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Environmental Risk Assessment for $PM_{2.5}$ Pollution from Non-Point Sources in the Mining Area Based on Multi-Source Superposition and Diffusion

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Supplementary Materials: Table S1: Multiyear meteorological conditions in Qipanjing town (1988-2018), Table S2: The formulas, parameter values and significances of emission factors and total emission of particulate matter emission sources in the mining area, Table S3: Data of production and operation in the mining area, Table S4: The sources of the model data and Settings, Table S5: Regional wind speed and wind frequency statistics in 2018, Table S6: Parameters of pollution sources in different scenarios for simulation.

Table S1. Multiyear meteorological conditions in Qipanjing town (1988-2018)

parameter	value	parameter	value	parameter	value	parameter	value
Annual sunshine hours	3000 h	Average relative humidity over the years	42%	Maximum permafrost thickness	1 m	Frost-free period	122 d
Average temperature over the years	6.4 ℃	Average annual precipitation	250 mm（The maximum is in July and August, accounting for more than 60%）	Average annual evaporation	3000 mm	Dry degree	4.05
Annual mean wind speed	3.2 m/s	Maximum instantaneous wind speed over the years	32 m/s	The number of gale days with wind force≥7	36.2 d（ concentrated in winter and spring）	High frequency wind direction over the years	West, northwest, north

Table S2. The formulas, parameter values and significances of emission factors and total emission of particulate matter emission sources in the mining area

Number	Formula/Parameter	Unit	Value	Significance
(1)	$E_{Pi} = k_i \times (sL)^{0.91} \times (W)^{1.02} \times (1-\eta)$	g/km		PM_i emission coefficient of

				paved road
	k_i	g/km	3.23	Particle size multiplier of $PM_{2.5}$ in dust
	sL	g/m^2	15.3	Dust load on road
	w	t	14/54	Average vehicle weight with no load/full load
	η	%	0.66	TSP removal efficiency for paved roads
(2)	$E_{UPi} = \frac{k_i (S/12) \times (V/30)^a}{(M/0.5)^b} \times (1-\eta)$	g/km		PM_i emission coefficient of unpaved road
	k_i	g/km	50.742	Particle size multiplier of $PM_{2.5}$ in dust
	a		0.5	$PM_{2.5}$
	b		0.2	$PM_{2.5}$
	s	%	0.45	Effective dust deposition rate on road surface [1]
	v	km/h	40	Average speed
	M	%	0.025	Road dust moisture content [1]
	η	%	0	$PM_{2.5}$ removal efficiency for unpaved roads
(3)	$W_{Ri} = E_{Ri} \times L_R \times (1 - \frac{n}{365}) \times 10^{-6}$	t/a		Total PM_i emissions from road dust sources
	E_{Ri}	g/km		Average emission coefficient of PM_i in road dust sources
	L_R	km	8.55×10^6/1.28×10^7	Driving length on paved/unpaved roads
	n	Day	46	Days without dust, replaced by days with more than 0.25mm/d of precipitation in a year
(4)	$E_h = k_i \times 0.0016 \times \frac{(u/2.2)^{1.3}}{(M/2)^{1.4}} \times (1-\eta)$	kg/t		Emission coefficient of dust from material handling
	k_i		0.053	Particle size multiplier of $PM_{2.5}$ in dust
	u	m/s	2.6	Average surface wind speed
	M	%	0.032	Material moisture content
	η	%	0	$PM_{2.5}$ removal efficiency for loading and unloading
(5)	$W_{Yh} = \sum_{i=1}^{n} (E_h \times G_{Yi} \times 10^{-3})$	t/a	1.71×10^8	Total emissions of particulate matter emitted from loading, unloading and transportation in the yard
	n			Total times of loading and unloading of stockpile per year
	G_{Yi}	t		The weight of the material during the i th loading and unloading process

(6)	$E_W = k_i \times \sum_{i=1}^{n} P_i \times (1-\eta) \times 10^{-3}$	kg/m²		Emission coefficient of dust from wind erosion on exposed surface of the yard
	k_i		0.2	Particle size multiplier of $PM_{2.5}$ in dust
	n			The number of times the stock piles are disturbed per year
	η	%	0.14	$PM_{2.5}$ removal efficiency for dumps and quarries
			0.49	$PM_{2.5}$ removal efficiency for coal piles
(7)	$P_i = \begin{cases} 58 \times (u^* - u_t^*)^2 + 25 \times (u^* - u_t^*) \left(u^* > u_t^* \right) \\ 0 \left(u^* \le u_t^* \right) \end{cases}$	g/m²		Wind erosion potential of the maximum observed wind speed in the i th disturbance
	u_t*	m/s	0.41/0.64/0.67	Threshold friction wind speed of coal piles [2] /stone piles [2] /dumps [3]
(8)	$u^* = 0.4u(z) / \ln\left(\frac{z}{z_0}\right)(z > z_0)$	m/s		Friction wind speed
	$u(z)$	m/s		The ground wind speed
	z	m	10	The detection height of ground wind speed
	z_0	m	0.2	Surface roughness
(9)	$W_{YW} = E_W \times A_Y \times 10^{-3}$	t/a		Total particulate matter emissions from wind-erosion of the stock piles
	A_Y	m²	1.26×10^8	The exposed surface area of mine pits and dumps
			1.16×10^7	The exposed surface area of the quarries
			9.90×10^6	The exposed surface area of coal piles

Table S3. Data of production and operation in the mining area

Parameter	Value	Parameter	Value
Production scale of open-pit mining enterprises（10^4 t/a）	512.5	Production scale of white ash enterprises（10^4 t/a）	795
Production scale of well mining enterprises（10^4 t/a）	1815	Stripping ratio of open pit mines	10
Ratio of solid waste to mining amount in white ash enterprises	10	The ratio of solid waste to mining amount in well mining enterprises	0.5
Average mileage per vehicle（km）	5	Total transportation distance（km）	21381250
Ratio of paved to unpaved roads	2/3	The total weight of materials handled or transported（10^4 t/a）	17105
Area of mine pits and dumps（hm²）	9866.67	The area of quarries（hm²）	1158.35
Area of coal piles（hm²）	773.67	The dead weight of a coal truck（t）	14
The load of a coal truck（t）	40		

Table S4. The sources of the model data and Settings

Data	Value	Data	Value
Study area size	100 km×70 km	resolution ratio	1 km
Longitude coordinates range	635047.8 E-706047.8 E	Latitude coordinate range	4326978 N-4426978 N
Surface meteorological data	3h ground observation data of Etoke Banner Station in 2018 (http://gis.ncdc.noaa.gov/map/viewer/#app=clim&cfg=cdo&theme=hourly&layers=1&node=gis)	Upper-air meteorological data	Radiosonde data from the Linhe station in 2018 (http://weather.uwyo.edu/wyoming/)
Terrain data	90m resolution DEM from SRTM (https://srtm.csi.cgiar.org/)	Land use data	Eurasian land use dataset with 1km resolution (http://src.com/calpuff/data/land_use.html)
Emission intensity of source	$PM_{2.5}$ emission inventory in mining areas	Location of WS weather stations	713786.8 E，4352092.7 N

Table S5. Regional wind speed and wind frequency statistics in 2018

Wind direction	Wind speed (m/s)						The total frequency (%)
	0.5 - 1.5	1.5-3.0	3.0-5.0	5.0-7.0	7.0-10.0	10.0-13.5	
WNW	1.33	1.07	**3.28**	2.03	1.73	0.44	9.89
N	1.96	2.47	1.99	1.11	0.33	0.07	7.93
NW	1.18	1.40	2.69	1.73	0.85	0.04	7.89
NNE	1.55	2.21	2.20	1.01	0.55	0.07	7.60
W	2.03	1.11	1.77	1.62	0.81	0.15	7.49
NNW	1.44	1.33	2.21	1.36	0.77	0.11	7.23
SSE	1.51	2.25	2.30	0.75	0.26	0.00	7.07
S	1.73	2.14	1.66	0.81	0.15	0.04	6.53
SW	1.73	1.96	2.10	0.41	0.04	0.00	6.23
WSW	2.29	1.29	1.73	0.59	0.22	0.00	6.12
SSW	2.29	1.51	1.33	0.63	0.07	0.00	5.83
SE	1.18	1.33	1.49	0.55	0.11	0.00	4.66
ESE	1.00	1.25	1.96	0.44	0.00	0.00	4.65
NE	1.03	0.92	1.70	0.70	0.07	0.00	4.43
E	0.92	1.00	1.18	0.52	0.00	0.00	3.61
ENE	0.44	0.52	1.00	0.18	0.00	0.00	2.14

Table S6. Parameters of pollution sources in different scenarios for simulation

	Code	X1 (m)	Y1 (m)	X2 (m)	Y2 (m)	X3 (m)	Y3 (m)	X4 (m)	Y4 (m)	Emission intensity (t/(m²•y))	Elevation (m)	Effective height (m)
Scenario 1	A1	666436	4366490	668436	4366490	668436	4364490	666436	4364490	3.0e-5	1273	3
Scenario 2	A2	665436	4367490	666436	4367490	666436	4366490	665436	4366490	3.0e-5	1273	3

	A3	668436	4367490	669436	4367490	669436	4366490	668436	4366490	3.0e-5	1273	3
	A4	665436	4364490	666436	4364490	666436	4363490	665436	4363490	3.0e-5	1273	3
	A5	668436	4364490	669436	4364490	669436	4363490	668436	4363490	3.0e-5	1273	3
Scenario 3	A6	664436	4368490	665436	4368490	665436	4367490	664436	4367490	3.0e-5	1273	3
	A7	669436	4368490	670436	4368490	670436	4367490	669436	4367490	3.0e-5	1273	3
	A8	664436	4363490	665436	4363490	665436	4362490	664436	4362490	3.0e-5	1273	3
	A9	669436	4363490	670436	4363490	670436	4362490	669436	4362490	3.0e-5	1273	3
Scenario 4	A10	665436	4365990	669436	4365990	669436	4364990	665436	4364990	3.0e-5	1273	3
Scenario 5	A11	666936	4367490	667936	4367490	667936	4363490	666936	4363490	3.0e-5	1273	3

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