

Supporting information

Localized Regional Environmental Risk in Mountainous Urban Areas of Southwest China: Identification, Assessment, and Management Strategies in Kunming

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Fig. S1. Identified hotspots areas in Kunming in 2022. The color gradient represents the intensity of environmental risks, with darker blue color indicating higher risk levels and lighter red color indicating lower risk levels.

Fig. S2. Distribution of (a) water and (b) atmospheric environmental risk index in Kunming in 2022.

Fig. S3. Correlations of population density, GDP, industrial output, and comprehensive environmental risk index (R_C).

Table S1 Identification of environmental risk source intensity index (S).

Table S2 Identification of vulnerability index (V).

Table S3 Identification of management capability index (M).

Table S4 Identified 136 key regulated enterprises.

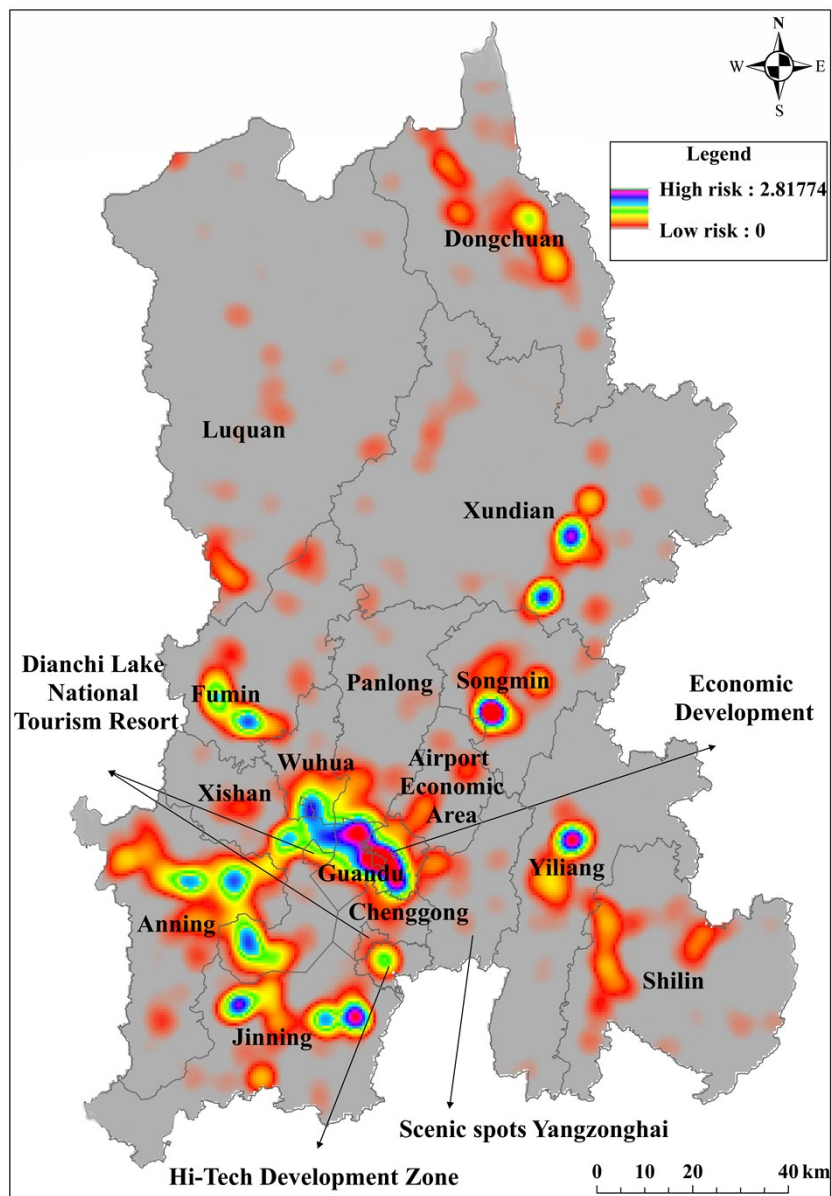


Fig. S1. Distribution of identified hotspots areas in Kunming in 2022. The color gradient represents the intensity of environmental risks, with darker blue color indicating higher risk levels and lighter red color indicating lower risk levels.

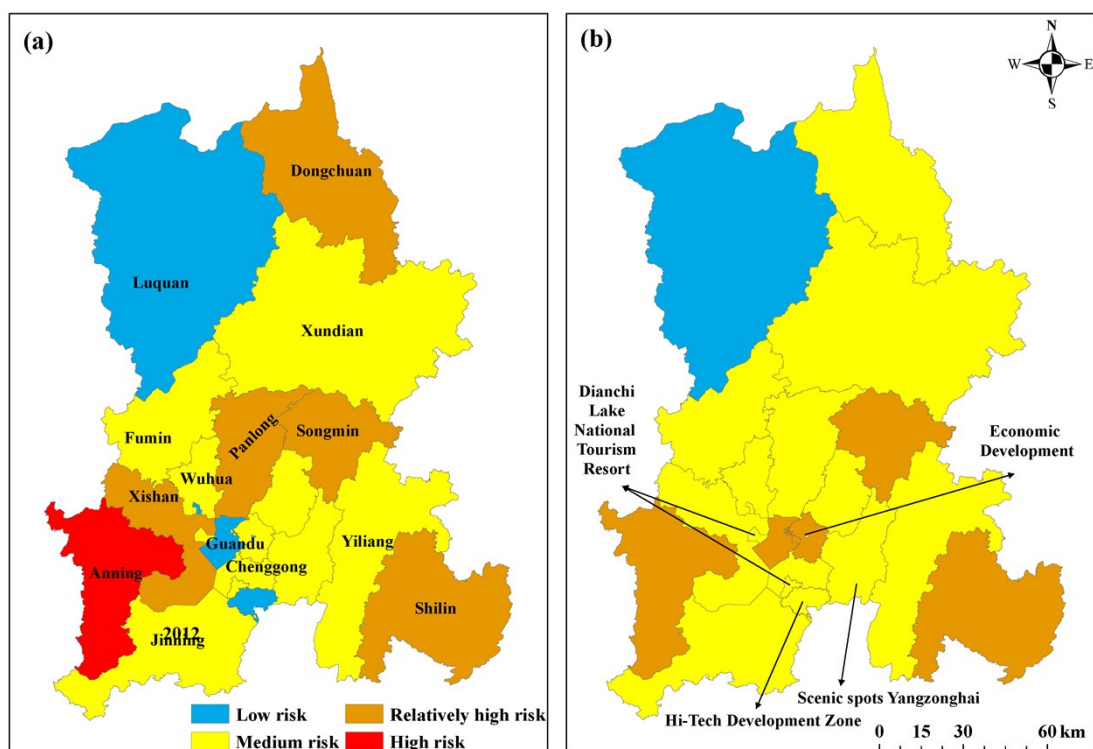


Fig. S2. Distribution of (a) water and (b) atmospheric environmental risk index in Kunming in

2022.

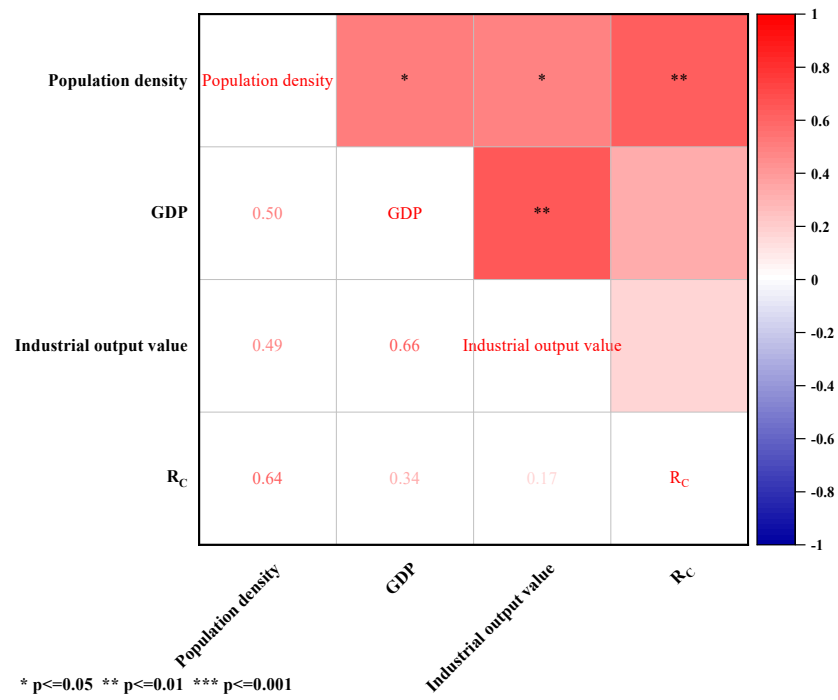


Fig. S3. Correlations of population density, GDP, industrial output, and comprehensive environmental risk index (R_C).

Table S1 Identification of environmental risk source intensity index (S).

Evaluation indicators	Data sources	Water environmental risk source intensity index (S_W)		Atmospheric environmental risk source intensity index (S_A)		Comprehensive environmental risk source intensity index (S_C)	
		Distribution	Value	Distribution	Value	Distribution	Value
Number of environmental risk enterprises per unit area	Environmental	> 0.5	12	> 0.5	15	> 1	12
	Protection Department,	(0.05-0.5]	9	(0.05-0.5]	11	(0.1-1]	9
	enterprise	(0.005-0.05]	5	(0.005-0.05]	6	(0.01-0.1]	5
	environmental risk assessment report	[0-0.005]	0	[0-0.005]	0	[0-0.01]	0
The ratio of the stock of environmental risk substances per unit area to the critical quantity	Environmental	> 50	12	> 50	15	> 100	12
	Protection Department,	(25, 50]	5	(25, 50]	8	(50, 100]	5
	enterprise environmental risk assessment report	≤ 25	0	≤ 25	0	≤ 50	0
The percentage of enterprises with relatively high environmental risks	Environmental	> 50	11	> 50	10	> 65	11
	Protection Department,	(20-50]	7	(20-50]	6	(30-65]	7
	enterprise	(10-20]	4	(10-20]	2	(15-30]	4
	environmental risk assessment report	≤ 10	0	≤ 10	0	≤ 15	0
Annual transportation of hazardous chemicals by road	The Ministry of Communication	> 300	20	> 300	25	> 300	20
		(30, 300]	12	(30, 300]	15	(30, 300]	12
		(3, 30]	4	(3, 30]	5	(3, 30]	4
		≤ 3	0	≤ 3	0	≤ 3	0
Number of tailings	Ministry of	≥ 3	10	/	/	> 5	10

ponds with relatively high environmental risk levels and above	Environmental Protection	2	6			[3-5]	6
		1	2			[1-2]	2
		0	0			0	0
Cross regional situation of oil, natural gas, and finished oil long-distance pipelines	Safety Supervision Department	Crossing Class I and Class II surface water environmental functional zones and protection targets	10	Crossing densely populated areas	10	Crossing Class I and Class II surface water environmental functional zones and protection targets or population concentration areas	10
		Crossing Class III and IV surface water environmental functional zones and protection targets	6	Not crossing population concentration areas	2	Crossing Class III and IV surface water environmental functional zones and protection targets	6
		Crossing Class V and Inferior Class V Surface water environmental functional zones and protection objectives	2			Crossing Class V and inferior Class V surface water environmental functional zones and protection objectives	2
The number and impact of sudden environmental incidents in the past five years	Ministry of Environmental Protection	The number of sudden water environmental incidents is ≥ 1 , and the number of sudden water environmental incidents with larger or higher	25	The number of sudden atmospheric environmental incidents is ≥ 1 , and the number of sudden atmospheric environmental incidents	25	The number of sudden environmental incidents is ≥ 2 , and the number of major and higher-level sudden environmental incidents is ≥ 1	15

		levels is ≥ 1		with larger or higher levels is ≥ 1			
		The number of sudden water environmental incidents is ≥ 1 , and there are no major or higher-level sudden water environmental incidents	13	The number of sudden atmospheric environmental incidents is ≥ 1 , and there are no major or higher-level sudden atmospheric environmental incidents	13	The number of sudden environmental incidents is ≥ 1 , and there are no major or higher-level sudden environmental incidents	8
		No sudden water environmental incidents occur	0	No sudden atmospheric environmental incidents occur	0	No sudden environmental incidents occurred	0
Number of environmental complaints	Ministry of Environmental Protection	/	/	/	/	> 300	10
			/	/	/	[201, 300]	7
			/	/	/	[100, 200]	4
			/	/	/	< 100	0

Note: The table has removed the characteristic environmental risk source indicators mentioned in the risk assessment index system for sudden environmental events, and the weights of the removed indicators have been distributed to other indicators at the same level as this indicator.

Table S2 Identification of vulnerability index (V).

Evaluation indicators	Water environmental risk receptor vulnerability (V _W)		Atmospheric environmental risk receptor vulnerability (V _A)		Comprehensive environmental risk receptor vulnerability (V _W)	
	Distribution	Value	Distribution	Value	Distribution	Value
Water quality categories of important water circulation channels	Class I and II	15	/	/	Class I and II	10
	Class III and IV	7			Class III and IV	5
	Class V, inferior	0			Class V, inferior Class	0
	Class V				V	
Water network density index	> 50	15	/	/	> 50	10
	(25, 50]	7			(25, 50]	5
	[0, 25]	0			[0, 25]	0
Pollution wind frequency in residential areas	/	/	> 20%	40	> 20%	10
			(13%-20%]	26	(13%-20%]	7
			[5%-13%]	13	[5%-13%]	4
			< 5%	0	< 5%	0
Number of permanent residents per unit area (person/km ²)	/	/	/	/	> 1500	10
					(1000, 1500]	7
					[500, 1000]	4
					< 500	0
Number of environmental risk receptors per unit area (number/km ²)	≥ 0.5	15	≥ 0.5	40	≥ 0.5	20
	[0.1-0.5)	10	[0.1-0.5)	26	[0.1-0.5)	14
	[0.01-0.1)	5	[0.01-0.1)	13	[0.01-0.1)	8
	< 0.01	0	< 0.01	0	< 0.01	0
Number of centralized	> 10	15	/	/	> 10	10

drinking water sources in townships and above	[5, 10]	10			[5, 10]	7
	[1, 4]	5			[1, 4]	4
	0	0			0	0
Number of populations served by centralized drinking water source areas in townships and above	> 10	20			> 100	10
	[7, 10]	14	/	/	[50, 100]	7
	[3, 7)	8			[30, 50)	4
	< 3	0			< 30	0
Per capita GDP level	< 3	20	< 3	20	< 3	20
	[3, 5)	14	[3, 5)	14	[3, 5)	14
	[5, 10)	8	[5, 10)	8	[5, 10)	8
	≥ 10	0	≥ 10	0	≥ 10	0

Table S3 Identification of management capability index (M).

Evaluation indicators	Data sources	Water environmental risk management capability (M _W)		Atmospheric environmental risk management capability (M _A)		Comprehensive environmental risk management capability (M _C)	
		Distribution	Value	Distribution	Value	Distribution	Value
Monitoring and warning ability	Ministry of Environmental Protection	No emergency monitoring or environmental quality monitoring points have been set up	20	Less than 50% of enterprises with environmental risks related to toxic and harmful gases install toxic and harmful gas warning devices	20	No water environment emergency monitoring points have been set up, and less than 50% of enterprises involved in toxic and harmful gas environmental risks install toxic and harmful gas warning devices	20
		Only set up environmental quality monitoring points	10	More than 50% and less than 80% of enterprises with environmental risks related to toxic and harmful gases shall install toxic and harmful gas warning devices	10	Emergency monitoring points for water environment have been set up, and toxic and harmful gas warning devices have been installed in enterprises with environmental risks related to toxic and harmful gases ranging from 50% to 80%	10
		Set up emergency monitoring and environmental quality monitoring points	0	More than 80% of enterprises with environmental risks related to toxic and harmful gases install toxic and harmful gas warning devices	0	Emergency monitoring points for water environment have been set up, and over 80% of enterprises with environmental risks related to toxic and harmful gases have installed toxic and harmful gas warning devices	0
The	Government	Inadequate interception,	20	/	/	Inadequate interception, diversion,	20

interception, dilution, and disposal capabilities of pollutants	Emergency Departments	diversion, dilution, and physicochemical processing capabilities				dilution, and physicochemical processing capabilities	
		Possess one of the capabilities in interception, diversion, dilution, and physicochemical treatment	10			Possess one of the capabilities in interception, diversion, dilution, and physicochemical treatment	10
		Possess two of the capabilities in interception, diversion, dilution, and physicochemical treatment	0			Possess two of the capabilities in interception, diversion, dilution, and physicochemical treatment	0
Preparation status of environmental emergency plans	Government Emergency Departments	No special emergency plan, and no relevant content in the department and plan	15	No special emergency plan, and no relevant content in the department and plan	20	Have no special emergency plan in place	10
		No special emergency plan, but have relevant content in the department's emergency plan or government's emergency plan	8	No special emergency plan, but have relevant content in the department's emergency plan or government's emergency plan	10	Have only one government emergency plan or departmental emergency plan	5
		Have a special emergency plan in place	0	Have a special emergency plan in place	0	Have a special emergency plan in place	0
Environmental emergency decision-making support	Environmental Emergency Department	/	/	/	/	No specialized environmental emergency agency or department has been established, and no emergency expert group for sudden environmental incidents has been established	15

				Environmental emergency specialized agencies or departments have been established, but no emergency expert group for sudden environmental incidents has been established				7
				Environmental emergency specialized agencies or departments have been established, and an emergency expert group for sudden environmental incidents has been established				0
Number of environmental emergency personnel	Environmental Emergency Department	Not meeting the standards	15	Not meeting the standards	20	Not meeting the standards	10	
		Level 3	6	Level 3	8	Level 3	4	
		Level 2	3	Level 2	4	Level 2	2	
		Level 1	0	Level 1	0	Level 1	0	
Emergency material reserves	Environmental Emergency Department	Local materials cannot meet the emergency needs of the event, and there is no information on material reserves in other regions	15	Local materials cannot meet the emergency needs of the event, and there is no information on material reserves in other regions	20	Local materials cannot meet the emergency needs of the event, and there is no information on material reserves in other regions	15	
		Local materials cannot meet the emergency needs of the event, but there is information on the reserve of materials in other regions that can be called up	7	Local materials cannot meet the emergency needs of the event, but there is information on the reserve of materials in other regions that can be called up	10	Local materials cannot meet the emergency needs of the event, but there is information on the reserve of materials in other regions that can be called up	7	

		Local materials basically meet the emergency needs of the event and do not need to be called from other areas	0	Local materials basically meet the emergency needs of the event and do not need to be called from other areas	0	Local materials basically meet the emergency needs of the event and do not need to be called from other areas	0
Environmental emergency monitoring capability	Environmental Monitoring Department	Not meeting the standards	15	Not meeting the standards	20	Not meeting the standards	10
		Level 3	6	Level 3	8	Level 3	5
		Level 2	3	Level 2	4	Level 2	2
		Level 1	0	Level 1	0	Level 1	0

Table S4 Identified 136 key regulated enterprises.

Administrative area	Number	Enterprises
Wuhua	4	Yunnan Copper Co., LTD. Southwest copper branch
		Yunnan Cloud copper and zinc industry Co., LTD
		Fumin salary metallurgy industry and trade Co., Ltd. Wuhua branch
		Kunming Pharmaceutical Group Co., LTD
Panlong	1	Kunming acetate fiber Co., LTD
Guandu	2	Kundong oil Depot, Kunming Petroleum Branch, China
		Petrochemical Sales Co., LTD
		Yangfangwa oil storage depot, Yunnan Petroleum Co., LTD., China Aviation Oil Group
Xishan	23	Yunnan petrochina Kunlun Gas Co., LTD. Kunming West Branch (Xishan)
		Yunnan Yuntianhua fluorine chemical Co., LTD
		Yunnan Tianyao Chemical Co., LTD
		Kunming Shenghong new material manufacturing Co., LTD
		Kunming Hewei Dongli Fuel Co., LTD
		Tianchi logistics limited liability company Haikou branch
		Yunnan Shengwei Chemical Co., LTD
		Yunnan phosphating Group Haikou phosphorus industry Co., LTD
		Kunming Yunpanshan Phosphorus chemical Co., LTD
		Yunnan Weng Fu Yun Tianhua fluorine chemical Technology Co., LTD
		Yunnan third ring chemical fertilizer Co., LTD
		Yunnan Baker Gini Tianchuang phosphate Co., LTD
		Yunnan Sanhuan Xinsheng fertilizer Co., LTD
		Yunnan Zhengbang technology Co., LTD
		Kunming Tongda phosphorus industry Co., LTD
		Zhongguang Yilan (Group) Co., LTD
		Yunnan Xinzhengda Phosphorus Chemical Co., LTD
		China National Petroleum and Natural Gas Pipeline Network Group Co., LTD. South China Branch Yunnan Oil Transmission Division 1 (Xishan)

Dongchuan	6	Kunming Fengde environmental protection electric power Co., LTD
		Sinopec Sales Co., Ltd. Yunnan Kunming Chenggong gas station
		Sinopec Sales Co., LTD. Kunming Chenggong Gas Station (B)
		Kunming Chuan Jin Nuo Chemical Co.,Ltd.
		Yunnan red rich fertilizer Co., LTD
		Kunming Xuxin environmental protection technology Co., LTD
		Kunming new Neidu non-ferrous metal Co., LTD
		Kunming Jinsida Technology Co., LTD
		Yunnan Sanjing waterproof building materials Co., LTD
		Yunnan Ruilang Environmental Engineering Co., LTD
Anning	26	Yunnan Kaling environmental protection Engineering Co., LTD
		Yunnan Xiangfeng Jinmai Chemical Co., LTD
		Yunnan Tianan Chemical Co., LTD
		Yunnan Yuntianhua Petrochemical Co., LTD
		Kunming Yunneng Chemical Co., LTD
		Yunnan Xiangfeng Petrochemical Co., LTD
		Petrochina Yunnan Petrochemical Co., LTD
		Wuhan Iron and Steel Group Kunming Iron and Steel Co., LTD. New branch
		Yunnan Hongxiang Chemical Co., LTD
		Yunnan energy Investment chemical Co., Ltd. Kunming company
		Yunnan Coal energy Co., LTD. Anning branch
		Yunnan Shanshi Chemical Co., LTD
		Yunnan Anning Xingming chemical plant
		Yunnan Kungang Jiahua cement building Materials Co., LTD
		Anning Yinzhou Chemical Co., LTD
		Yunnan Sinopec High-speed Petroleum Co., LTD. Kunming Anning Shupu Gas Station (Station A)
		Yunnan Sinopec High-speed Petroleum Co., LTD. Kunming Anning Shupu Gas Station (Station B)
		Sinopec Sales Co., Ltd. Yunnan Kunming Changpo oil depot
		Kunming Iron and Steel Group limited liability company power energy branch
		Anning city Hongyuan economic and trade co., Ltd. phosphating

		factory
		Polyfluoro (Kunming) Technology Development Co., LTD
		Kunming Huiquan high purity semiconducting material Co., LTD
		Anning Dyke Fine chemical Co., LTD
		Yunnan Kaiyu photoelectric technology Co., LTD
		Anning Yunzhou new building materials Co., LTD
		China National Petroleum Company Limited Southwest pipeline
		Kunming oil and gas branch Anning first station
		Yunnan Hongxiang Chemical Co., LTD. Anning City
		Yuanbaoshan phosphate rock
		Yunnan Jinning yellow phosphorus Co., Ltd. second street branch
		Yunnan Yunda technology agrochemical Co., LTD
		Kunming Wenfeng fertilizer manufacturing Co., LTD
		Yunnan Zhongzheng Chemical Industry Co., LTD
		Jinning oil depot of Yunnan Qianglin Petrochemical Group Co., LTD
		Yunnan Xingkun Chemical Co., LTD
		Yunnan Zesen Environmental protection Technology Co., LTD
		Yunnan phosphating Group Co., LTD. Phosphorus chemical division
Jinning	18	Kunming Hongteng Phosphorus chemical Co., LTD
		Kunming Red Sea phosphate fertilizer Co., LTD
		Yunnan Zhongmin Gas Co., LTD
		Yunnan Fuhui gas trade Co., LTD
		Yunnan Ning fluorine environmental protection technology Co., LTD
		Yunnan Lilong Chemical Co., LTD
		Yunnan Haokun phosphorus Chemical Co., LTD
		Yunnan tree fertilizer Co., LTD
		Budweiser (Kunming) Beer Co., LTD
		Kunming Fuhui environmental protection Technology Co., LTD
		Yunnan Dadi Fengyuan Environmental protection Co., LTD
Fumin	11	Fumin salary metallurgy industry and trade Co., LTD
		Fumin Zhongbo new materials Co., LTD
		Fumin county Yunfu phosphate limited liability company

Songmin	11	Yunnan great interworking titanium Co., LTD
		Fumin Jincheng Chemical Co., LTD
		Fumin Longteng titanium industry limited liability company
		Yunnan Fumin Shixiang feed additive Co., LTD
		Yunnan Zechang titanium Co., LTD
		Yunnan Xinlong mineral feed Co., LTD
		Yunnan new Zexing wood-based panel Co., LTD
		Songming Junjie circuit equipment Co., LTD
		Kunming Zichuang infrared technology Co., LTD
		Yunnan Bo Rui Biological Technology Co., LTD
		Kunming Guosong Special coating Co., LTD
Yiliang	6	Baic Yunnan Ruili Automobile Co., Ltd. Kunming branch
		Yunnan Tianchuang Technology Co., LTD
		National expressway network G85 Chongqing to Kunming
		Expressway Songming (Xiaopu) to Kunming expressway project
		National Petroleum and Natural Gas Pipeline Network Group Co., LTD. South China branch of Yunnan oil transmission Division
Shilin	2	Kunming East Branch line project of Yunnan petrochina Kunlun Gas Co., LTD
		Songming Changsong Avenue gas station
		Songming Changsong Avenue gas station
		Kunming Dongsheng metallurgical chemical Co., LTD
		Yunnan Surui technology Co., LTD
Xundian	11	Yiliang Pengcheng liquefied gas Co., LTD
		Yiliang Yaosheng trading Co., LTD
		Kunming Hongli cement Co., LTD
		Yiliang County Xingyun rice noodle processing plant
		Sinopec Sales Co., LTD. Kunming, Yunnan Shilin Dadiashui Gas Station (South Station)
		Yunnan Shilin Oil Co., LTD
		Yunnan Guoneng Chemical Co., LTD
		Zhonghua Yunlong Co. LTD
		Yunnan South phosphorus Group electrochemical Co., LTD
		Yunnan Yunnan wood wood-based panel Co., LTD

		Yunnan Yalong aluminum Co., LTD
		Yunnan Evergreen tree Chemical Co., LTD
		Yunnan Pioneer Chemical Co., LTD
		Yunnan Sinopec high-speed Petroleum Co., LTD Kunming
		Xundian Pansuohai gas Station Station A
		Yunnan Sinopec high-speed Petroleum Co., LTD Kunming
		Xundian Pansuohai gas Station Station B
		National Petroleum and Natural Gas Pipeline Network Group Co., LTD. South China Branch Yunnan Oil Transmission Division (Xundian)
		Yunnan petrochina Kunlun Gas Co., LTD. Kunming East Branch (Xundian)
Luquan	1	Yunnan Chuanyun health care food Co., LTD
Kunming		Yunnan Shennong meat industry food Co., LTD
Economic	3	Kunming North infrared Technology Co., LTD
Development		Yunnan Chengda frozen food logistics Co., LTD
Kunming		Kunming Jida Pharmaceutical Co., LTD
National		Kunming cloud germanium high-tech Co., LTD
High-Tech	4	Yunnan Seiko plate making Co., LTD
Industrial		Kunming Aoshuo petrochemical Co., LTD
Development		
Kunming		Yunnan Chaoguan Chemical Co., LTD
Airport	3	China Aviation Oil Co., LTD. Yunnan Company Kunming
Economic		Changshui Airport oil depot
Area		Petrochina Kunming Yangtian Chong oil depot
		Yunnan cold cloud food and beverage Co., LTD
Kunming		Yunnan Yuanxin carbon Co., Ltd. Yangzonghai branch
scenic spots	4	Yunnan Sinopec high-speed Petroleum Co., LTD. Kunming
Yangzonghai		Yangzong Service area gas station (A) station
		Yunnan Sinopec high-speed Petroleum Co., LTD. Kunming
		Yangzong Service area gas station (B) station