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Environmental Radiation Impact of the NORM Activities in China

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Contents

1 Legislation, regulations and Standards

(1) Law of the People's Republic of China on the Prevention and Control of radioactive pollution，2003
(2) The regulation of the radiation environment supervision and management on the exploitation and utilization of mineral resources (first batch) in China, 2013
(3) National Standards -Basic Safety Standards for protection against ionization radiation and for the Safety of radiation sources (the CBSS or GB18871-2002).
(4) Emission Standards of Pollutants from Rare Earths Industry(GB26451-2011）
(5) National Standard of Limit of radionuclides for building materials (GB 6566-2001) ,2002

1 Legislation, regulations and Standards

Law of the People's Republic of China on the Prevention and Control of radioactive pollution

Chapter V, Prevention and Control of radioactive pollution resulting from mining and processing of uranium, thorium ores and NORM industry activities.

1 Legislation, regulations and Standards

The regulation of the radiation environment supervision and management on the exploitation and utilization of mineral resources (first batch) in China, 2013

Supervision and management on five minerals exploited, including the raw materials, intermediate products, and tailings (waste) or residues of rare earth elements, niobium/ tantalum, zircon and its oxides, vanadium, coal gangue have been implemented in 2013.

2 Monitoring and assessment of NORM industries in China

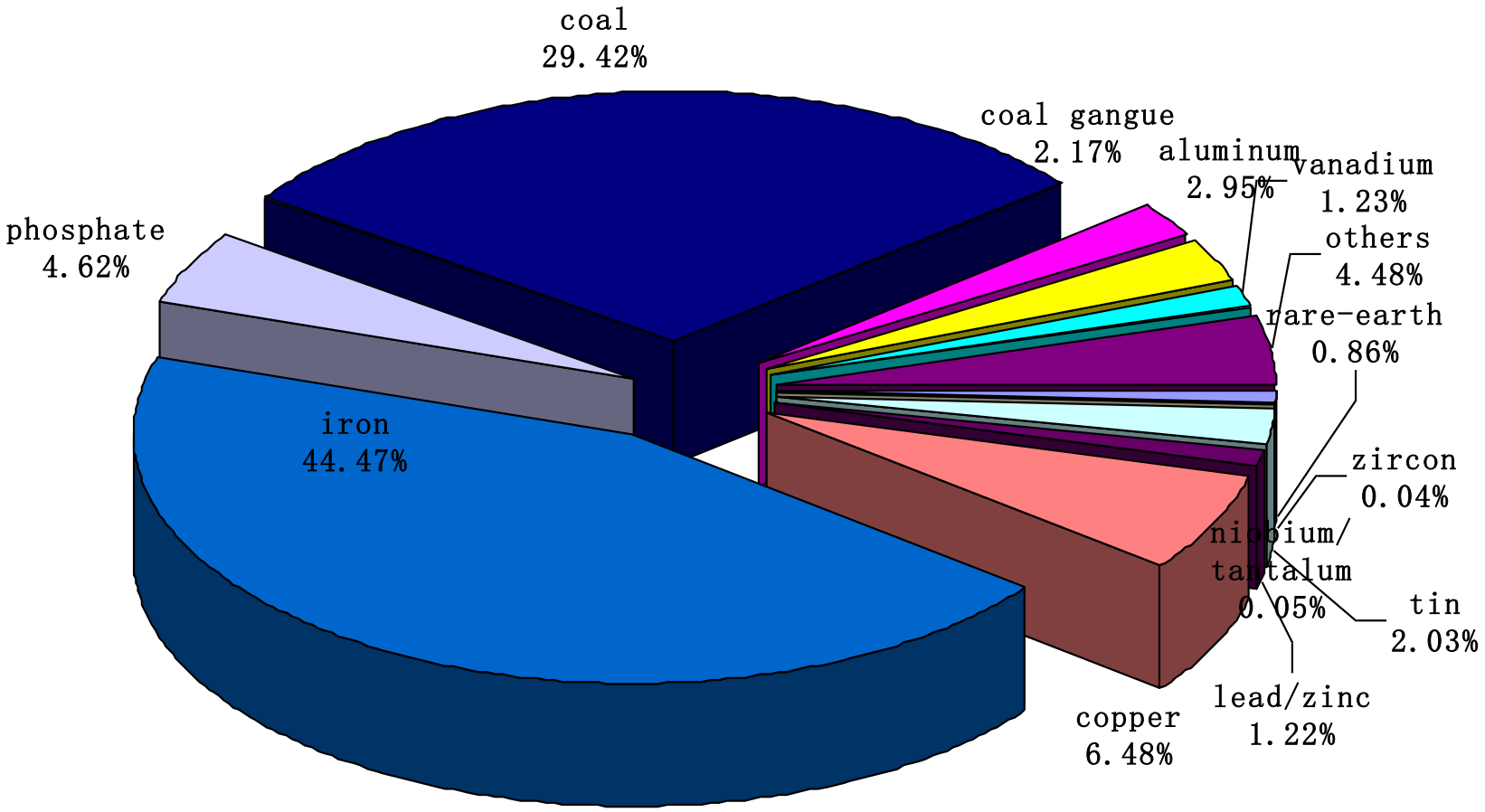
Eleven mining and processing (or using) mineral resources

- rare earth elements
- niobium/ tantalum
- zircon and its oxides
- Tin
- lead /zinc
- Copper
- Aluminum
- Vanadium
- iron and steel
- Phosphate
- coal including coal gangue

A Census of Pollution Source generated from NORM industry, First China Pollution Source Census, organized by the Ministry of Ecology and Environment of China in 2007

2 Monitoring and assessment of NORM industries in China

The amount of NORM solid waste distribution in China



Total amount of waste: 0.1714 billion tons in 2007

Table 1 Summary of the average concentration of nature radionuclides in ores and raw materials

Element / mineral	U	Ra	Th	γdose rate
	Bq/kg	Bq/kg	Bq/kg	nGy/h
REES	3972	2529	5782	2578
Nb/Ta	4,476	18131	2015	3,263
zircon	1,289	3510	1733	1,592
tin	218	540	133	272
lead /zinc	649	465	69	173
copper	142	163	34	170
iron and steel	270	288	68	162
phosphate	396	404	26	273
coal	383	212	51	153
coal gangue	171	118	82	135
aluminum	482	289	240	323
vanadium	1036	908	1501	280
others	503	744	508	422

Table 2 Summary of the average concentration of nature radionuclides in solid waste

Element / mineral	U	Ra	Th	γdose rate
	Bq/kg	Bq/kg	Bq/kg	nGy/h
REES	2081	1240	4876.3	3308
Nb/Ta	7725	7212	4191	1624
zircon	1026	945	327	358
tin	922	1377	802	601
lead /zinc	118	195	38.4	130
copper	142	155	36	153
iron and steel	246	247	135	189
phosphate	123	191	35.3	144
coal	225	326	91	162
coal gangue	191	79	92	115
aluminum	402	282	349	300
vanadium	813	675	73	264
others	338	435	119	200

Note:

The values of tab1 and tab 2 is not the average concentration of nature radionuclides in all ores and raw materials or solid waste, but just recognized as NORM materials by screening in the First China Pollution Source Census, organized by the Ministry of Ecology and Environment of China in 2007 .

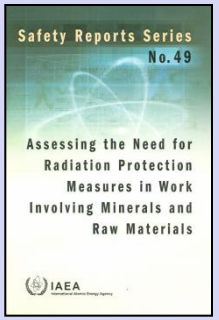
Second China Pollution Source Census (including Pollution Source generating NORM) started in 2017, and the results will be very different.

Fifteen mining and processing (or using) mineral resources have been identified in the Second China Pollution Source Census, organized by the Ministry of Ecology and Environment of China in 2007

（1）Rare earth elements
（2）Niobium/ tantalum
（3）Zircon and its oxides
（4）Tin
（5） Lead /zinc
（6）Copper
（7）Aluminum
（8）Vanadium
（9）Iron and steel
（10）Phosphate
（11）Coal including coal gangue
（12）Nickel(Ni)
（13） Molybdenum (Mo)
（14） Gold(Au)
（15）Germanium (Ge)

Industry sectors have been identified by IAEA

（1）Uranium mining and processing
（2）Rare earths extraction
（3）Thorium extraction & use
（4）Niobium extraction
（5）Non-U mining – incl. radon
（6）Oil and gas
（7）TiO_2
（8）Phosphates
（9）Zircon & zirconia
（10）Metals production
(Sn, Cu, Al, Fe, Zn, Pb)
（11）Burning of coal etc.
（12）Water treatment – incl. radon



Monitoring and assessments on NORM industries (including residues)

Since 1980s, the investigation of natural radioactivity background and some research projects had been carried out.

Especially since 2011, projects of radiation monitoring and radiological assessment on NORM industry have been implement.

Inner Mongolia(REE,Coal), Yunnan(Coal,Sn), Hunan(REE,Cu), Hubei(Fe), Xizang(Cu), Gansu(Ni), Hebei(Coal combution), Ningxia(Ta), Xingjiang(Oil and Gas) , Guizhou(Phasphatize), Jiangxi(REE, Zircon), etc.

3 A case study of the NORM site in Yunnan

3.1 General information

The coal mining area and thermal plants are located about 10 km northwest of the City, a chemical plant in northern city. The total population is 245,000 within a 20km radius, with an average population density of 195 people/km^2.

An annual average temperature of 18.3℃,

wind speed of 1.24 m/s, and

precipitation of 1311 mm.

3 A case study of the NORM site in Yunnan

The NORM site in the southwestern Yunnan province,China

3.2 Source term description

(1) coal piles and waste rocks

(2) Gas discharges to atmosphere and radon releases from coal piles and waste storages

(3) contaminated water from coal mining wells and plants discharge to surface water

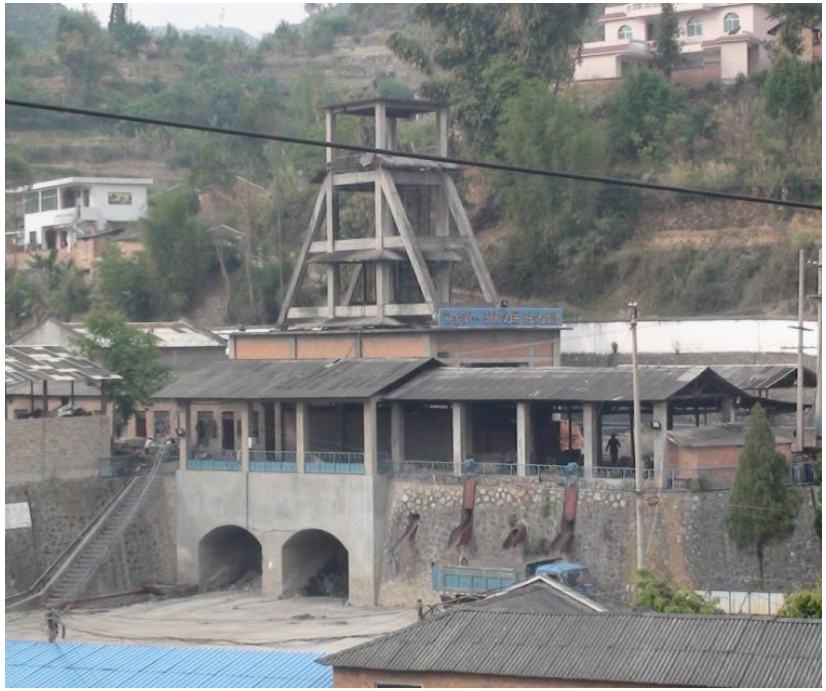
(4) Wastes generated(bottom ashes) and contaminated soils

A thermal Plant

3.2 Source term description

Ashes deposited >1000 nGy/h，
$^{238}U > 1$ Bq/g。

3.2 Source term description



A coal mining site

A waste storage

A chemical plant

Chemical waste and waste water

A waste storage

3.3 Radiation monitoring program

Gama dose rate monitoring

Airborne radioactivity survey

Aerosol measurement

Soil sampling

Outdoor Radon measurement

Indoor Radon measurement

Sampling

3. 4 Results

Radioactivity concentrations in Coal Ores and Slag （Bq ŀkg^{-1}）

Samples	^{238}U	^{232}Th	^{226}Ra
Coal	60.1-1816	38.0-284	9.8-1648
Bottom ashes	187.5-3186	68.2-260	176.6-3289
Chemical slag	2000-2300	5.6-140	65-5000

Radioactivity concentrations in waste water

Samples	Total U	Total Th	^{226}Ra	^{210}Pb	^{210}Po
	μg ŀL^{-1}	μg ŀL^{-1}	mBq ŀL^{-1}	Bq ŀL^{-1}	Bq ŀL^{-1}
Waste Water	10.5-225	0.05-2.96	0.1-6.0	0.1-23.7	0.11-10.7

Radioactivity concentrations in aerosol samples (mBq/m^3)

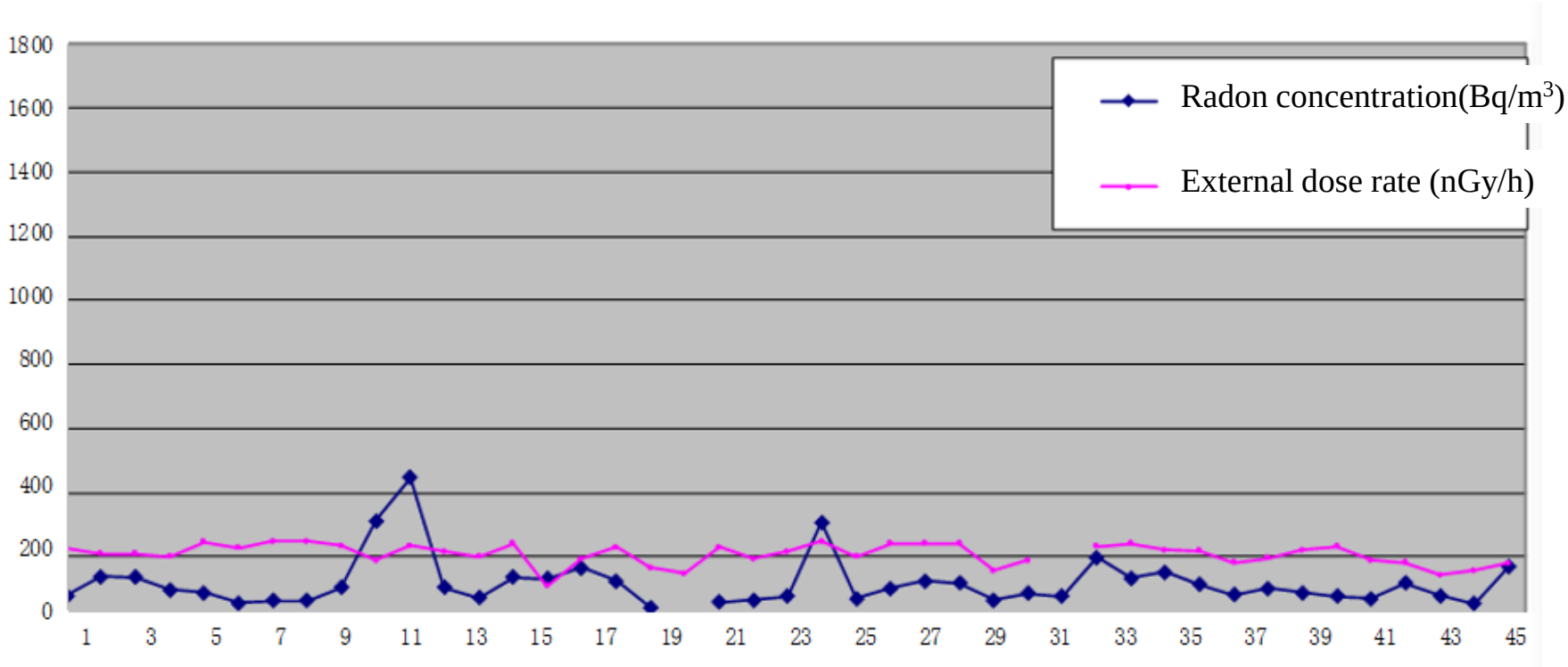
Area	Location	Po-210	±2δ	Pb-210	±2δ
Countryside	CHB	0.79	0.08	1.28	0.13
Countryside	BM	0.90	0.09	1.23	0.12
Countryside	DZ	0.92	0.09	1.30	0.13
Countryside	MW	0.64	0.06	1.08	0.11
City	CT	0.68	0.07	1.95	0.19
City	CT	0.52	0.06	1.60	0.16

Radioactivity concentrations in drinking water（mBq/L）

Area	Location	Ra-226	±2δ	Po-210	±2δ	Pb-210	±2δ
Countryside	DZ	0.86	0.12	2.09	1.02	3.60	0.56
Countryside	DTH	1.71	0.15	1.92	0.48	3.46	0.52
Countryside	MT	3.36	0.20	6.41	1.00	6.44	0.98
City	HD	1.16	0.12	4.18	1.02	2.52	0.39
City	CZ	2.94	0.30	1.79	0.73	1.18	0.19
City	CN	1.77	0.21	6.06	1.56	1.48	0.23

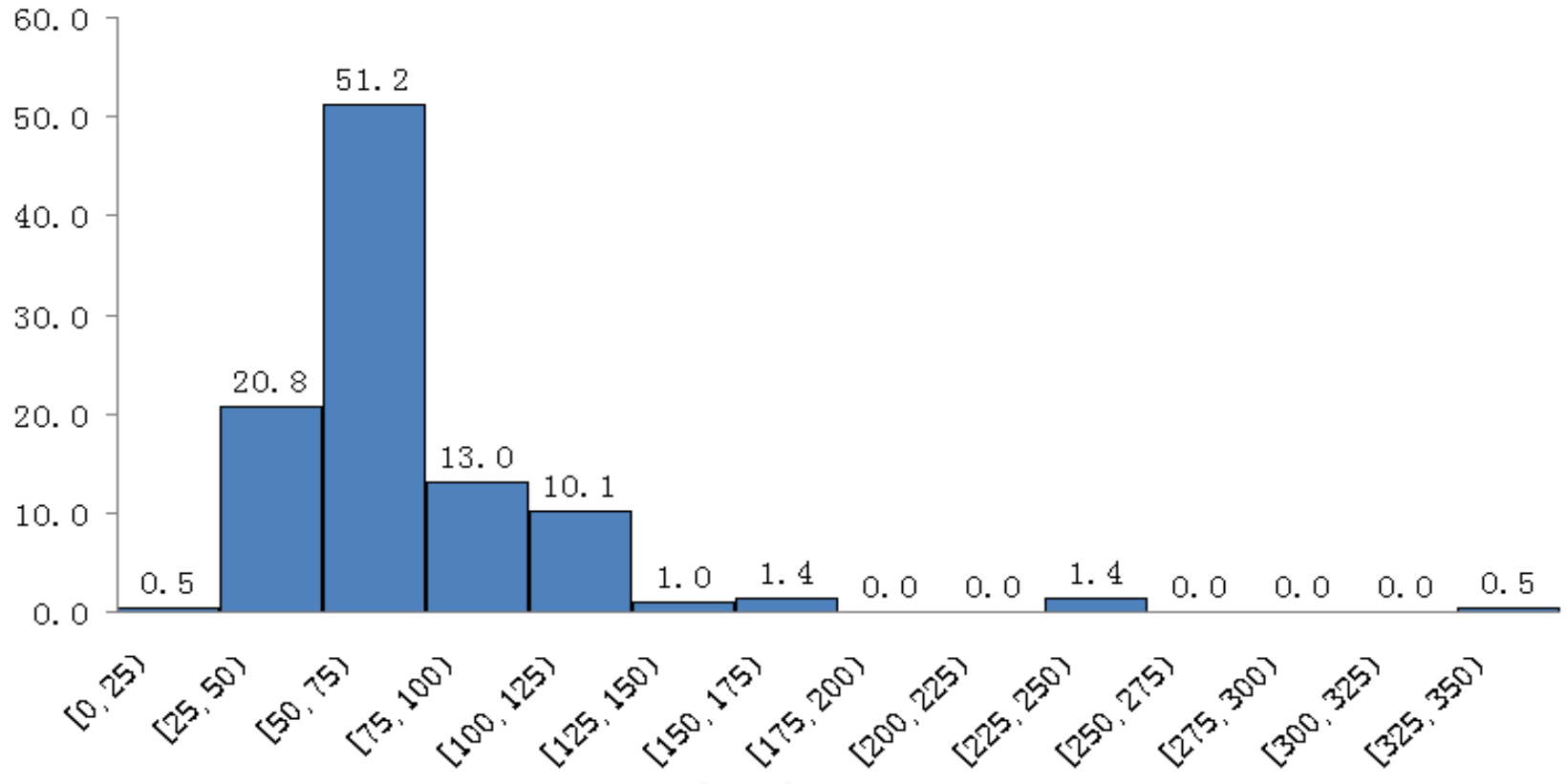
Radioactivity concentrations in biota samples

location	samples	Pb-210 Bq/kg.dry	Po-210 Bq/kg.dry	group
MW	wheat	1.92	2.73	Crop
DTH	Paddy	7.27	5.80	Crop
DTH	maize	1.13	0.48	Crop
BM	green vegetables	6.42	2.24	Leaf vegetable
BM	Banana taro	1.19	0.80	Root vegetable



Indoor radon concentration external dose rate in countryside area

Frequency(%)



Indoor radon concentration in city area (Bq/m^3)

Dose assessments were based on environmental monitoring data

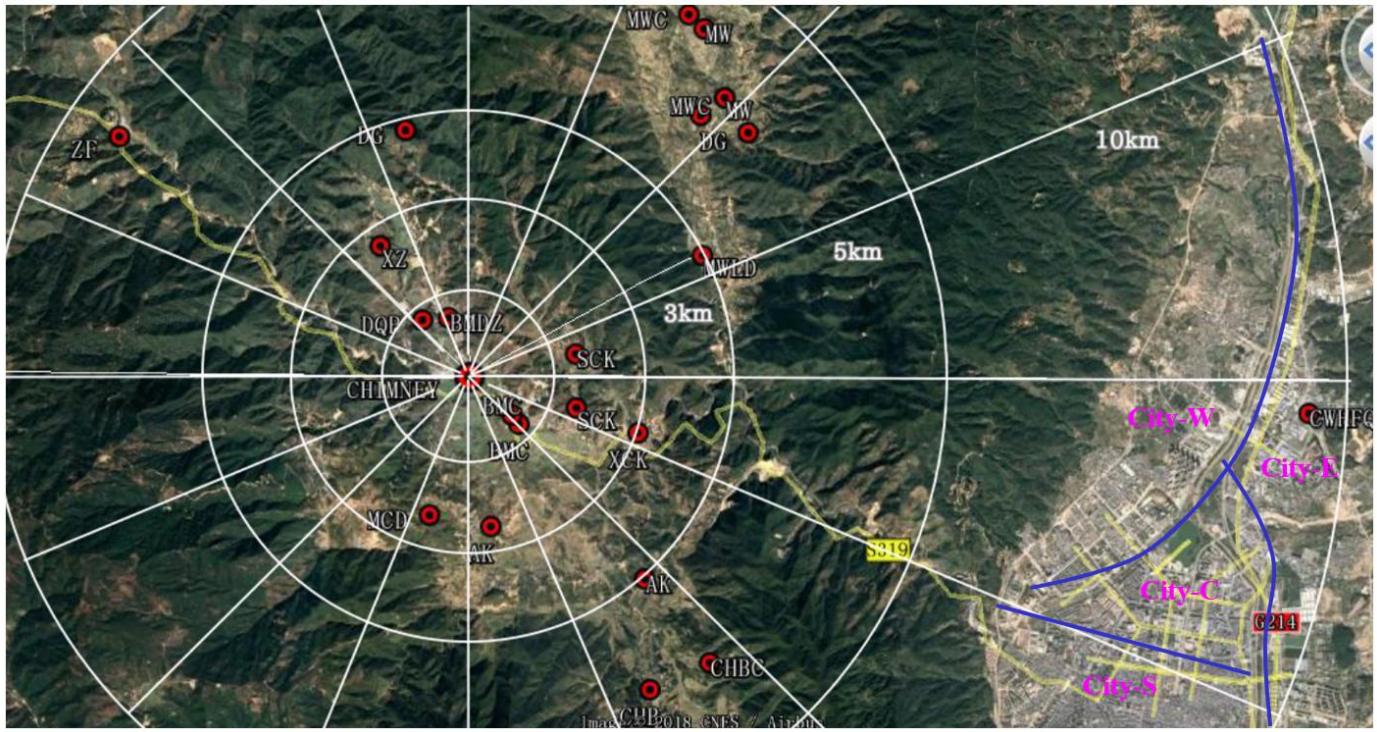
(1)Data sets:

- external radiation dose rate
- out door and indoor radon concentration
- ^{210}Po and ^{210}Pb in aerosol, crop and vegetable
- ^{226}Ra, ^{210}Po and ^{210}Pbin drinking water.

Dose assessment: two sub-areas

One is NORM site in countryside, as the center, extending to the circles with a radius of 1 km, 2 km, 3 km and 5 km, respectively, and then divide these concentric circles into 22.5°sub-sections, or 64 sub-regions(4*16).

The second is city area, 10 km in the direction of ESE, divided into four sub-regions.



Red cycles refer to villages located in the countryside area

City area

(3) The result of dose assessment

E

Annual effective dose of the public exposure in each section

Receptor	Exposure types						Path		Total (mSv)
	Radon (mSv)	Gamma (mSv)	Cosmic (mSv)	Aerosl (mSv)	Biota(mSv)	Drinking water (10^{-3}mSv)	Internal (mSv)	External (mSv)	
o	5.65	0.89	0.36	0.05	0.09	3.34	5.83	1.25	7.08
A4	3.66	0.79	0.36	0.04	0.09	3.34	3.84	1.15	4.99
A8	1.7	1.08	0.36	0.04	0.18	3.34	1.92	1.45	3.36
A16	3.66	1.06	0.36	0.04	0.05	3.34	3.76	1.42	5.18
B1	2.51	0.97	0.36	0.04	0.02	6.63	2.58	1.33	3.91
B5	9.87	1.03	0.36	0.04	0.05	3.33	9.95	1.39	11.34
B7	2.23	1.13	0.36	0.04	0.36	9.9	2.65	1.49	4.14
City-w	2.3	1.15	0.36	0.03	0.17	5.62	2.46	1.51	3.98
City-s	2.51	0.97	0.36	0.03	0.17	5.62	2.67	1.33	4.0
City-E	2.07	0.97	0.36	0.03	0.17	2.48	2.22	1.33	3.56
City-C	1.84	0.98	0.36	0.03	0.17	2.42	1.99	1.35	3.34

(3) The result of dose assessment

Average annual effective dose for the public exposure is 5.1 mSv/a in the site research area.

In total value:

Internal dose take 72.5%

(^{222}Rn 68%, ^{210}Pb 2.2%, ^{210}Po 2.4%, ^{226}Ra 0.01%)

External dose take 27.5%

Considering the path way:

Aerosol:0.7%

Foodstuff:5%

Drinking water:0.12%

Average value of 5.1 mSv/a, max 11.3 mSv/a in the site is much higher than the average level in China.

4 Conclusions and discussions

(1) The result presents annual effective dose in current situation. Historical background data is difficult to make.

(2) The activity concentrations of radionuclides in materials (some the coal, bottom ash and fly ash) are higher than the radiation exemption level, or exceed 1Bq/ g.

(3) Radon concentration level is higher, and turns to be most contribution of annual effective dose, and results from waste spread.

(4) Regulatory and management approaches for the control of NORM should be strengthen

Thank you for your attention!

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