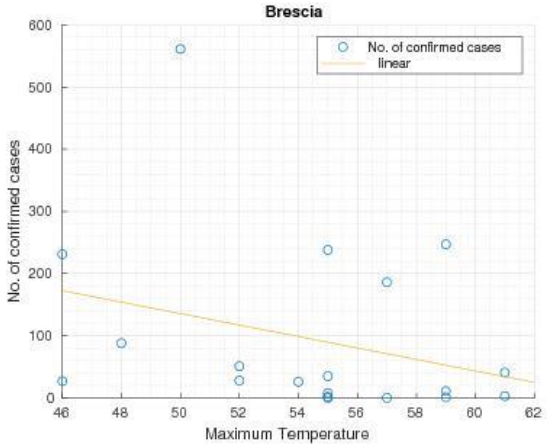

Figure 15: Effect of maximum temperature in Brescia

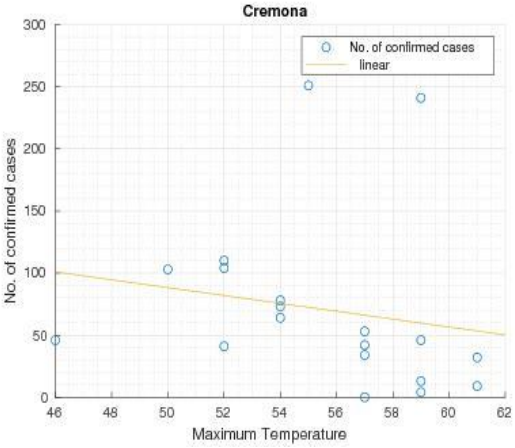

Figure 16: Effect of maximum temperature in Cremona

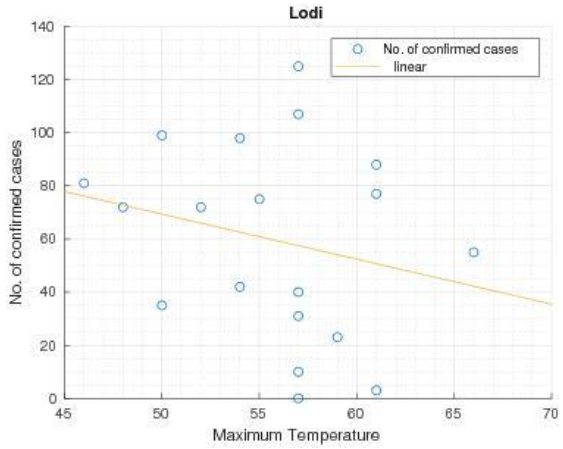

Figure 17: Effect of maximum temperature in Lodi

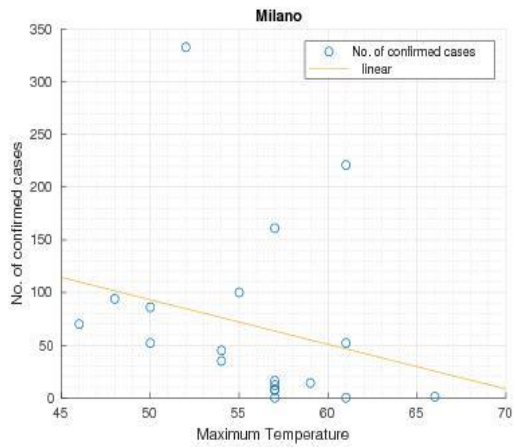

Figure 18: Effect of maximum temperature in Milano

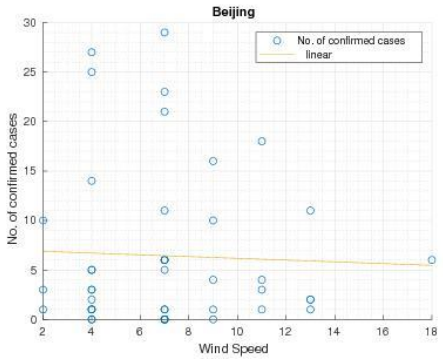

Figure 19: Effect of maximum wind speed in Beijing

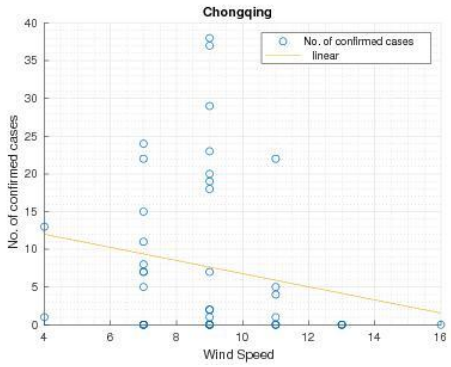

Figure 20: Effect of maximum wind speed in Congqing

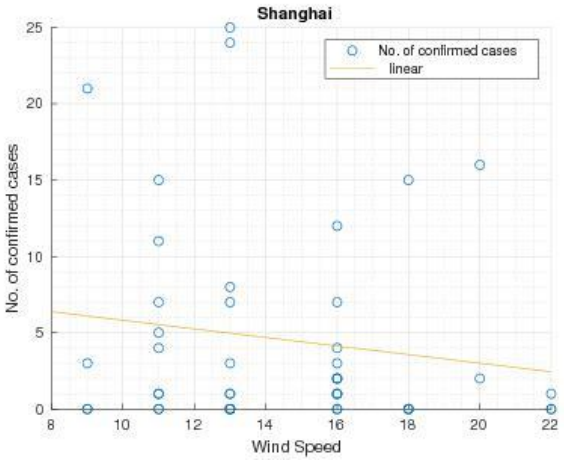

Figure 21: Effect of maximum wind speed in Shanghai

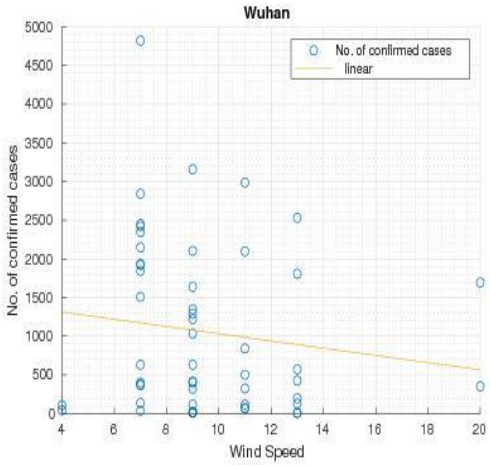

Figure 22: Effect of maximum wind speed in Wuhan

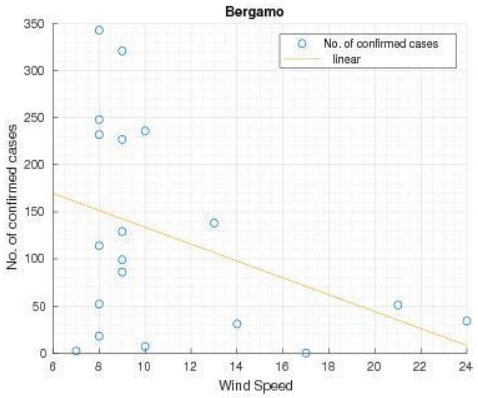

Figure 23: Effect of maximum wind speed in Bergamo

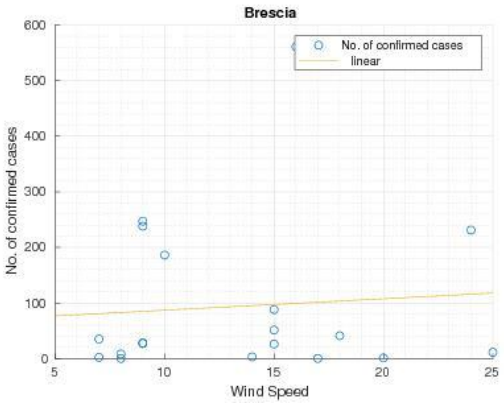

Figure 24: Effect of maximum wind speed in Brescia

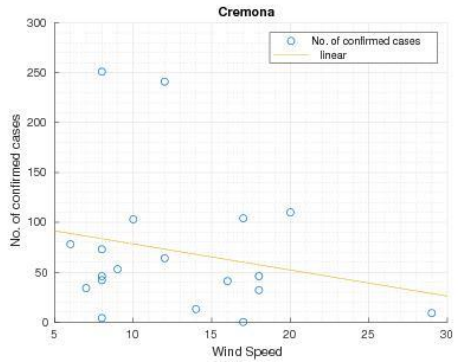

Figure 25: Effect of maximum wind speed in Cremona

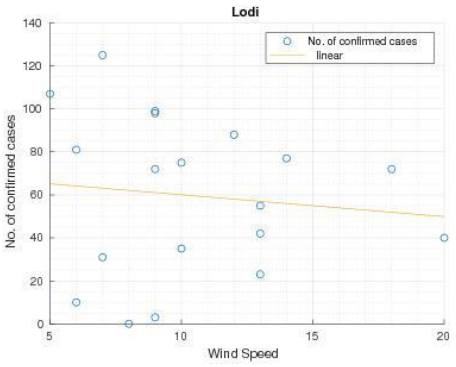

Figure 26: Effect of maximum wind speed in Lodi

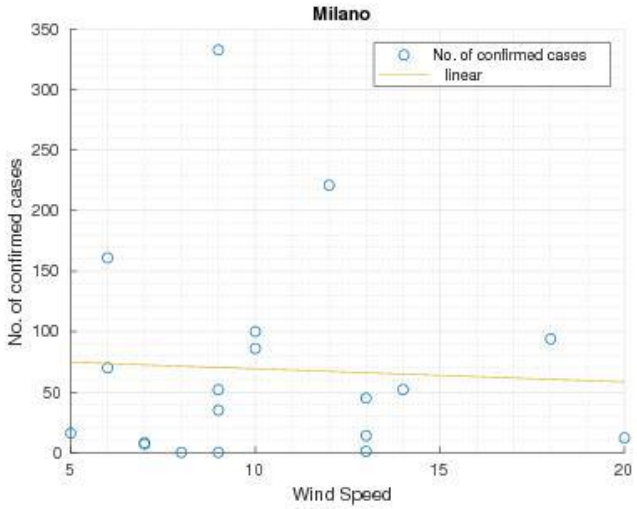

Figure 27: Effect of maximum wind speed in Milano

Table 3: Values and interpretation of statistical indicators

Country	Place	Statistical Indicator	Highest RH on that day		HIGHEST TEMP on that day (FAHRENHEIT)		HIGHEST WIND SPEED on that day (mph)	
China	Beijing	r	0.054	Negligible	-0.2335	Negligible	-0.0388	Negligible
		BF	1.575587437	Negligible	1.429067674	Negligible	2.064372541	Negligible
	Chongqing	r	0.0344	Negligible	-0.3925	Low negative	-0.1919	Negligible
		BF	2.290063003	Negligible	9.817365187	Moderate	1.129149822	Negligible
	Shanghai	r	-0.0497	Negligible	-0.325	Low negative	-0.149	Negligible
		BF	1.682343457	Negligible	3.547988527	Moderate	1.00598094	Negligible
	Wuhan	r	0.0282	Negligible	0.0421	Negligible	-0.1338	Negligible

		BF	2.55369917	Negligible	1.806152414	Negligible	1.002067883	Negligible
Italy	Bergamo	r	0.2925	Negligible	-0.3515	Low negative	-0.3854	Low negative
		BF	1.097402009	Negligible	1.336500235	Negligible	1.569611454	Negligible
	Brescia	r	0.417	Low negative	-0.2953	Negligible	0.0808	Negligible
		BF	1.882892321	Negligible	1.105067996	Negligible	1.662529557	Negligible
	Cremona	r	0.1139	Negligible	-0.1797	Negligible	-0.2221	Negligible
		BF	1.294281055	Negligible	1.030928263	Negligible	1.000186398	Negligible
	Lodi	r	-0.3817	Low negative	-0.2305	Negligible	-0.1113	Negligible
		BF	1.539157003	Negligible	1.002461915	Negligible	1.314347928	Negligible
	Milano	r	0.2569	Negligible	-0.2436	Negligible	-0.0504	Negligible
		BF	1.025950716	Negligible	1.011070479	Negligible	2.478388031	Negligible

Conclusion: COVID-19 started in the month of December 2019, from China and is rapidly spreading to different countries of the world. Millions of people have already been infected by the virus SARS-CoV-2. Amidst the commotion, a belief is getting popular that the virus would die its own death with the arrival of summer season, but in the current paper, it has been found that the relationship between the effectiveness of virus and different environmental factors is not that strong. Hence, it can be concluded that the virus shows no sign as of now, to become dormant during summer days. The current piece of work is based on preliminary data that's available. A better relation can be predicted when more data become available.

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