Supplementary Information

Title: Different response characteristics of ambient hazardous trace metals and health impacts to global lockdown

Authors: Wenwen Sun[a b c 1], Xing Liu[d 1], Rui Li[e *]

Affiliations: [a] *Department of Research, Shanghai University of Medicine & Health Sciences Affiliated Zhoupu Hospital, Shanghai 201318, China*

[b] *Shanghai Key Laboratory of Atmospheric Particle Pollution and Prevention (LAP^3), Department of Environmental Science and Engineering, Fudan University, Shanghai 200433, China*

[c] *College of Medical Technology, Shanghai University of Medicine & Health Sciences, Shanghai 201318, China*

[d] *State Environmental Protection Key Laboratory of Coastal Ecosystem, National Marine Environmental Monitoring Center, Dalian 116023, China*

[e] *Key Laboratory of Geographic Information Science of the Ministry of Education, School of Geographic Sciences, East China Normal University, Shanghai, 200241, PR China*

*** Corresponding author**

Prof. Rui Li (rli@geo.ecnu.edu.cn)

[1]Wenwen Sun and Xing Liu contributed to the work equally.

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Number of figures: 15

Number of tables: 2

Text 1 The development of anthropogenic trace metal emission inventory.

This study quantifies global anthropogenic atmospheric emissions of nine high-toxicity trace metals (As, Cd, Cr, Cu, Mn, Ni, Pb, V, and Zn) by integrating dynamic emission factors with activity levels across source categories. The calculation methodologies for different source sectors are summarized as follows:

$$E(t)=\sum_i\sum_j\sum_k[A_{i,j,k}(t)\times C_{i,j,k}(t)\times R_{i,j}\times(1-\eta_{PM})(1-\eta_{SO_2})(1-\eta_{NOx})\quad(1)$$

$$E(t)=\sum_i(F\times C_{Pb}\times A_i)\quad(2)$$

$$E(t)=\sum_i\sum_m\sum_n(N_{i,m}\times M_m\times EF_{EF}^{TSP}\times C_n^v)\quad(3)$$

$$E(t)=\sum_i\sum_j[A_{i,j}(t)\times EF_j^{nc}(t)]\quad(4)$$

where (1), (2), (3) and (4) represent the calculation equations for coal combustion by power plants, industrial sectors and other sectors, Pb emission from vehicle gasoline combustion, brake wear, and coal combustion by residential sectors and non-coal combustion sources power plants, respectively. where E(t) is the anthropogenic atmospheric emissions of As, Cd, Cr, Cu, Mn, Ni, Pb, V, and Zn; EF^c and EF^{nc} denote the emission factors for coal combustion and non-coal combustion sources in calendar year t, respectively; A represents the annual activity level, while C is the average concentration of each trace metal in coal; R indicates the fraction of trace metals released into flue gas from coal combustion facilities; η_{PM}, η_{SO2}, and η_{NOx} represent the average removal efficiencies of trace metals by conventional $PM/SO_2/NO_x$ emission control devices, respectively; F represents the proportion of lead in gasoline emitted to the atmosphere. C_{Pb} is the average content of Pb in the gasoline; N denotes the vehicle population; M is the average annual mileage driven by vehicle in category m (passenger car, bus and coach, light-duty truck, and heavy-duty vehicle); EF^{TSP} is the emission factor of total suspended particles (TSP) for brake pad by vehicle category m.

All of the countries are classified into five clusters and each cluster possessed different EF by source categories. The detailed emission factors used in our study were collected from Zhu et al. (2020).

Text 2 The natural emission inventory of trace metals.

The natural trace metal emissions, including those from soil dust, biomass burning, and sea salt spray, were also estimated in our study. The detailed equations are summarized as follows:

$$W_i(t) = \sum_j \sum_k c_{i,k} \times E_{j,k} \times A_{j,k} \quad (1)$$

$$W_i(t) = \sum_{j,k} c_i \times EF_{j,k} \times A_{j,k} \quad (2)$$

$$W_i(t) = \sum_{j,k} c_i \times F_j \times V_j \times A_k \times \rho_k \quad (3)$$

where (1), (2), and (3) represent the calculation equations for the trace metal emissions from soil dust, biomass burning and sea salt, respectively.

In the equation 1, W(t) represents trace metal emissions from soil dust; c is the average mass concentration of each element in the soil; E represents the emission factors for total suspended particulates (TSP); A is the exposed area of different land use type j in each country k, which represents activity level of this source while subscript i stands for different types of trace metals.

In the equation 2, W(t) denotes trace metal emissions from biomass burning; c is the average mass ratio of elements i in terrestrial plants; EF is the emission factor of TSP. Most of trace metals are released from the particulate matters in combustion processes, and thus particulate matters emissions are applied to estimate emissions of trace metals indirectly; A represents the activity level of biomass burning.

In the equation 3, W_i is emission of element i derived from sea salt aerosol spray; c_i is the average mass concentration for element i in seawater; F is sea spray flux of radius j; V represents the volume of aerosol particles of radius j; A is sea area, and r denotes seawater density; k refers to different oceans.

Table S1 Recommended values of the parameters for health risk assessment of trace metals.

Parameter	Adult	Child	Unit
InhR	16.5	8.6	m^3/d
EF	365	365	d/a
ED	24	6	a
BW	70	15	kg
Cancer AT	70*365	70*365	d
Non-cancer AT	ED*365	ED*365	d

Table S2 Reference dose (RfD) (mg kg^{-1} d^{-1}) and cancer slope factor (CSF) (kg d mg^{-1}) of selected trace elements in references.

Element	RfD	CSF
As	3×10^{-4}	1.5
Cd	1×10^{-3}	6.3
Cr	3×10^{-3}	5×10^{-1}
Cu	4×10^{-3}	/
Mn	1.4×10^{-5}	/
Ni	2.1×10^{-2}	9×10^{-1}
Pb	2×10^{-2}	5×10^{-1}
V	/	/
Zn	3×10^{-1}	/

Figure S1 The sampling sites of ambient hazardous trace metals at the global scale. The pink color denotes the sampling sites. The colobar reflects the elevation (m).

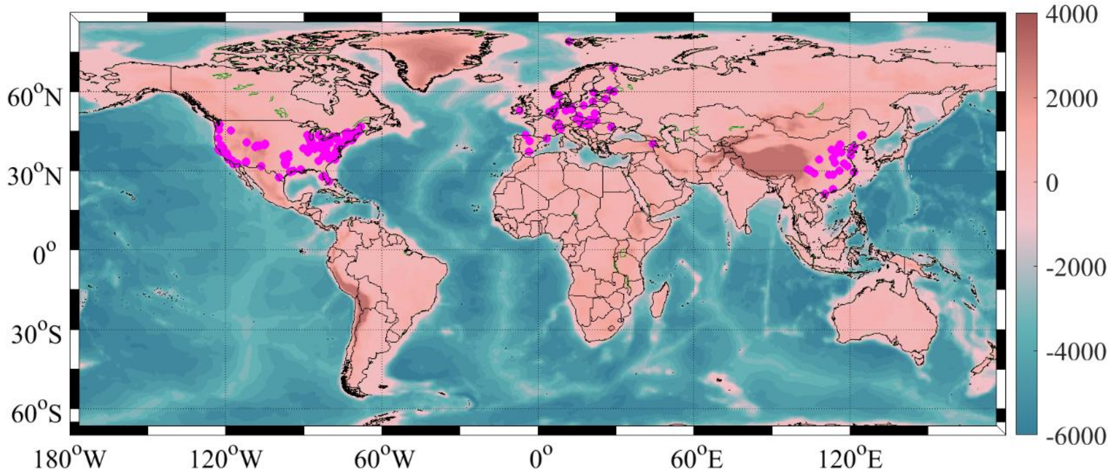

Figure S2 The global variations of ambient trace element concentrations (mean values) during January-April in 2019. The colorbar reflects the concentrations of trace elements.

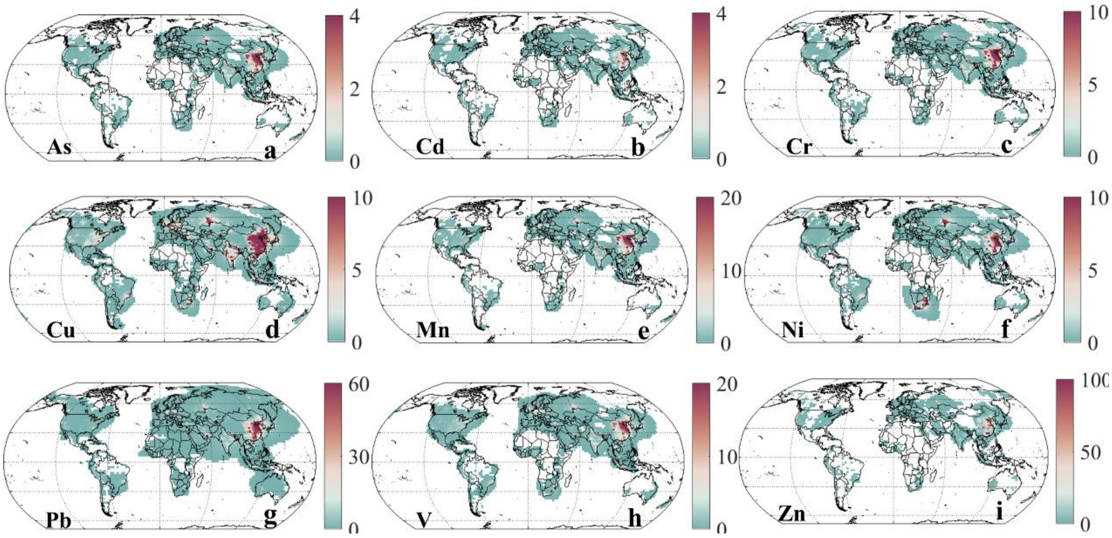

Figure S3 The global variations of ambient trace element concentrations (mean values) during January-April in 2020. The colorbar reflects the concentrations of trace elements.

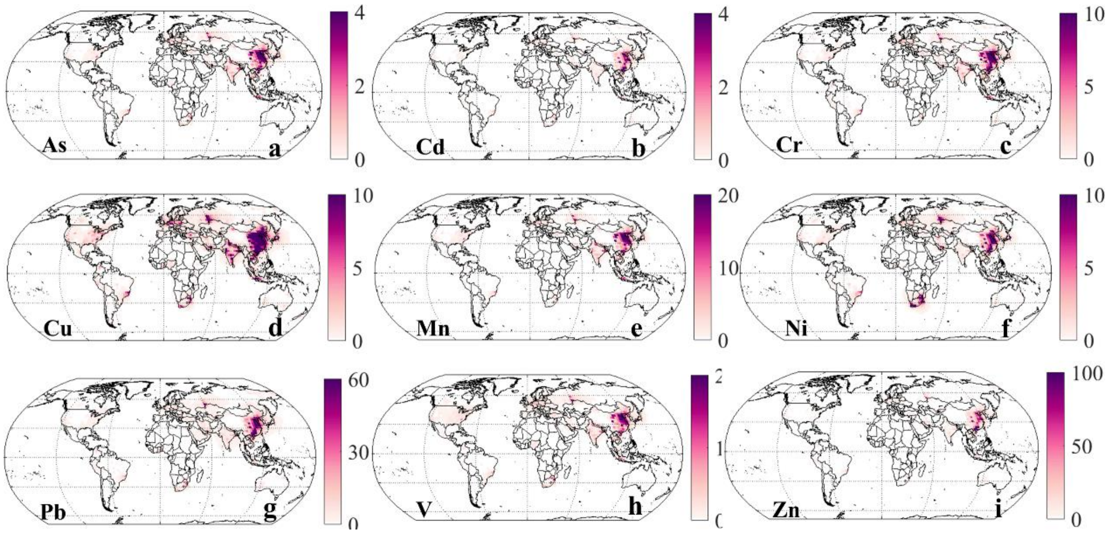

Figure S4 The violin graphs of nine trace elements including As (a), Cd (b), Cr (c), Cu (d), Mn (e), Ni (f), Pb (g), V (h), and Zn (i) in eight major regions during January-April in 2019. Chi, Ind, WE, NA, SA, SS, Rus, and Aus represent China, India, West Europe, North America, South America, Sub-Sahara Africa, Russia, and Australia, respectively.

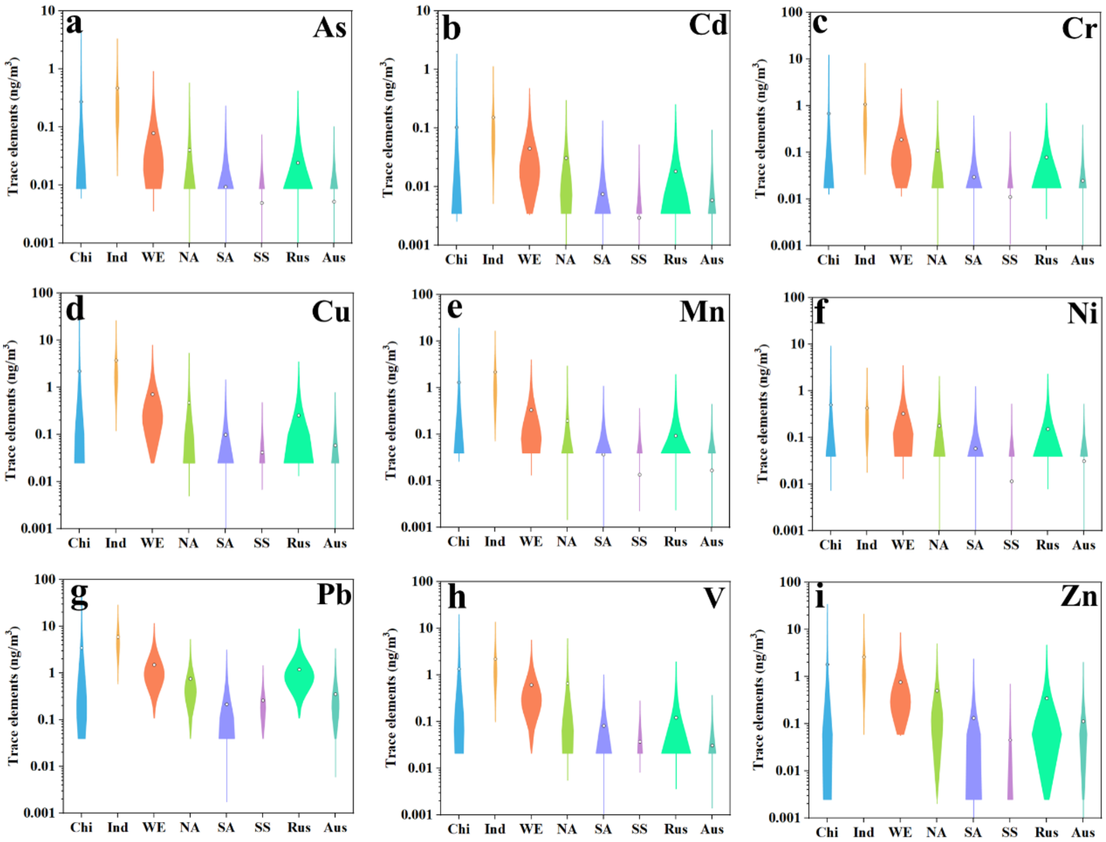

Figure S5 The emission and meteorological contributions to ambient Cd concentrations during 2019-2020 at global and eight major regions.

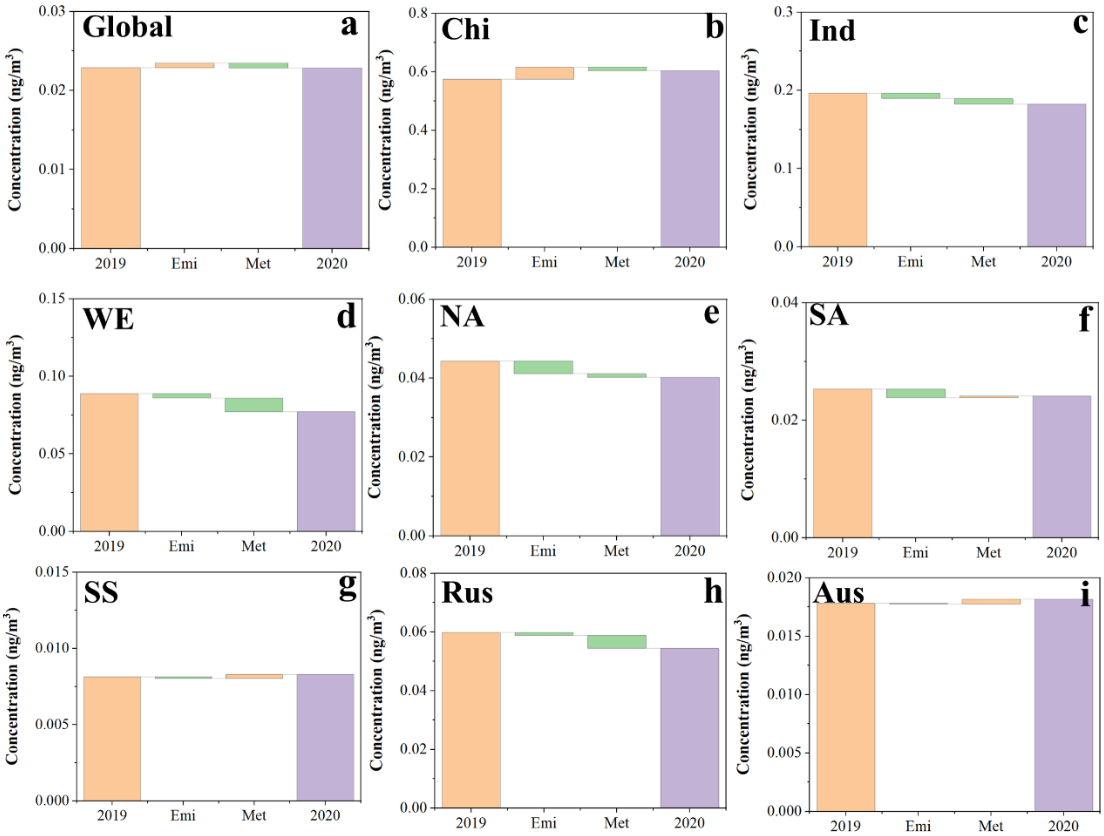

Figure S6 The emission and meteorological contributions to ambient Cr concentrations during 2019-2020 at global and eight major regions.

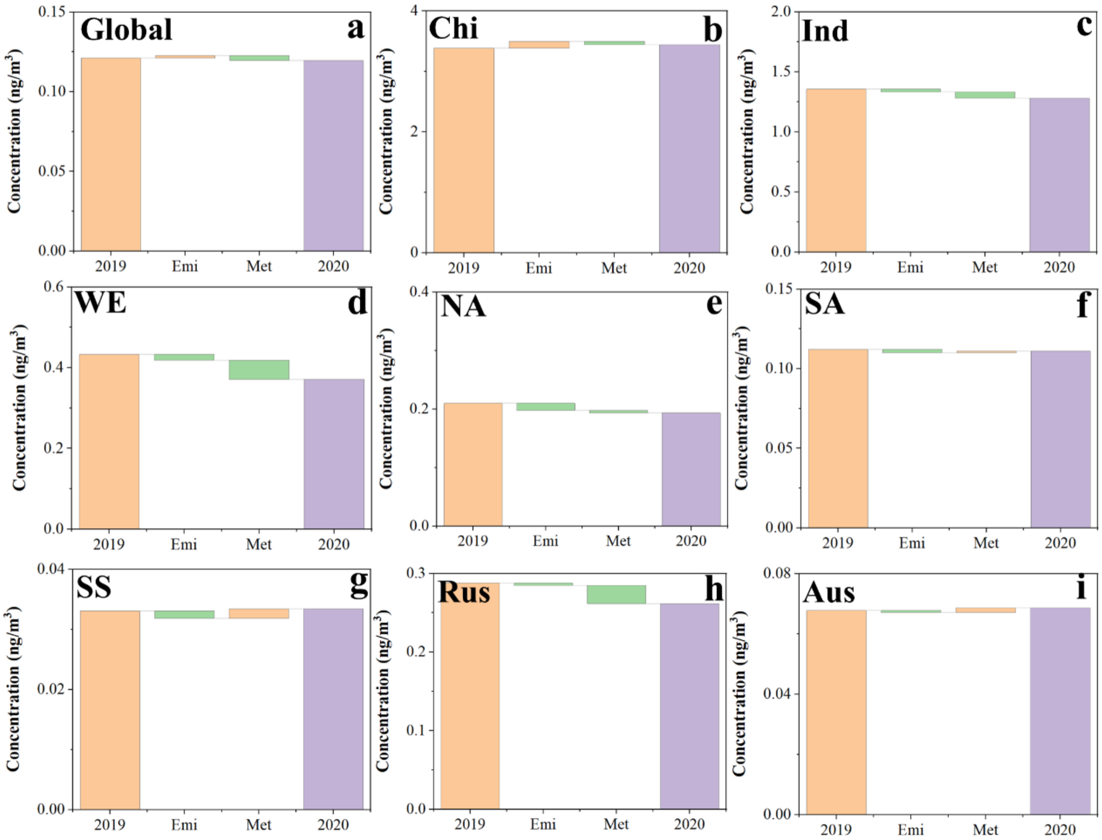

Figure S7 The emission and meteorological contributions to ambient Cu concentrations during 2019-2020 at global and eight major regions.

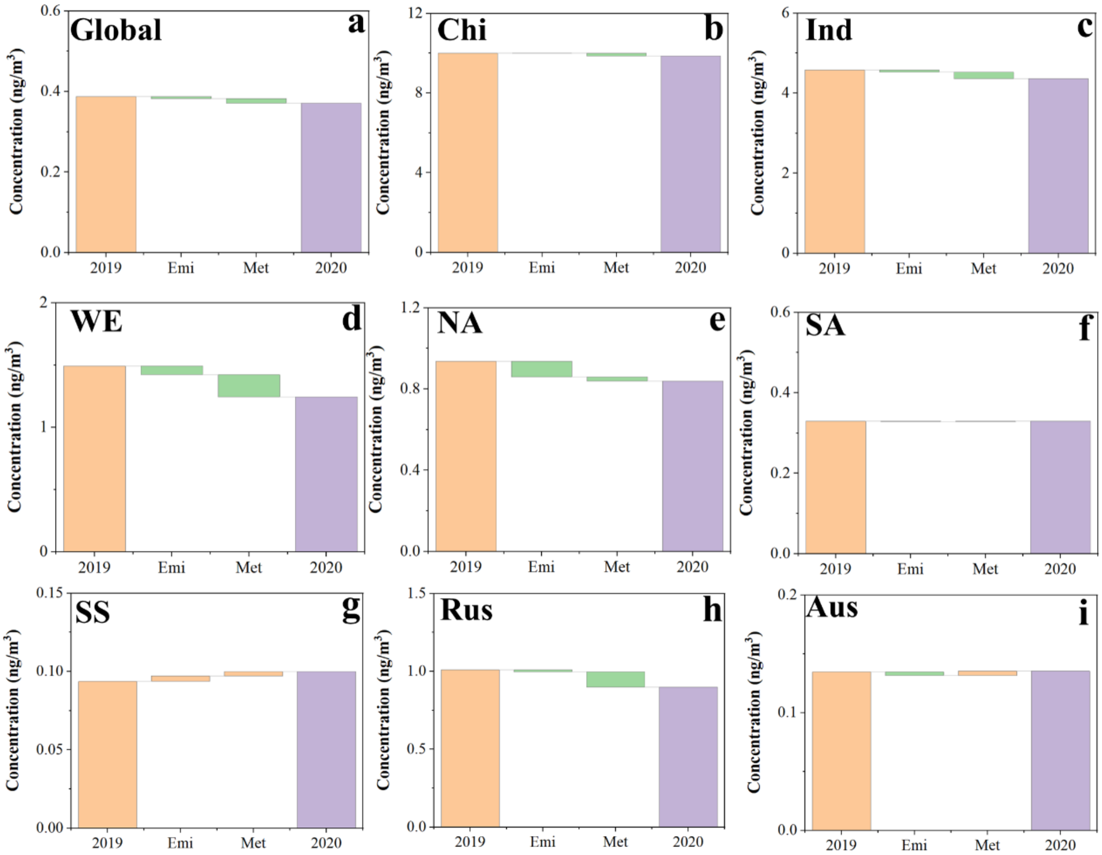

Figure S8 The emission and meteorological contributions to ambient Mn concentrations during 2019-2020 at global and eight major regions.

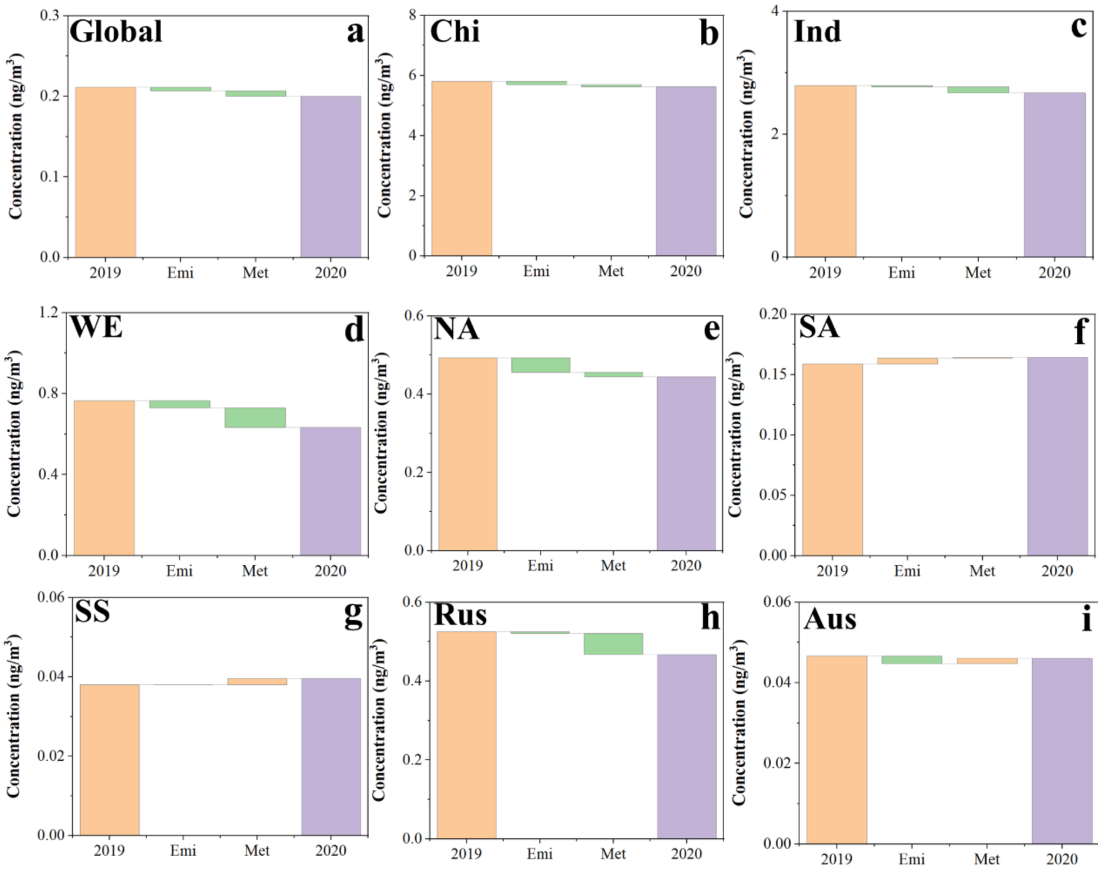

Figure S9 The emission and meteorological contributions to ambient Ni concentrations during 2019-2020 at global and eight major regions.

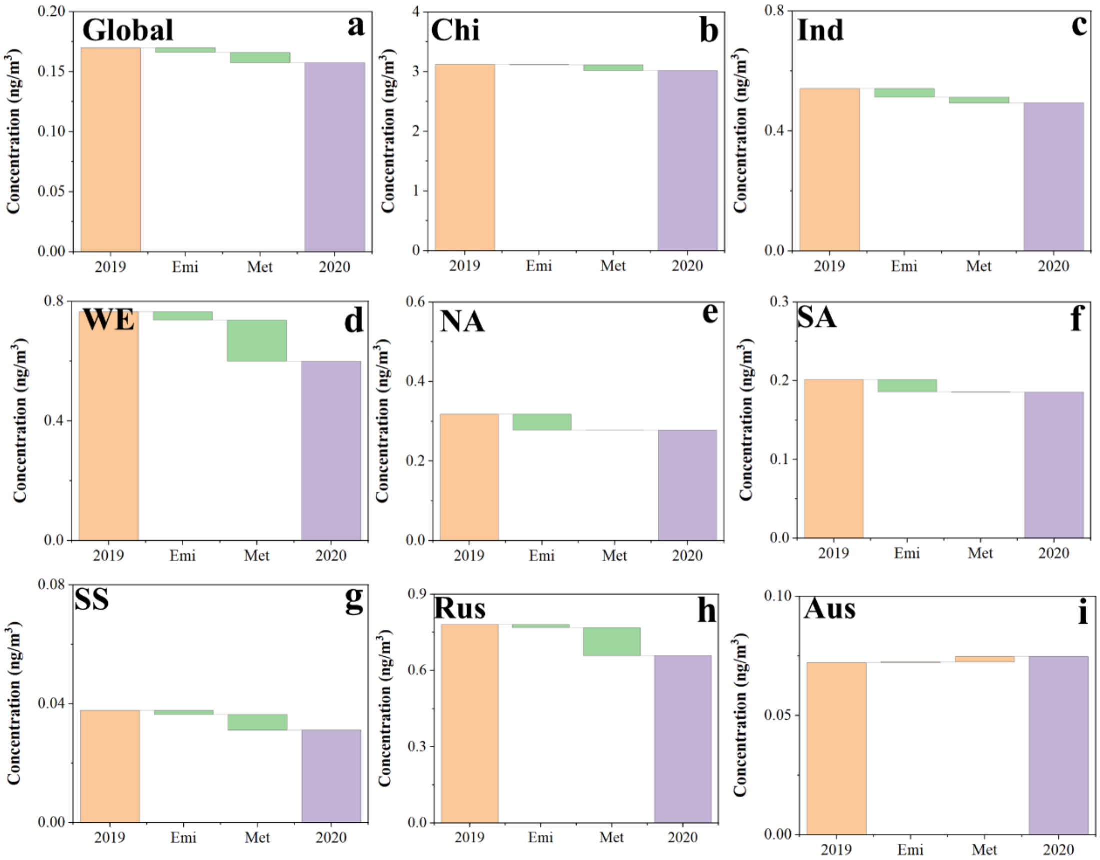

Figure S10 The emission and meteorological contributions to ambient Pb concentrations during 2019-2020 at global and eight major regions.

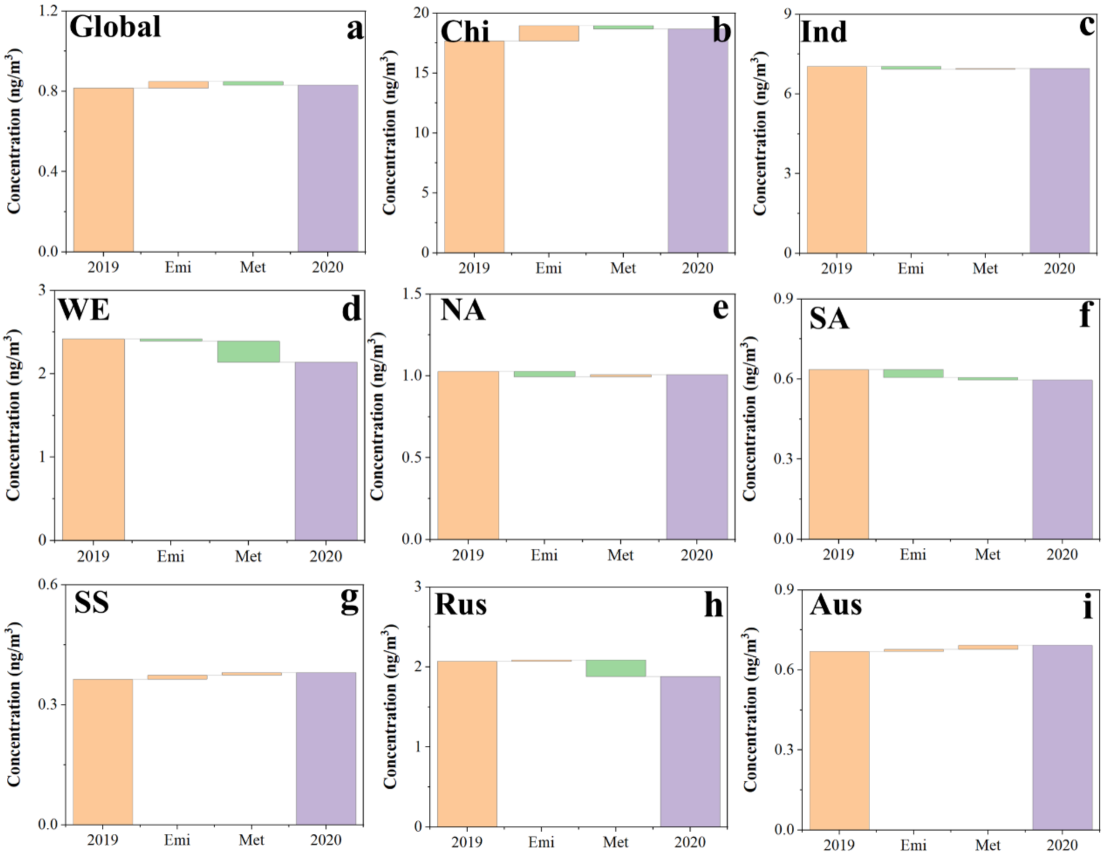

Figure S11 The emission and meteorological contributions to ambient V concentrations during 2019-2020 at global and eight major regions.

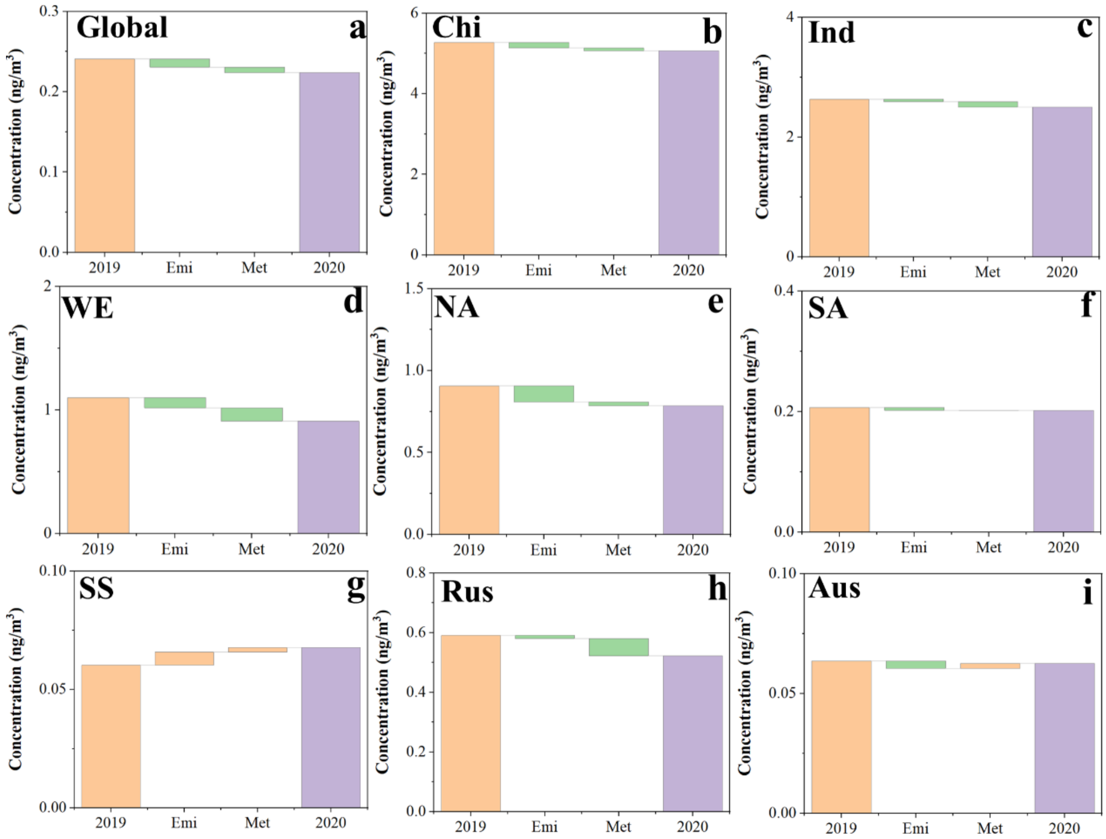

Figure S12 The emission and meteorological contributions to ambient Zn concentrations during 2019-2020 at global and eight major regions.

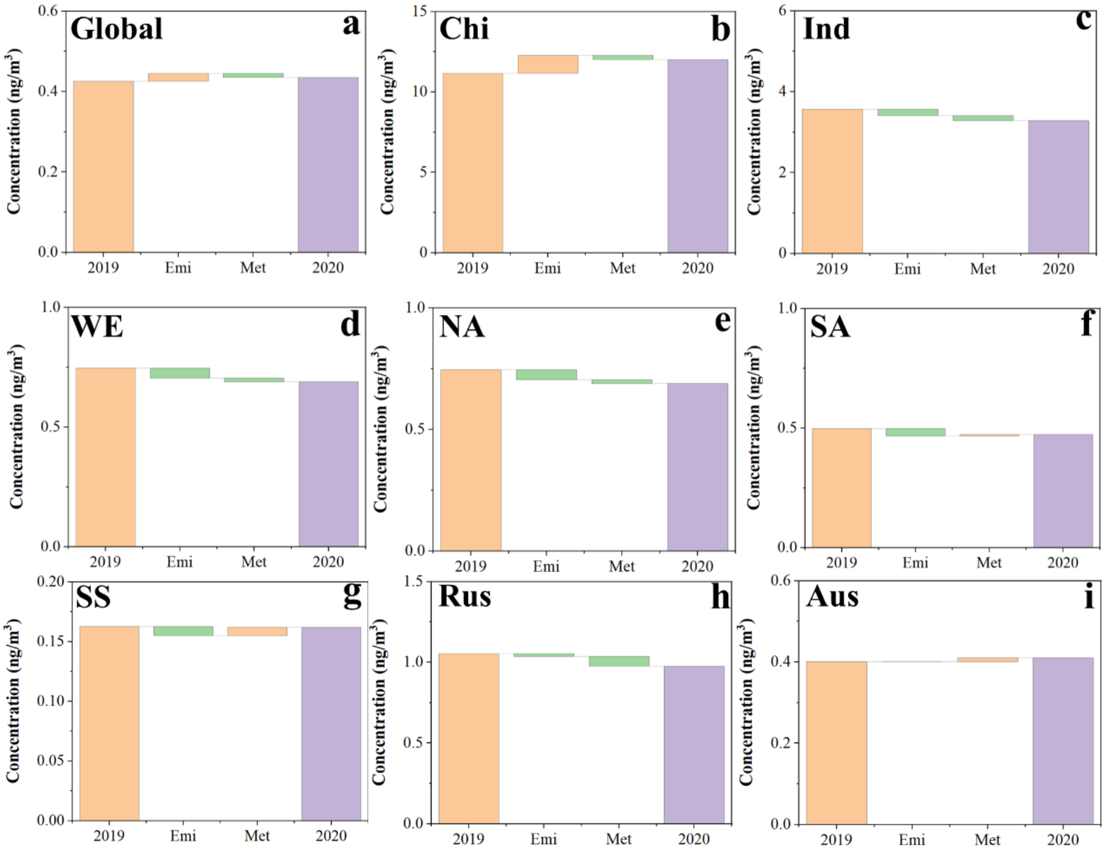

Figure S13 The ambient trace metal concentrations in major regions on the global scale in different emission scenarios. R, R_20%, R_40%, R_60%, and R_80% represent the global emission reduction ratios of 0% (base), 20%, 40%, 60%, and 80%, respectively.

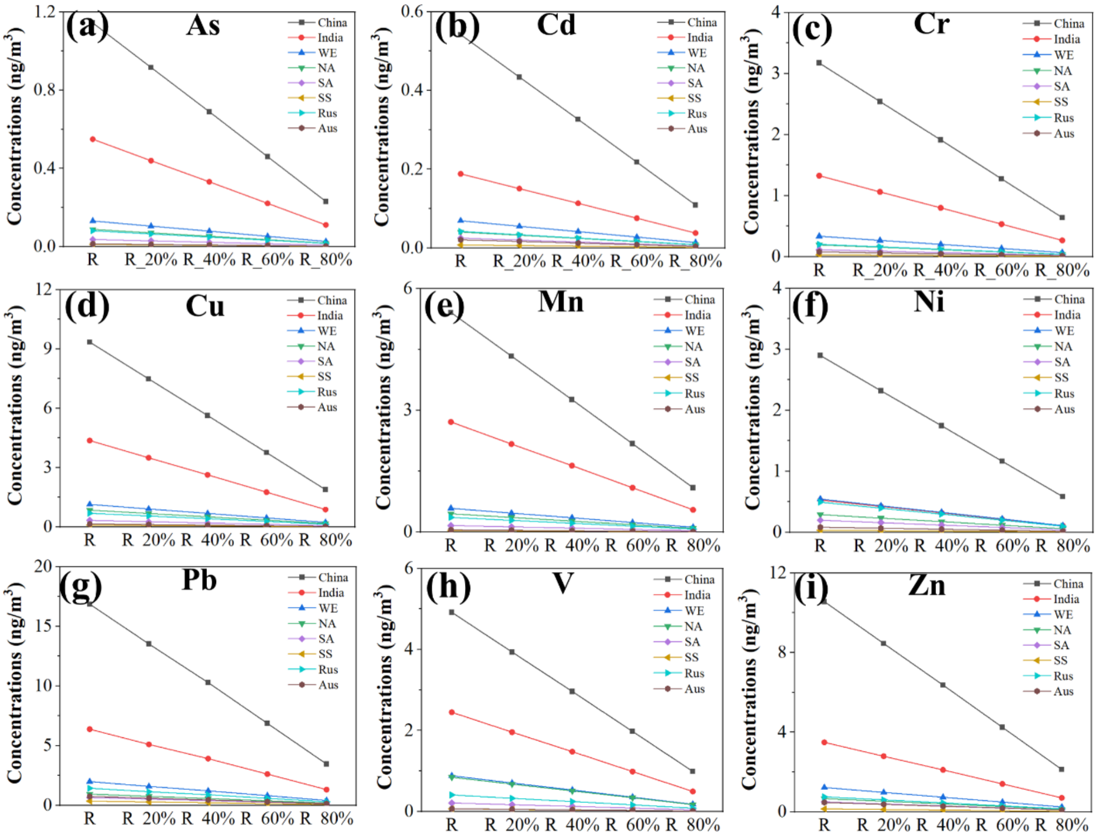

Figure S14 The total CR and HQ values of adults (a and c) and children (b and d) for all of the nine hazardous trace metals during January-April in 2019.

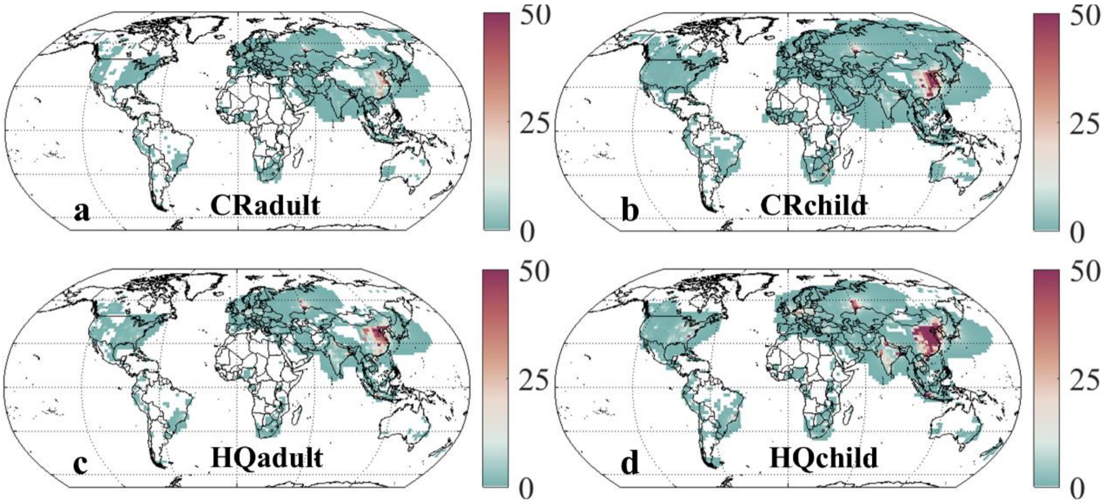

Figure S15 The total CR and HQ values of adults (a and c) and children (b and d) for all of the nine hazardous trace metals during January-April in 2020.