Electronic Supplementary Material (ESI) for Environmental Science: Processes & Impacts.

Gaseous and Soil OCPs and PCBs along the Indus River Pakistan: Spatial Pattern and Air-Soil Gradients

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Text S1. More detail on Air circulation pattern and POPs occurrence trends along Indus River, Pakistan

Other sites like Islamabad (S-17), the capital city of Pakistan, is located in the lesser Himalayan areas, and high OCPs and PCBs contamination in these areas has been suggested to stem from local air circulation (64%), with a relatively minor influence of northwest winds from central Asia (36%). Similarly, Abbottabad (S-6) and Swabi (S-7) were mostly influenced by local-origin air masses (67% and 58%), which are mainly responsible for OCPs and PCBs mobilization into these regions. At the same time, northwestern air movement (~5 %) from the central Asia region and low-lying areas of Pakistan (~10%) may further aggravate the situation and contribute to the atmospheric POPs in these areas. Nowshera city (S-8) has been reported to possess the obsolete pesticides store and demolished DDT factory, which mainly contributed by local air mass (60%) towards high POPs burden in these areas. In comparison, 40% of air masses arrived from western parts of the country and across the border from Central Asia and Afghanistan. On the other hand, air masses entering into Indus riverine delta [(e.g., Mianwali (S-9), Bakkhar (S-10), and Layyah (S-11)] originated majorly from local sources (25%, 59%, and 55%) and also from northwestern directions of central Asia and Afghanistan (~40%) and contributed towards the gaseous OCPs and PCBs burden.

Furthermore, 33% of air masses that arrived in D.G khan (S-12) were associated with north westerlies from central Asia, 46% traveled from westerlies from regional areas of Baluchistan/Afghanistan, and the remaining 41% were dominated by winds of the Arabian Sea traveling across the coastal part of Pakistan. Areas in the South of Pakistan near to the coastal regional Sukkur (S-13) and Khairpur (S-14) are mainly influenced by local air masses originating from the Arabian Sea and coastal areas in the southwestern direction (~ 60%) as compared to the western and northwestern part of the country (i.e., <30%). Hyderabad City (S-15) is a gateway of Arabian Sea winds where 100% of air masses movement is either from south and southwest direction from Arabian cost. Sukkur area exceptionally showed the highest OCPs/PCBs contamination measurement and reflected the extensive input from ongoing local industrial and urban activities.

Table S1.

Sampling Location	Sampling Year	ΣDDTs	ΣPCBs	References
Indus River Flood - Plain Pakistan	**2014**	**0–413.20**	**10.43–1108.89**	**Current Study**
Province Punjab, Pakistan	2011	347–24		(1)
Province Punjab, Pakistan	2011		34–390	(1)
Coastal Length of India	2006	16–2952		(2)
Agricultural Region, India	2006, 2007		12,100	(3)
Urban, Rural, Background, China	2005		250	(2)
Taihu Lake, China	2004	*p,p´*-DDT (124)		(4)
Mexico	2005-2006	15.0–1975		(5)
Japan	2008		184	(6)
Southern USA	2003	0.06–26		(7)

Table S2.

TEQ (**Dioxin Like PCBs)**	**Studied Zone**												
		FMZ			WMZ			ARZ			LLZ		
	TEF	Min	Max	mean	min	Max	mean	Min	max	mean	min	Max	mean
PCB-118	0.00003	0	0.000103	3.58E-05	0	1.51E-05	3.77E-06	0	0.000101	3.06E-05	5.17E-05	0.00013	9.09E-05
PCB-114	0.00003	0	0.000137	5.19E-05	0	0	0	0	0.000283	7.39E-05	0	0.000235	0.000118
PCB-105	0.00003	0	0.000132	5.65E-05	0	4.17E-06	1.04E-06	0	0.000609	0.000162	2.79E-05	0.000336	0.000182
PCB-156	0.00003	0	6.32E-05	2E-05	0	0	0	0	0.000588	0.000147	0	5.27E-05	2.63E-05
Mono-ortho DL-PCBs		0.0000	0.0001	0.0000	0	0	0	0	0.000609	0.000103	0	0.000336	0.000104
PCB-77	0.0001	0	0.00061	0.000159	0	0	0	0	7.06E-06	1.77E-06	9.03E-05	0.000524	0.000307
PCB-126	0.1	0	0.537605	0.211659	0	0	0	0	2.871326	0.734383	0	1.341775	0.670888
PCB-169	0.03	0	0.316009	0.079002	0	0.010757	0.002689	0	1.334158	0.33354	0	0.137453	0.068726
Non-ortho DL-PCBs		0	0.537605	0.09694	0	0.010757	0.000896	0	2.871326	0.355975	0	1.341775	0.24664
DL-PCB		0.000137	0.537646	0.09694	0	0.010757	0.000896	0.000609	2.871429	0.355975	0.000336	1.341 88	0.24674

118 **Table S3.**

Sampling Location	**ΣDDTs**	**ΣPCBs**	**References**
Surface soil- Indus River Pakistan	0–413.20	10.43–1108.89	This study
Soil of Province Punjab, Pakistan	347.24		(1)
Soil of Province Punjab, Pakistan		34–390	(1)
Dust fall along Indus River	7.17	16.17	This study
Indoor dust Pakistan	46		(8)
Indoor dust Pakistan	88.2	0.75	(9)
Soil Coastal Length of India	16–2952		(2)
Soil Agricultural Region, India		12,100	(3)
Soils, China		250	(2)
Soil of Taihu Lake, China	*p,p´*-DDT (124)		(4)
Soil of Mexico	15.0 - 1975		(10)
Soil of Japan		184	(6)
Soil of Southern USA	0.06–26		(7)
Soil of Spain and UK	6.0 - 83.0		(11)
House dust in Singapore	67	5.4	(12)
Lake Chaohu China	14.97		(13)
Indoor Dust in Romania	1050	26.25	(14)
Guangzhou China outdoor dust	136.07	40.53	(15)

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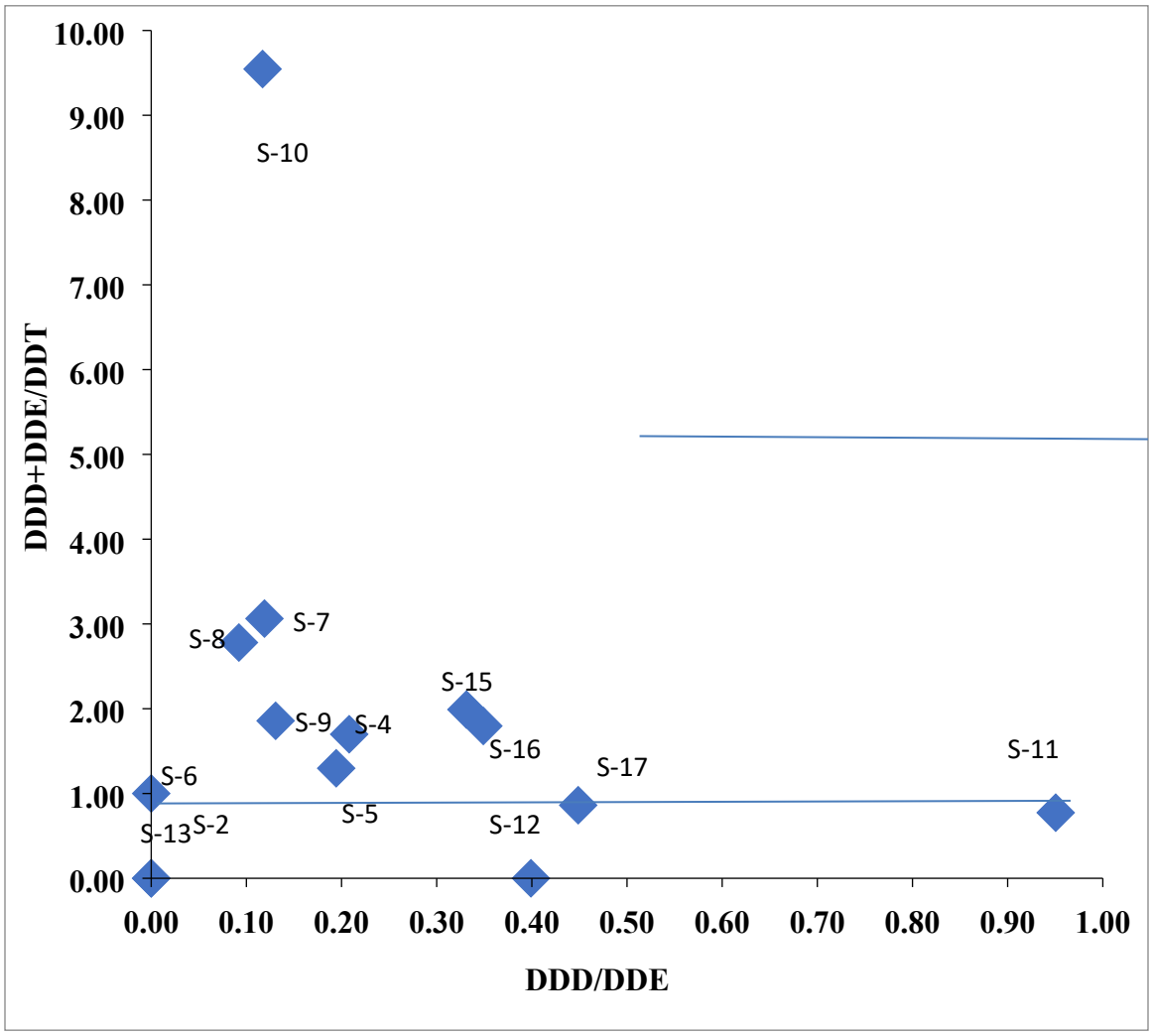
Table S4.

Studied Zones													
Dioxin Like PCBs pg TEQs/g (Soil)	**TEF**	**FMZ**			**WMZ**			**ARZ**			**LLZ**		
		Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
PCB-118	0.00003	0.001	0.011	0.005	0.000	0.007	0.004	0.002	0.003	0.003	0.000	0.007	0.003
PCB-114	0.00003	0.000	0.010	0.002	0.000	0.001	0.000	0.000	0.002	0.001	0.000	0.004	0.001
PCB-105	0.00003	0.003	0.016	0.007	0.000	0.001	0.001	0.000	0.004	0.002	0.000	0.011	0.005
PCB-156	0.00003	0.000	0.009	0.004	0.000	0.000	0.000	0.000	0.002	0.001	0.000	0.005	0.003
∑Mono-ortho DL-PCBs		**0.005**	**0.042**	**0.019**	**0.001**	**0.007**	**0.004**	**0.002**	**0.009**	**0.006**	**0.002**	**0.026**	**0.012**
PCB-77	0.0001	0.000	0.024	0.005	0.000	0.001	0.000	0.000	0.003	0.001	0.000	0.001	0.001
PCB-126	0.1	6.720	139.417	33.421	0.000	1.455	0.978	0.000	12.682	6.054	6.430	24.778	12.877
PCB-169	0.03	0.443	13.331	4.979	0.000	0.600	0.150	0.000	0.246	0.061	0.000	8.642	2.998
Non-ortho DL-PCBs		**8.386**	**152.77**	**38.405**	**0.000**	**1.601**	**1.128**	**0.000**	**12.928**	**6.116**	**6.783**	**33.420**	**15.875**

Table S6. Atmospheric circulation over the sampling sites and their % age contribution.

Sites	Ist air source	2nd air source	3rd air source	4rth air source
S-1 (Hunza)	75% Central Asia	15% Local	10% China	
S-2 (Gilgit)	76 Central Asia	14% Local	9% China	
S-3 (Skardu)	53% Local	36% Central Asia	11% eastern side	
S-4 (Swat)	22 % North direction Central Asia	47% northwest part of Asia	32% northwest part of Asia	
S-6 (Abbottabad)	40% local	27% local	27% Central Asia	6% Regional
S-7 (Swabi)	58% local	42% Central Asia		
S-8 (Nowshera)	40% Central Asia	32% Local	28% local	
S-9 (Mianwali)	20% Central Asia	31% Local	23% Regional	25% Local Punjab
S-10 (Bhakkar)	42% Central Asia	59% Local Punjab		
S-11 (Layyah)	19% Central Asia	26% Regional	55% local Near Karachi	
S-12 (D.G Khan)	13% Central Asia	46% Regional	41% Southwest Arabian Sea	
S-13 (Sukkur)	31% Central Asia	62% Southwest	8% South Arabian Sea	
S-14 (Khairpur)	28% Central Asia	63% SW Arabian Sea	8% South Arabian Sea	
S-15 (Hyderabad)	12% South Arabian Sea	67% SW Arabian Sea	22% Arabian Sea	
S-17 (Islamabad)	36% Central Asia	64% Local		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4.00
3.00
2.00
1.00
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DDD+DDE/DDT
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
DDD/DDE
S-10
S-7
S-8
S-15
S-9
S-4
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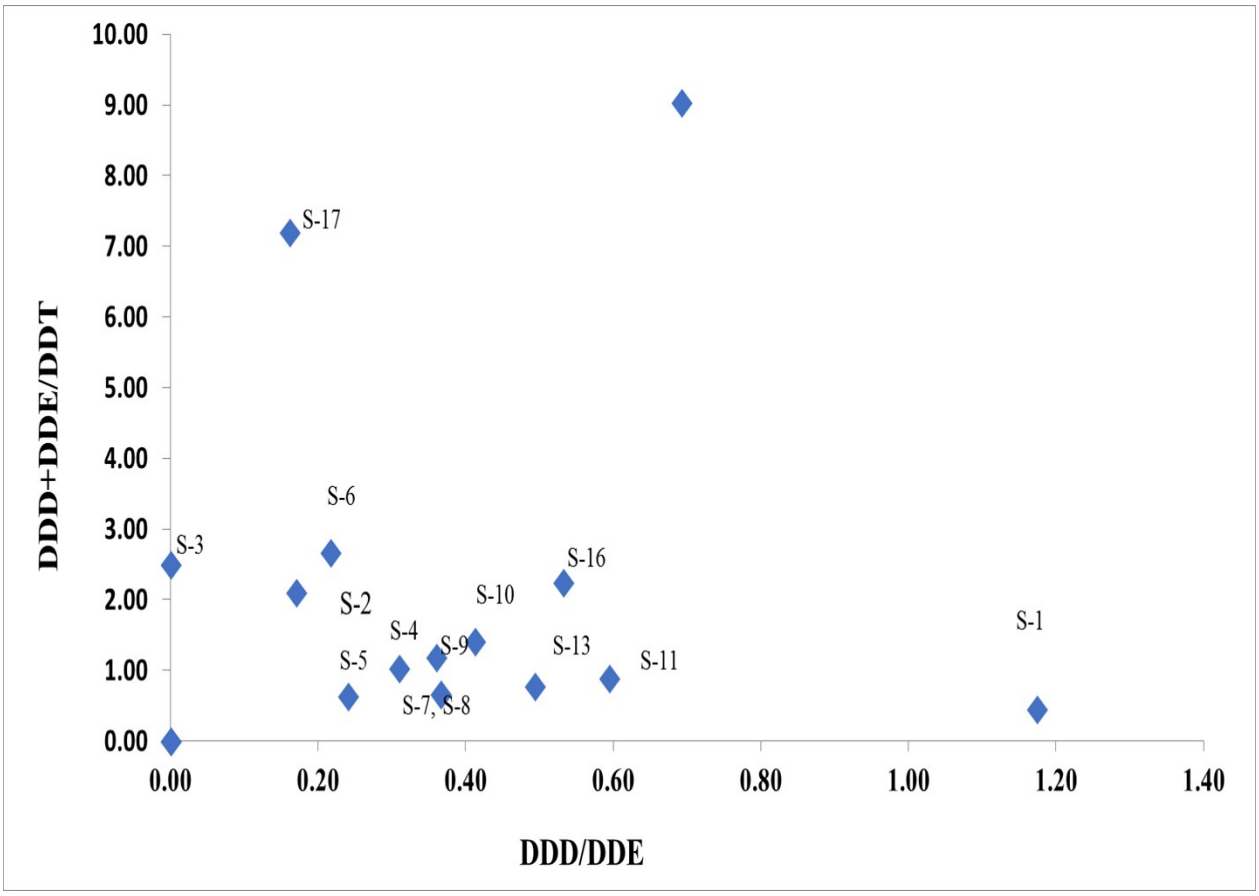
S-17
S-11
S-6
S-13
S-2
S-5
S-12

Figure S1.


10.00
9.00
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4.00
3.00
2.00
1.00
0.00
DDD+DDE/DDT
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
DDD/DDE
S-17
S-6
S-3
S-16
S-2
S-10
S-4
S-9
S-13
S-1
S-5
S-11
S-7, S-8

Figure S2.

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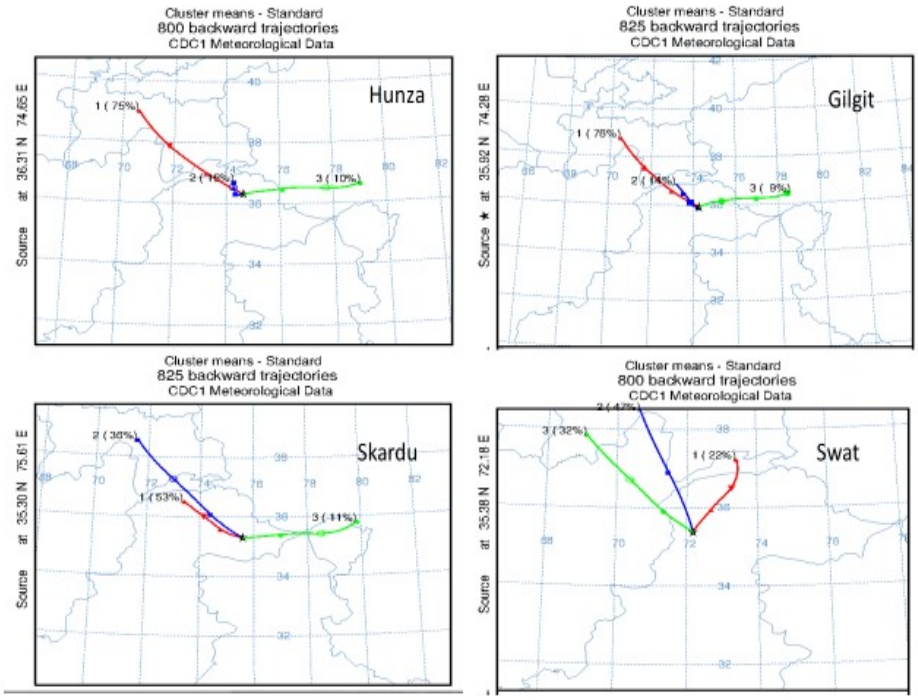
Cluster means - Standard
800 backward trajectories
CDC1 Meteorological Data
Hunza
Source at 36.31 N 74.65 E
1 (75%)
3 (10%)
Cluster means - Standard
825 backward trajectories
CDC1 Meteorological Data
Gilgit
Source at 35.92 N 74.28 E
1 (78%)
3 (9%)
Cluster means - Standard
825 backward trajectories
CDC1 Meteorological Data
Skardu
Source at 35.30 N 75.61 E
2 (36%)
1 (53%)
3 (11%)
Cluster means - Standard
800 backward trajectories
CDC1 Meteorological Data
Swat
Source at 35.38 N 72.18 E
3 (32%)
1 (22%)

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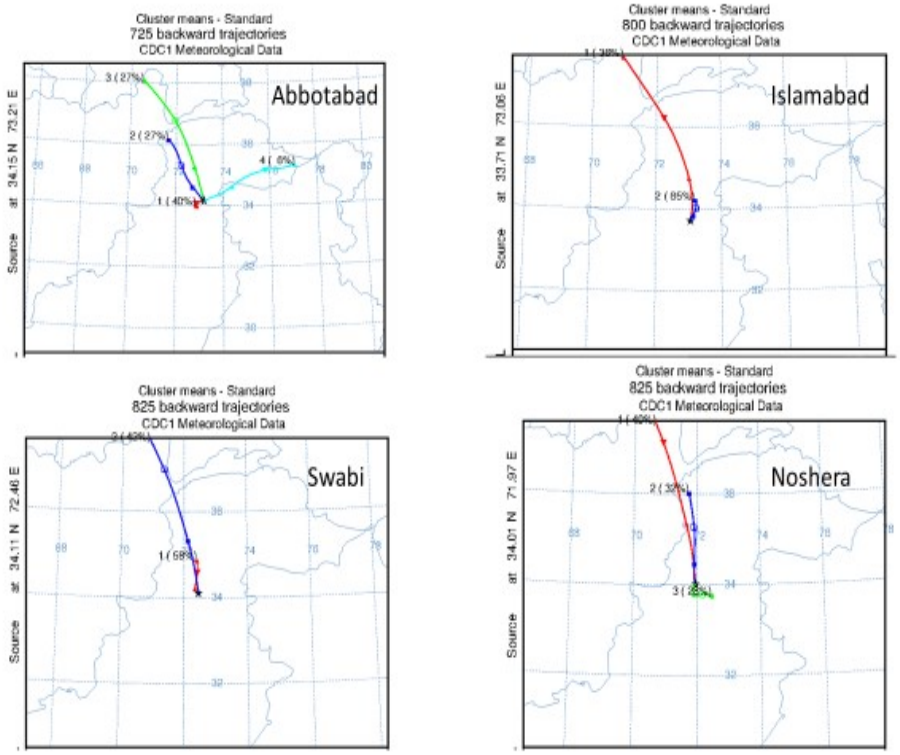
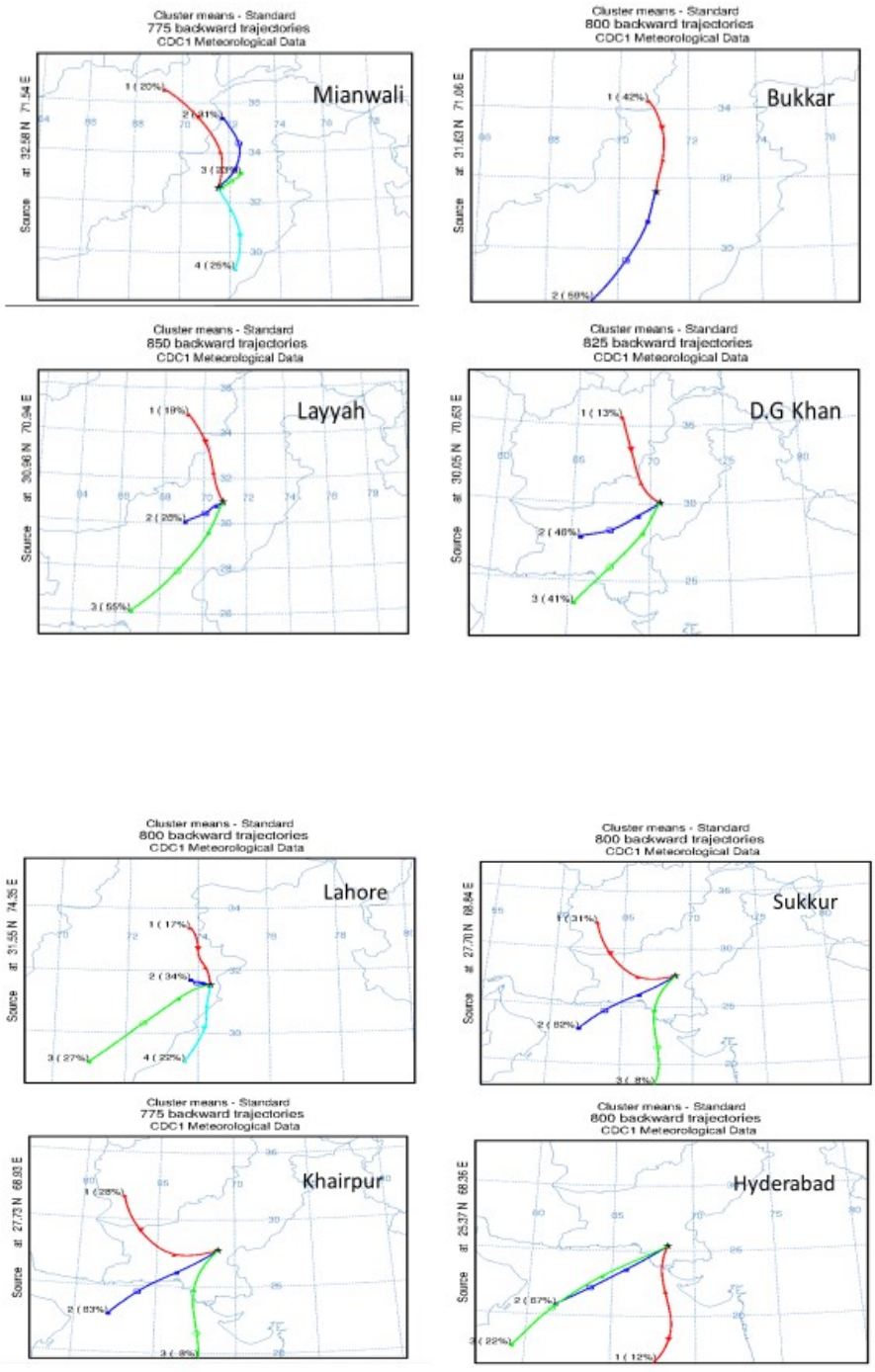

Cluster means - Standard
725 backward trajectories
CDC1 Meteorological Data
Abbotabad
Source at 34.15 N 73.21 E
3 (27%)
2 (27%)
4 (6%)
1 (40%)
Cluster means - Standard
800 backward trajectories
CDC1 Meteorological Data
Islamabad
Source at 33.71 N 73.06 E
2 (85%)
Cluster means - Standard
825 backward trajectories
CDC1 Meteorological Data
Swabi
Source at 34.11 N 72.46 E
1 (58%)
Cluster means - Standard
825 backward trajectories
CDC1 Meteorological Data
Noshera
Source at 34.01 N 71.97 E
2 (32%)
3 (28%)



148 **Figure S3.**

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