EMRAS II WG2 4th Meeting

Enhanced Natural Radiation Exposure in China

Wu Qifan
Dept. of Engineering Physics, Tsinghua University
Liu Hua, Ma Chenghui, luo Jianjun
Dept. of Nuclear Safety Management of MEP
Pan Ziqiang
China National Nuclear Corporation

Wuqifan@tsinghua.edu.cn

Enhanced Natural Radiation Exposure in China

Contents

I. Introduction of the Third Symposium of Natural Radiation Exposure and Control in China

Organized by

- **Committee of Nuclear Safety and Radiation Environmental Safety，Chinese Society for Environmental Sciences**
- **Committee of Radiation Protection，Chinese Nuclear Society**
- **Chinese Society of Radiological Medicine and Protection，Chinese Medical Association**
- **Committee of Radiological Health，Chinese Preventive Medicine Association**
- **Committee of Radiological Toxicology，Chinese Society of Toxicology**

The Third Symposium of Natural Radiation Exposure and Control

Aug 30- Sep 3,2010 Baotou, Inner Mongolia,China

hosted by Nuclear and Radiation Safety Center of MEP

in co-operation with China Institute of Atomic Energy.

1. Topics

(1) Exposure to NORM and management
(2) Natural Radiation Exposure measurement and assessment
(3) indoor and environmental Radon exposure and radiation control
(4) Exposure to NORM Industries and radiation control
(5) Natural Radiation level and control in underground workplaces
(6) space radiation and High Levels of Natural Radiation Background
(7) Natural Radiation control technique
Technical Visits(2days)
visit Bayan Obo, the largest REEs open pit mine in the world.

2. Conference Participation

- About 200 participants attended the meeting.

  participants were from national environmental protection system, health system, nuclear industry, ministry of construction and universities, totally 78 units.

- About 140 papers had been submitted

- Programme included:

  Opening Session (12 Invited Presentations) and

  6 Subsections (36 Oral presentations)

3. summary

A series of significant achievements concerning norm radiation exposure and control have been made under the support of the Ministry of Environment Protection, the Ministry of Science and Technology ,the Ministry of Health, National Industries, and the National Natural Science Foundation Committee, etc.

As a result, enhanced natural radiation is the major contributors to the public exposure and occupational exposure in China.

II. Overview of NORM Source term from the First China Pollution Source Census

First China Pollution Source Census

A Census of Pollution Source generated from NORM

- Organized by central government

  The Ministry of Environment Protection

- Carried out by local government

  provincial and county environment protection units

1. Time limit for census

*Scope

All pollution sources from industry, agriculture , daily life and pollution treatment centers including those generated from NORM.

*Working Period

From early 2008 to 2009

Census period up to Dec 31, 2007

*Target

Year 2007

2. The Source Census of NORM

Concerning the 11 mining resources as follows:

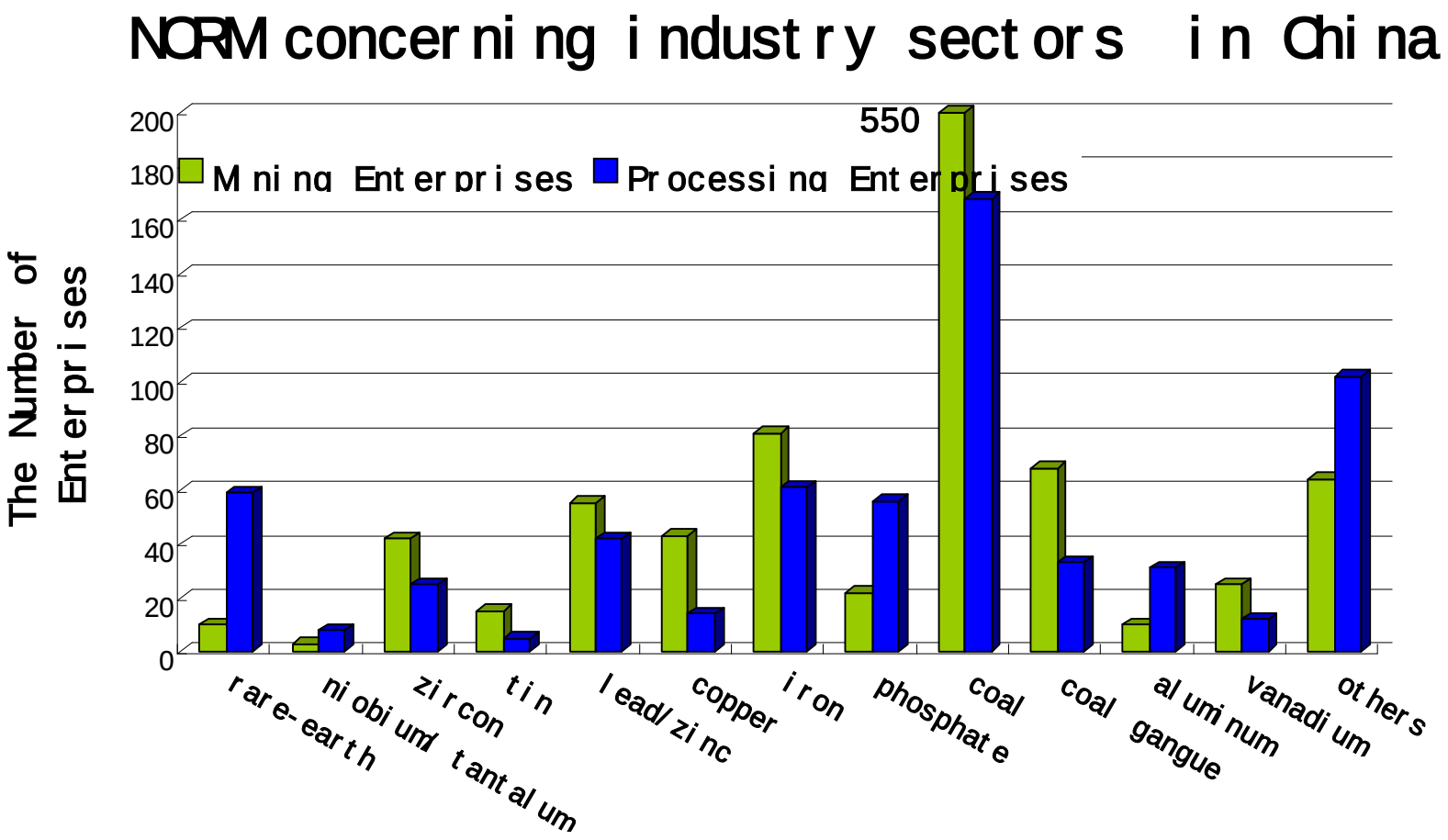
- **Processing rare earth elements ,**
- **niobium/ tantalum,**
- **zircon and its oxides,**
- **tin,**
- **lead /zinc,**
- **copper,**
- **aluminum,**
- **vanadium,**
- **iron and steel,**
- **phosphate,**
- **coal including coal gangue etc.**

It does not include uranium mining and milling!!

3. Preliminary results

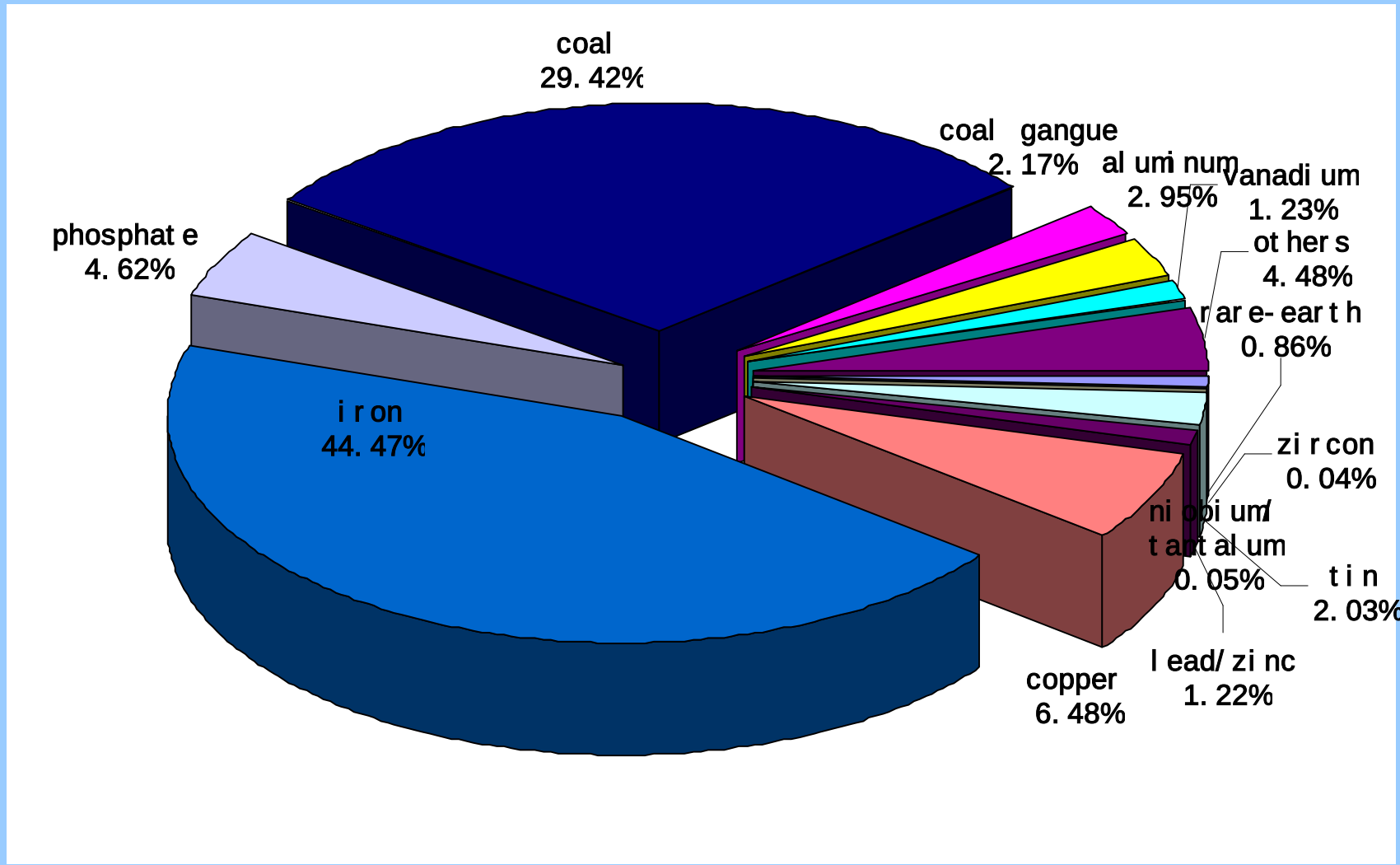
•11000 enterprises were censored in 2007. In which, 1433 enterprises are monitored in more Detail, they either produce ores, raw materials (concentrates), or wastes (slag, tailing) with that γdose rate on 1 meter distance is over 50 nGy/h of local background level.

3. Preliminary results -cont.



3. Preliminary results -cont.

The amount of NORM solid waste distribution in China



3. Preliminary results -cont.

Data analysis is in process .

III. A case study of Legacy/NORM sites in Baotou, Inner Mongolia, China

A case study of Legacy/NORM sites in Baotou, Inner Mongolia, China

Contents

1. Introduction

Inner Mongolia **B**ao**T**ou **I**ron and **S**teel **P**lant (Group Ltd.)

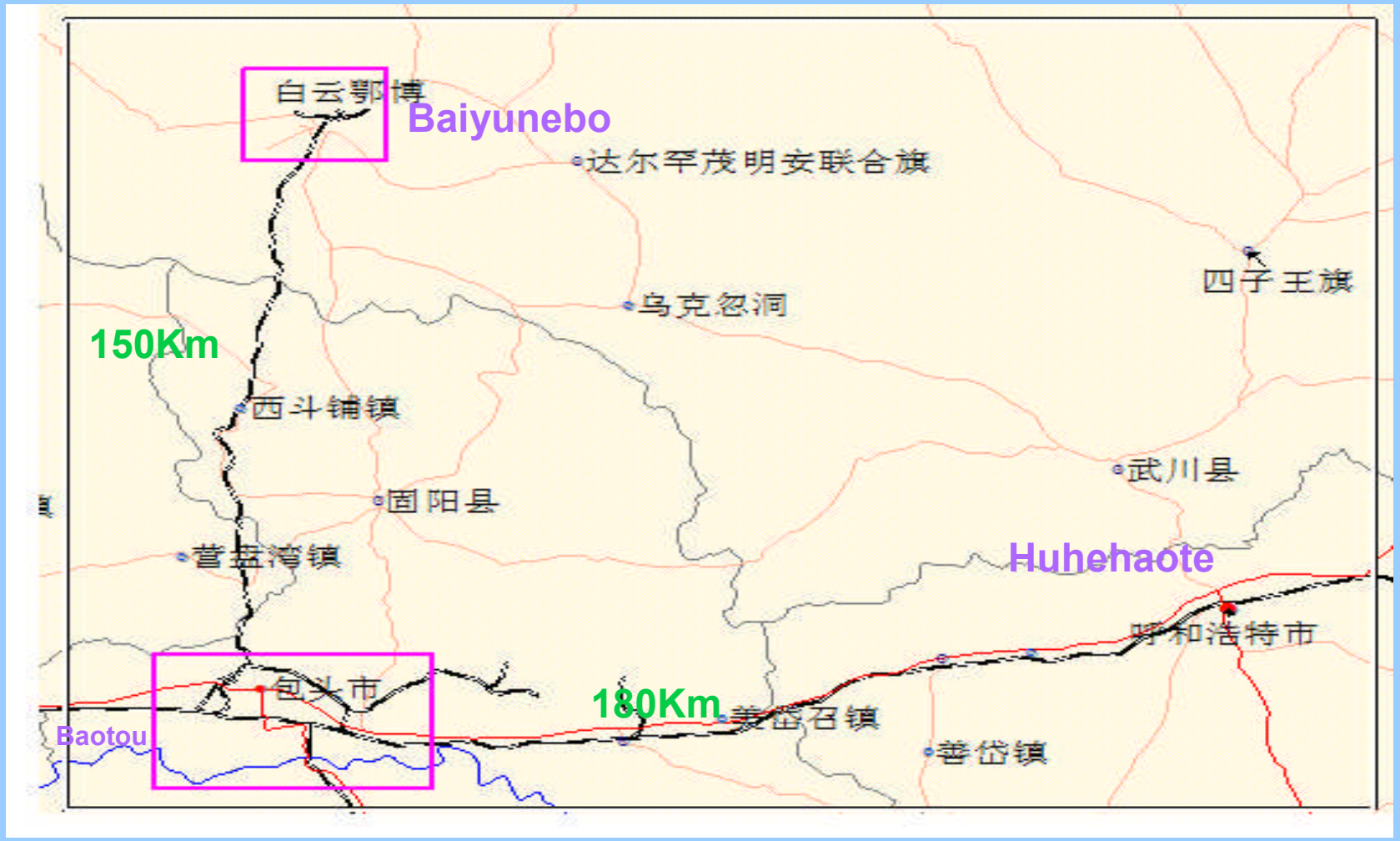
or **BTISP**

founded in 1954

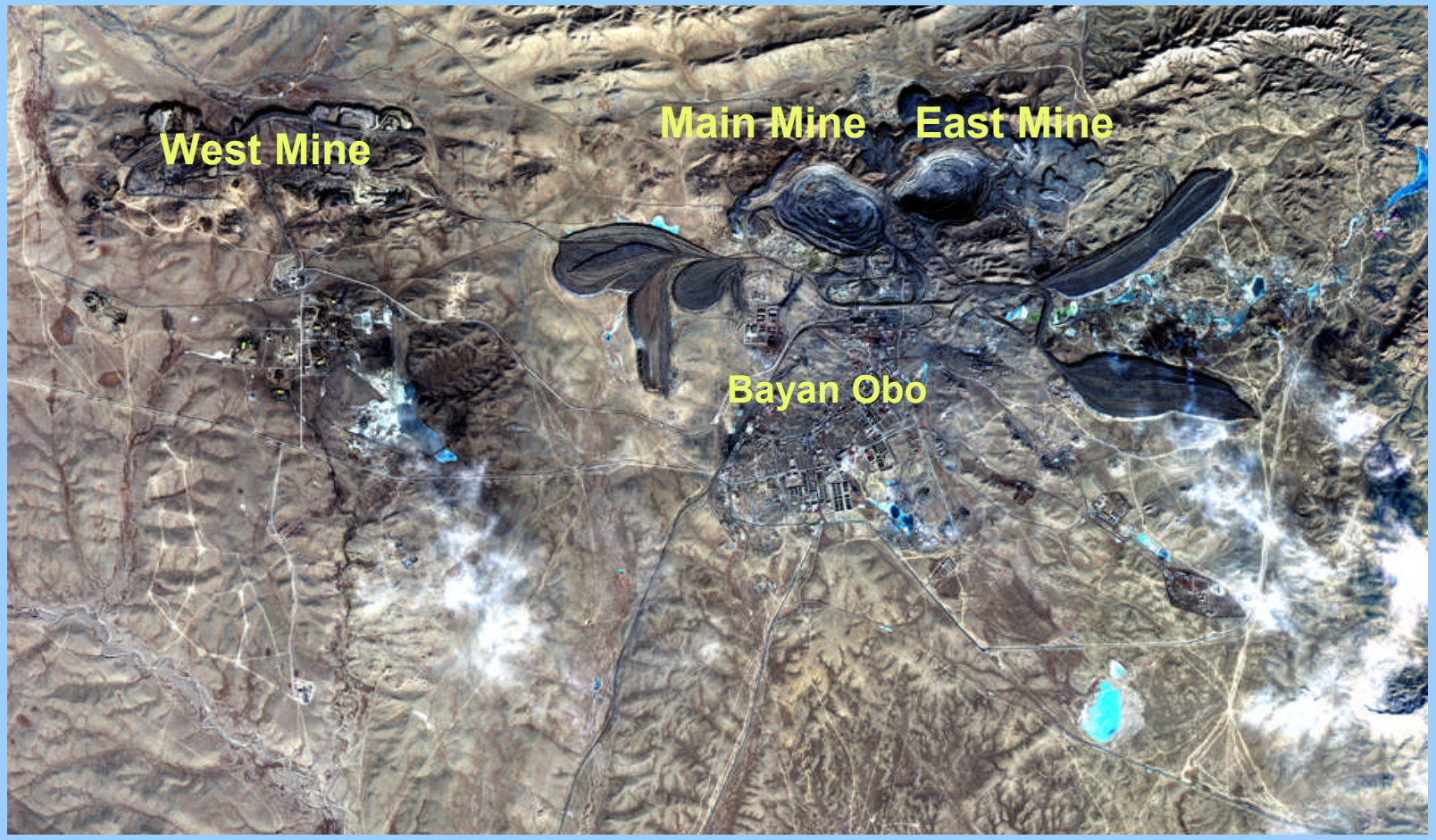
- **Bayan Obo mine**
  Mining and crashing
- **Iron and Steel Plant**
- **Rare earth plants (1974)**

1. Introduction - cont.

- **12×10^6 t/a of ores from Bayan Obo mine**
- **9×10^6 t/a products of iron and steel**
- **more than 7×10^3 t/a products of oxide equivalent of REO (**2006**).**

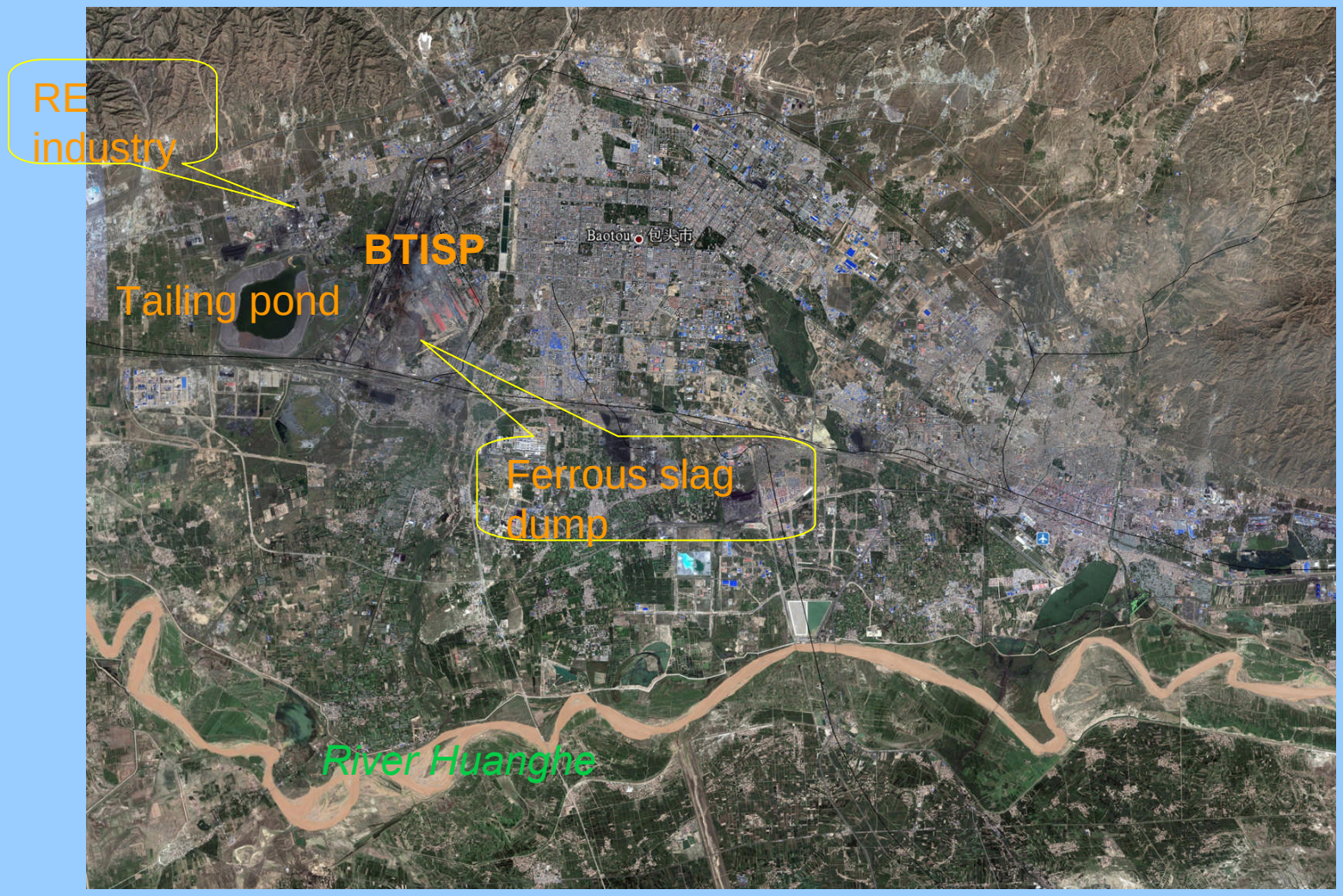

白云鄂博
Baiyunebo
达尔罕茂明安联合旗
四子王旗
乌克忽洞
150Km
西斗铺镇
固阳县
武川县
营盘湾镇
Huhehaote
呼和浩特市
包头市
180Km
美岱召镇
Baotou
善岱镇

Bayan Obo and Bayan Obo mine(the BTISP)



Bayan Obo mine: **18Km × 2 - 3Km.**

The BTISP and Baotou City



1. Introduction-cont.

The Bayan Obo ores are rich in thorium, so it causes a certain radiological impact on both work places and the environment during mining and processing.

2. The Monitoring Programme

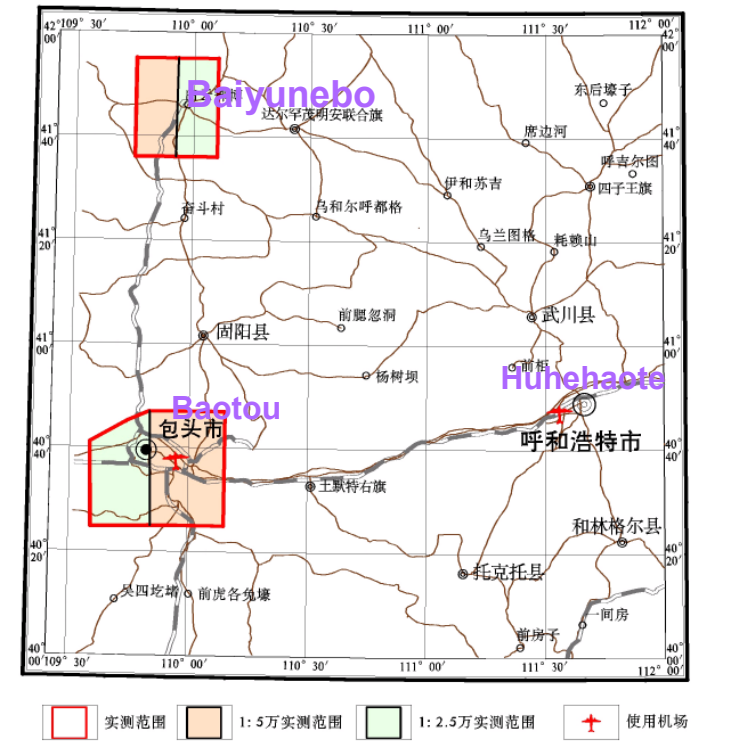
- Aero survey and ground measurements
  Work was done during 2006-2009

- Other data
  The Monitoring Data of Baotou Radioactive Environmental Quality , required by regulation(year 2006) , and
  A Study of Radiological Impact on Baotou Area resulting from Exploitation of Bayan Obo Ores (1998), INNER MONGOLIA RADIOACTIVE ENVIRONMENT MANAGEMENT INSTITUTE

Airborne gamma spectrometry

about 2060km^2 has been flown in 2006.

The follow-up ground measurements to verify the sites with elevated levels of radioactivity



Baiyun:23Km×28Km

Baotou:42.5Km×30 Km

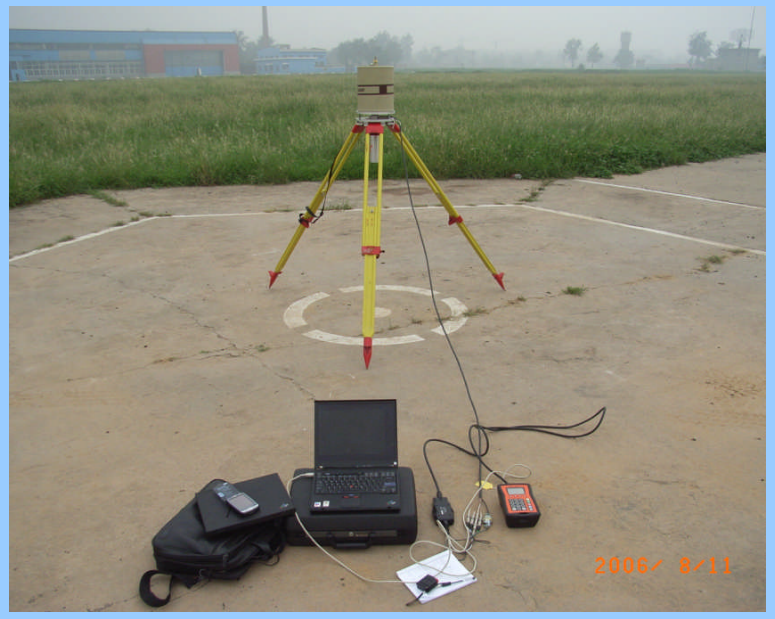
Airborne gamma spectrometry

The AGS system was installed in fixing wings aircraft, with large volume(32L) sodium iodide (NaI(Tl))detector.

GR-820

NaI (Tl) detector

Follow up ground work



In Situ HPGe Gamma Spectrometer

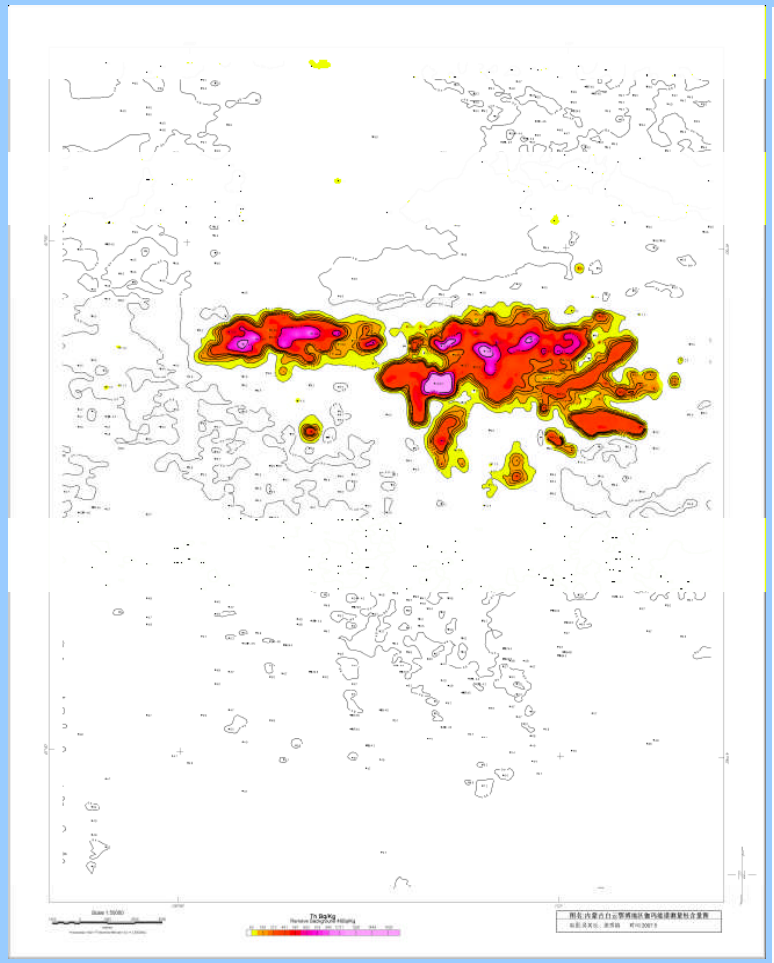
The CGS system was installed in jeep, with large volume(4L) , GR460 , NaI(Tl) detector.

Follow up ground work

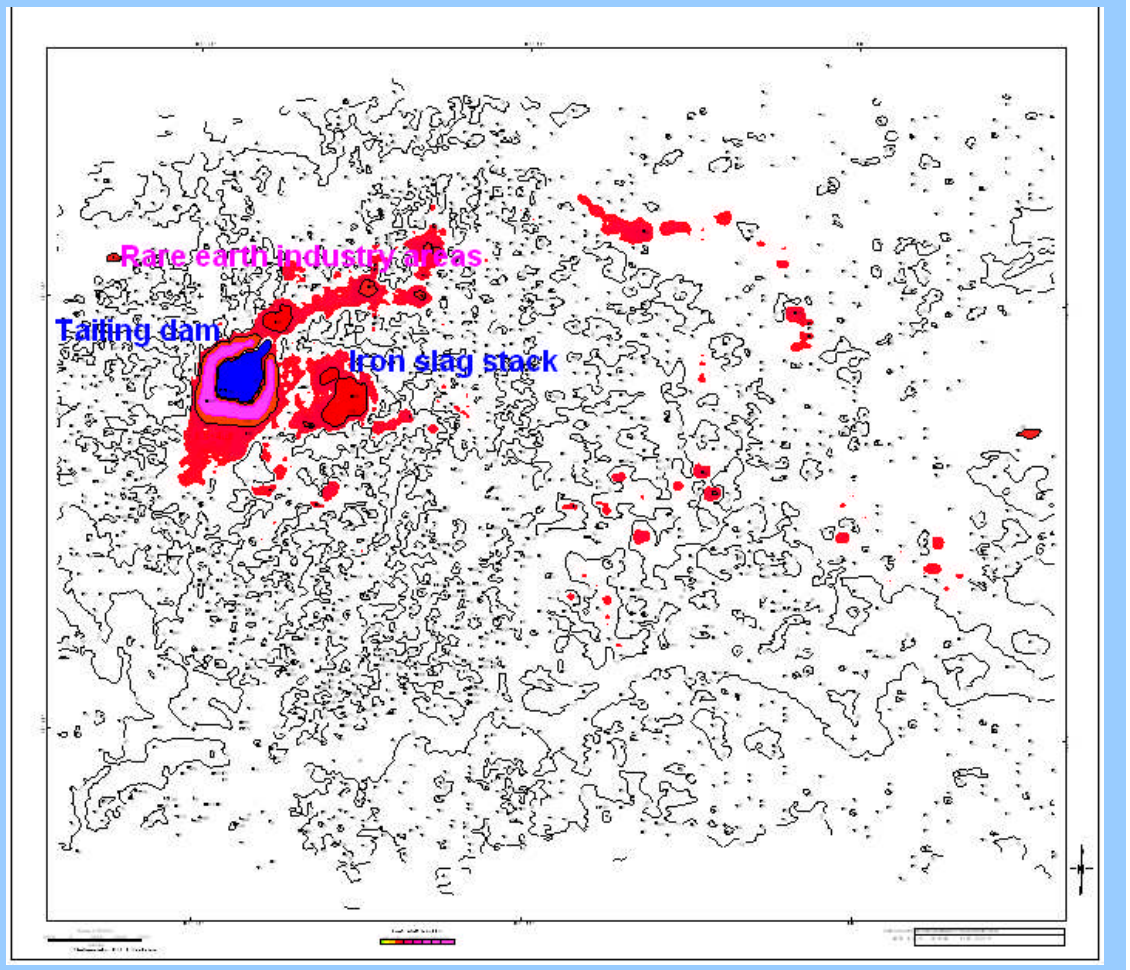
Dose meter

^{222}Rn/ ^{220}Rn and ^{220}Rn progeny CR-39 detector

3.Regional Radiological data

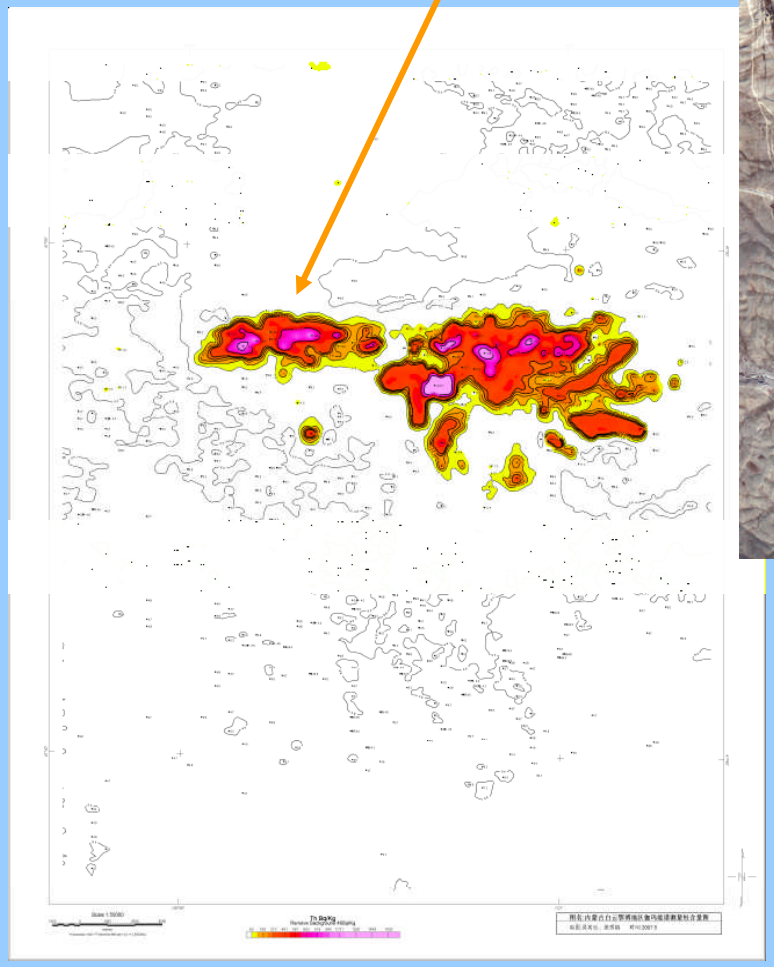


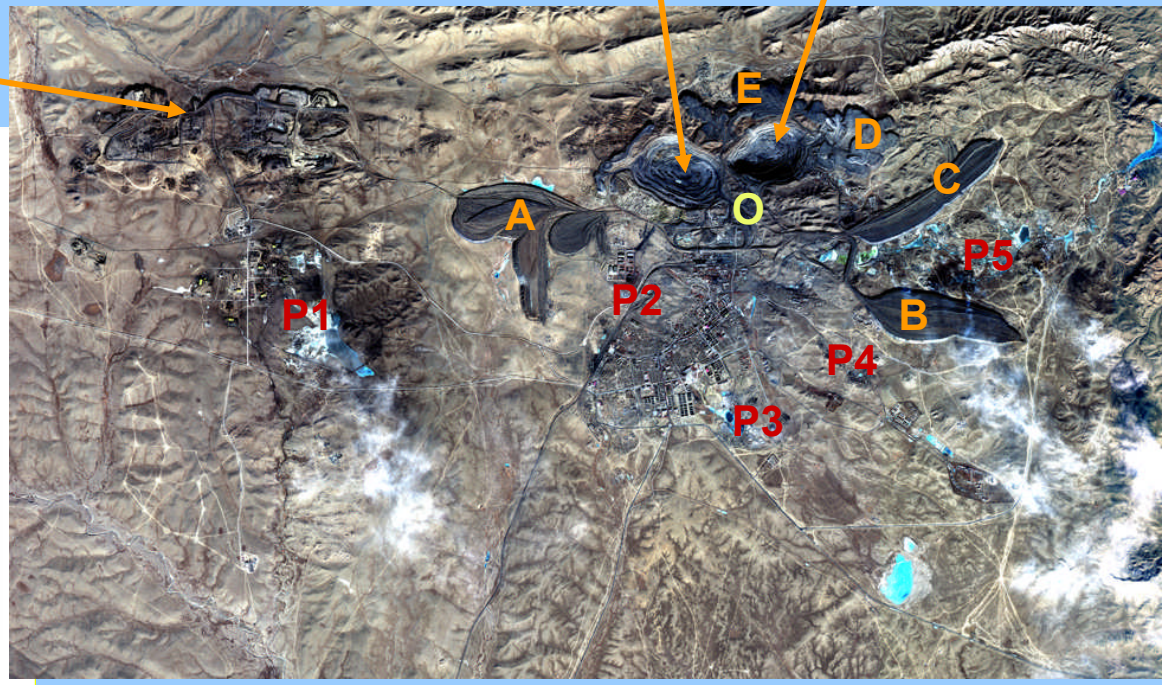
Gamma radiation levels in Baiyunebo



Gamma radiation levels in Baotou

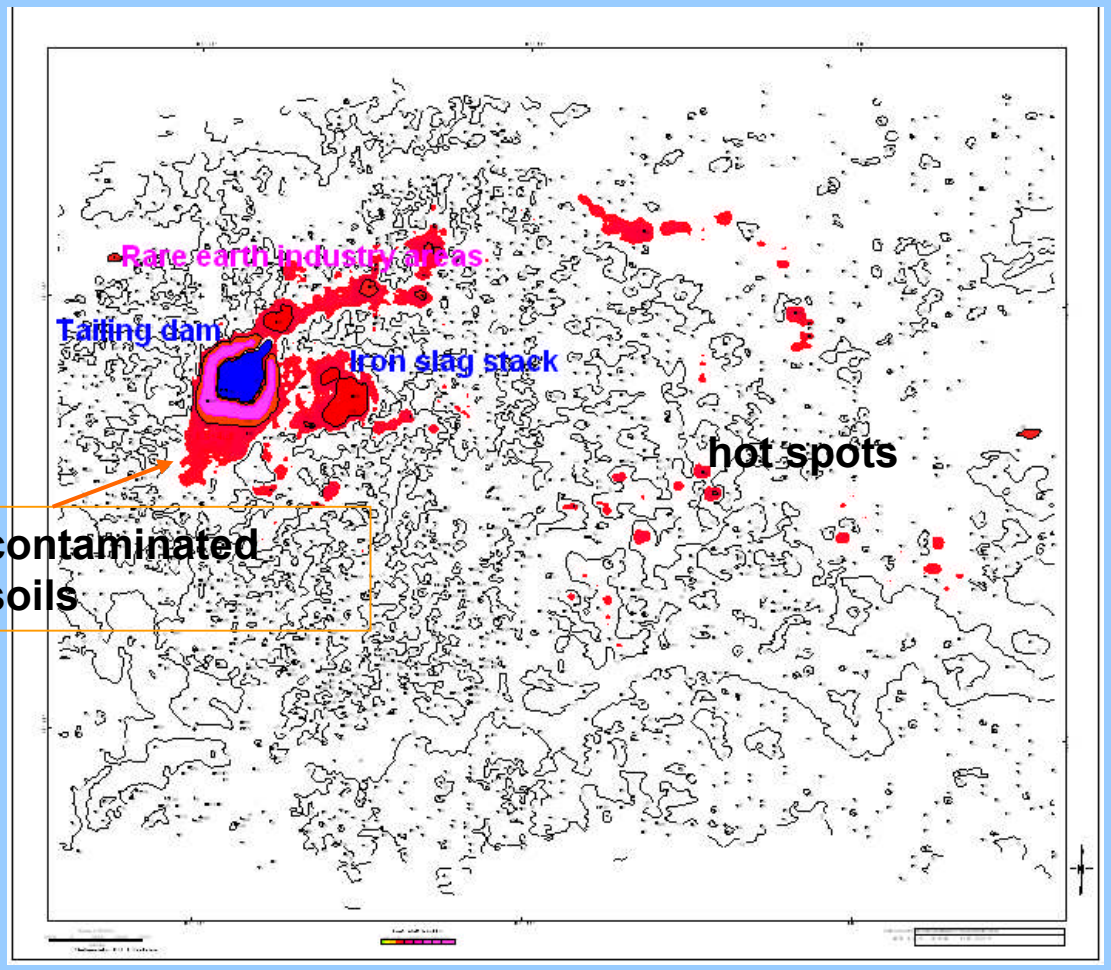
sites with elevated levels of radioactivity





BG: 85nGy/h
HBG:200—800nGy/h (about 55.4 Km^2)
Mining sites and Ores (O):600 to 2000nGy/h
Dumping sites(A,B,C,D,E): 400 to 800nGy/h
1200nGy/h
hot spots (P1-5): 500-2000nGy/h

sites with elevated levels of radioactivity



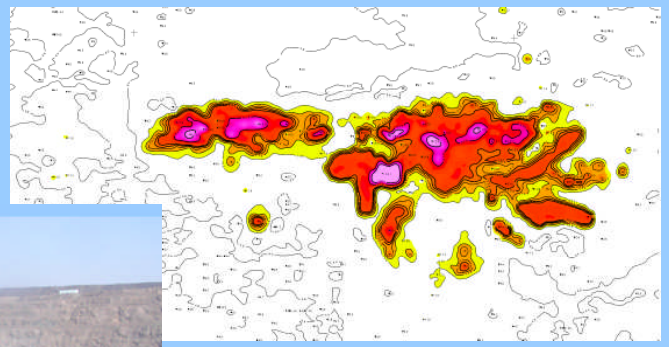
BG: 65nGy/h (50Bq/Kg for Th)
Tailing pond: 650-1200 nGy/ h (11 Km^2)
Ferrous slag dump: 500-1200 nGy/ h
The contaminated soil area:
85-150nGy/h
80-200Bq/kg for Th in the upper layer of 10 -20cm.
32 hot spots : 120-1200nGy/h

4.Legacy/NORM sites

Legacy/NORM sites in Bayan Obo

- Main Mine and East Mine

About 276×10^6 t of ores had been mined by the end of 2006.
About 10×10^6 t/a of ores are recently mined



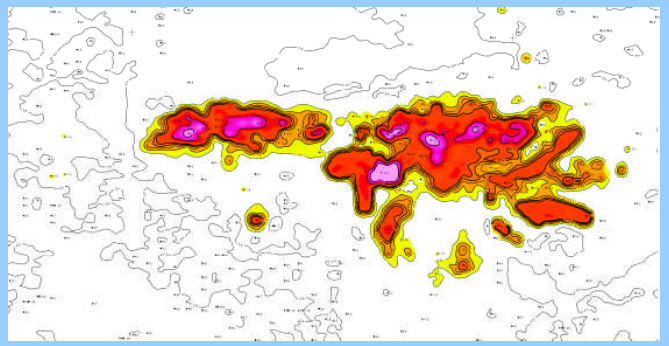
open pit mines

$1520\times1080m^2$ for Main Mine, $1400\times1020m^2$ for East Mine

Legacy/NORM sites in Bayan Obo

•West Mine

a big open pit mine, started in May, 2006.



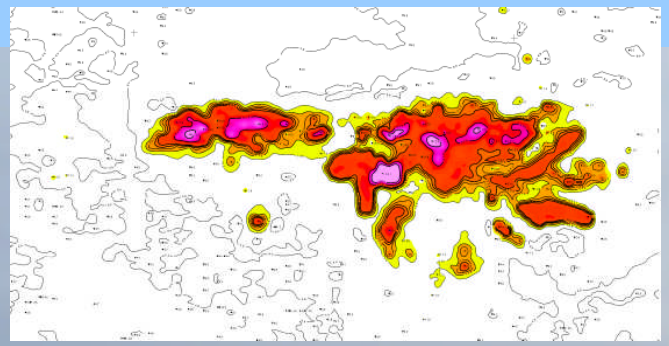
4,600 m in length
1,000 m to 1,200 m in width.
The present production of ores is expected to be 3×10^6 t/a,

Legacy/NORM sites in Bayan Obo

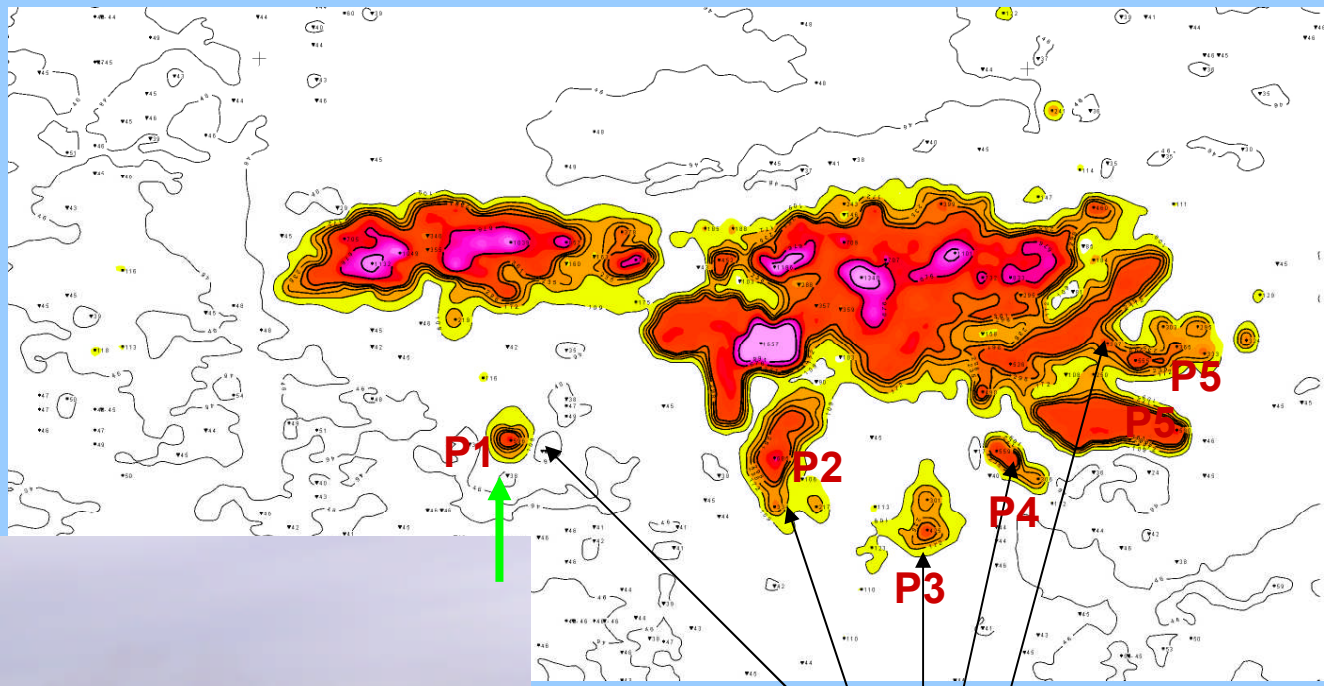
- **waste rock dumps**

About 10×10^6 t of waste rocks are produced annually.

Total amount of waste rocks is about 560×10^6 t , piled up in the waste rock dumps.



Legacy/NORM sites in Bayan Obo



P1 A new milling plant

Tailings,675 nGy/h

A new milling plant and some other plants in Bayan Obo
P2-railway platform constructed by waste rocks 596nGy/h
P3-an abandoned milling plant, tailings,756nGy/h
P4-an abandoned RE plant, Slag 15m*30m,2000nGy/h
P5-a small milling plant, tailings,500nGy/h

Legacy/NORM sites in Baotou

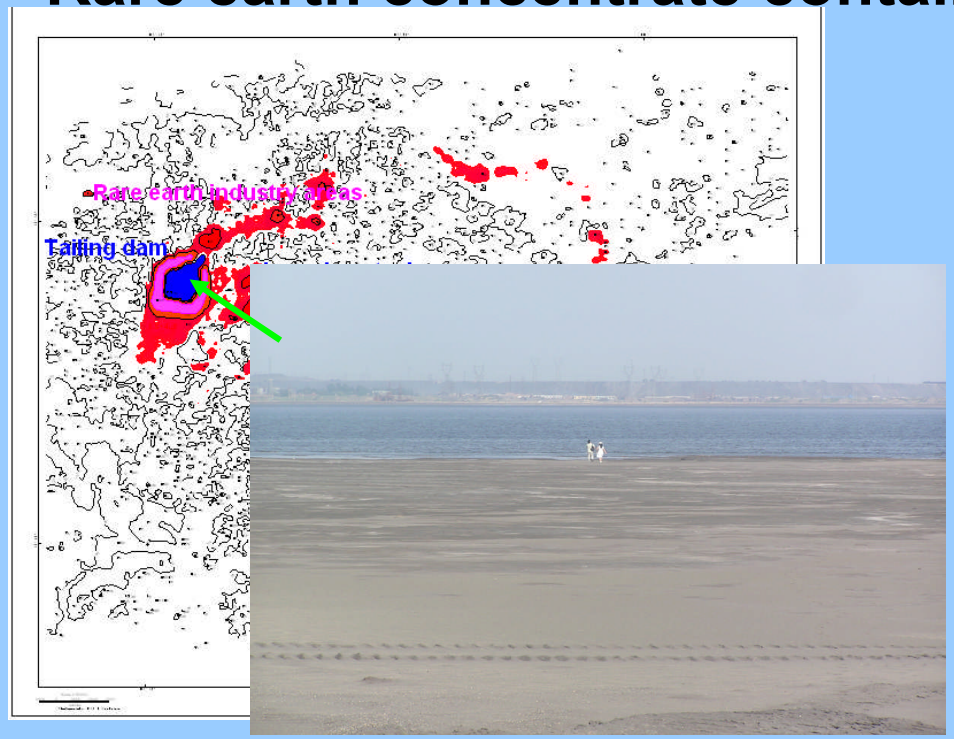
Milling

Production of iron and RE concentrates

4.5×10^6 t/a and 100×10^3 t/a respectively

Iron concentrate contains thorium 0.024% to 0.0073%

Rare earth concentrate contains 0.2% thorium



Tailings , 149 $\times10^6$ t , 2006

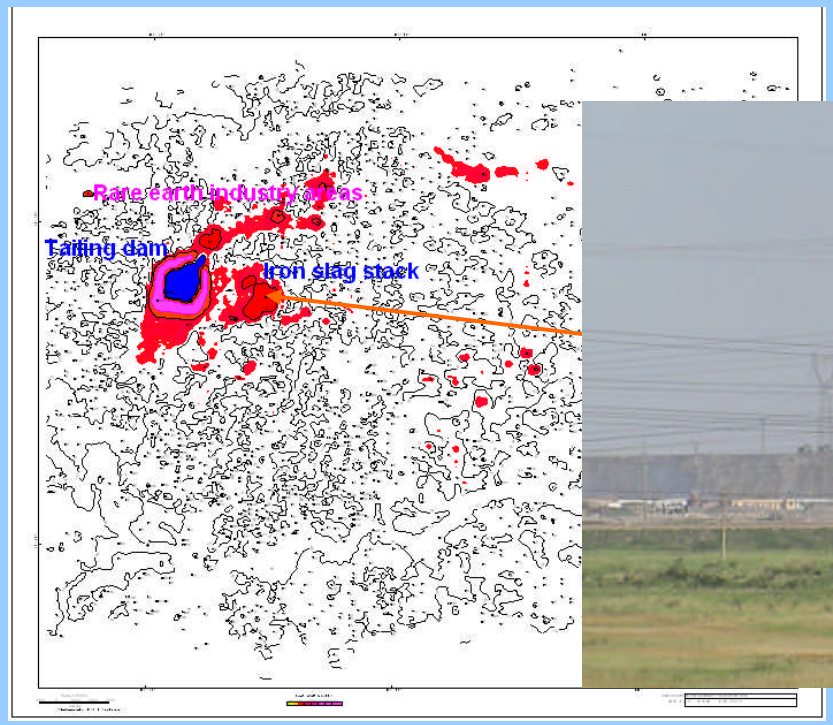
an area of 11km^2

About 6.55×10^6 t/a with 0.048% Th

Legacy/NORM sites in Baotou

Refining

iron and steel



- The BTISP recently produces 9×10^6 t of iron and steel, yielding 3.55×10^6 t of ferrous slag annually

brickyard

Recovery of iron

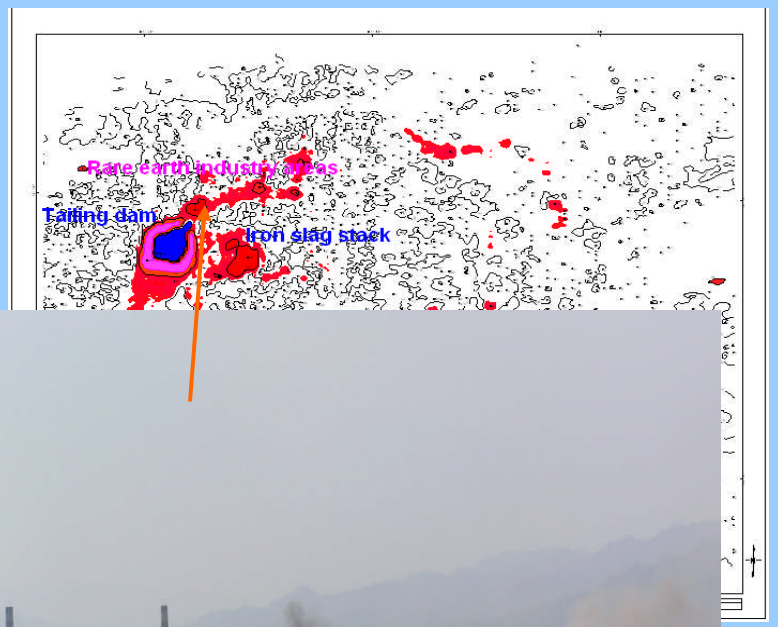
about 1450,000 t/a of ferrous slag has been used to make cement, bricks and other building products

Indoor radiation	PAEC of ^{222}Rn progeny	PAEC of ^{220}Rn progeny	**Gamma dose rate**
	nJ/m^3	nJ/m^3	E-8Gy/h
BS	212.5	186.25	16.12
BNS	**60.86**	**37.78**	**12.63**

BS-the buildings made of slag bricks.
BNS-the normal buildings not containing slag

Legacy/NORM sites in Baotou

RE Processing

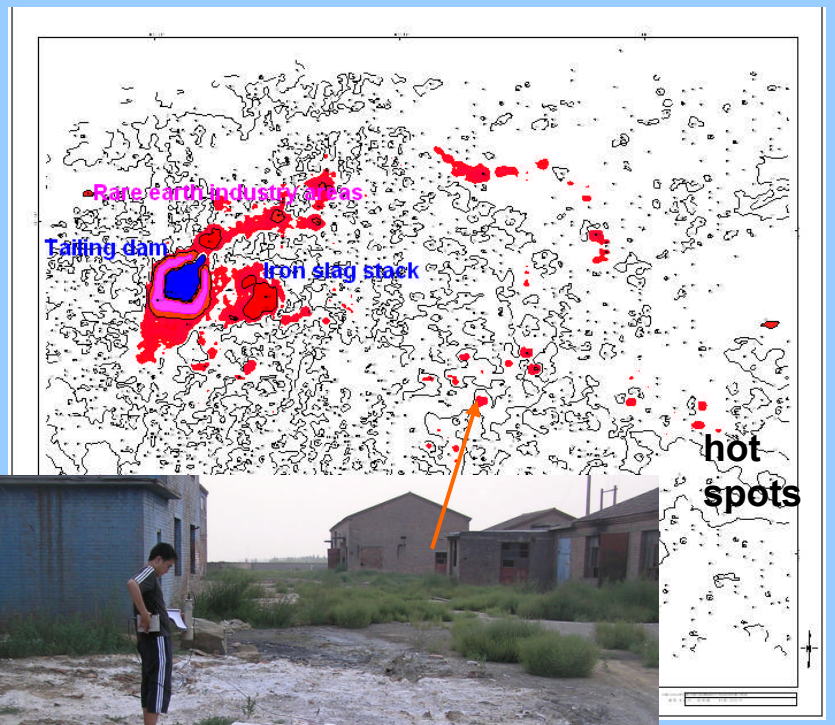


acidic process slag

The gross α , 8×10^{4}-2×10^{5}Bq/kg

- There are 13 RE plants in Baotou city area.
- Products include RE oxides, RE chlorides, RE carbonates and alloy products.
- 60×10^{3} t/a of RE slag is produced and disposed in Baotou Radioactive Waste Storage Facility

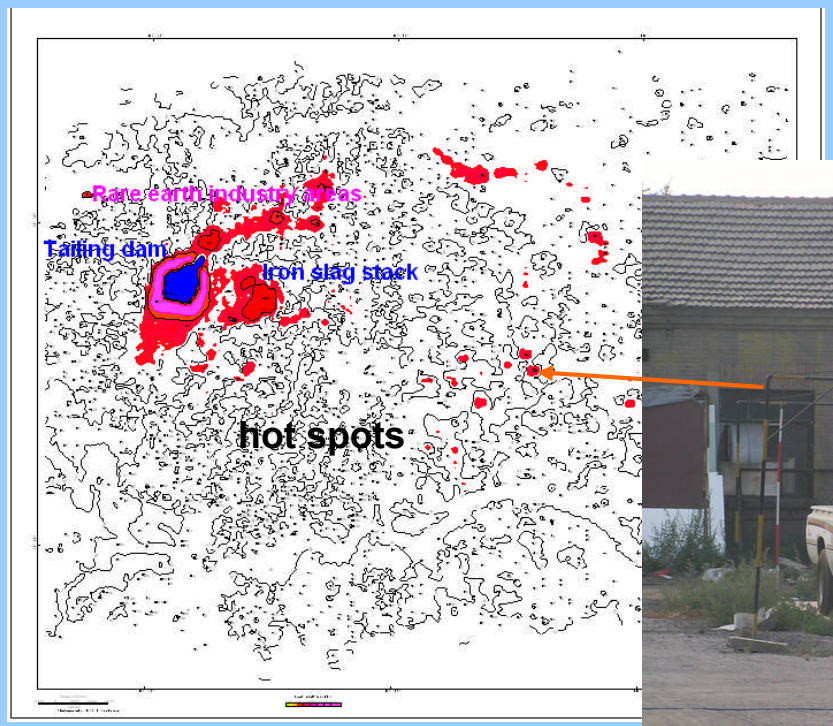
Legacy/NORM sites in Baotou



abandoned rare earth plants

RE slag 10m*15m
1830nGy/h

Legacy/NORM sites in Baotou



		Above slag pile	central site of driver training
Rn	^{222}Rn、(Bq/m^3)	916	218
	^{220}Rn (Bq/m^3)	2693	342
progeny	^{222}Rn (nJ/m^3)	12.5	11.1
	^{220}Rn (nJ/m^3)	234.1	174.8
Gamma dose rate(nGy/h)		1600	360

The plant is closed, but rare earth slag left

5. dataset available for radiological assessment

Typical ranges of radiation level in work places and environment

Type of samples	*Gamma dose rate nGy/h	**PAEC of ^{220}Rn progeny Mev/l
Bayan Obo background	85	
Mining sites	600-2000	
Dumping sites	400 to 800	226.1
Work places in plants	300-500	
Bayan Obo City area	100 -150, average 121	199.4
Background in Baotou	65	
Work places in plants	Mostly,300-500; Some,500-1000,max 1518	25-500 (average 126)
Taillings	650-1200	75.4-590.1 (average 243)
RE slag pile	1500-4000	
Contaminated soil in Baotou	85-150	
Baotou City	Background	69-125.6 (average 94)

*PAG- data after the Programme of Aero survey and ground measurements

**MIMRE- data after the results of Monitoring by Inner Mongolia Radioactive Environment Management Institute

5. dataset -cont.

Typical ranges of radionuclide concentration in environmental materials

Type of samples		units	^{226}Ra	^{232}Th	^{228}Ra	
Soil background in Bayan Obo		Bq/kg	33	46		PAG
tailings				about 1600		PAG
ferrous slag		Bq/kg		$0.5\text{-}1.6\times10^{3}$		PAG
RE slag		Bq/kg		$2.0\text{-}3.8\times10^{3}$		PAG
contaminated soil(upper layer 10 cm) in Bayan		Bq/kg		80-120		PAG
dust powder from	crushing and sorting plant	Bq/kg		$1.3\text{-}1.9\times10^{3}$	$1.2\text{-}2.0\times10^{3}$	MIMRE
	sintered plant	Bq/kg		$0.5\text{-}1.6\times10^{2}$	$1.2\text{-}2.0\times10^{2}$	
	steel smelting plant	Bq/kg		$0.2\text{-}1.2\times10^{2}$	$0.2\text{-}1.1\times10^{2}$	
exhaust gas from RE plant		10^{-2} Bq m^{-3}		3.2		MIMRE
Soil background in Baotou		Bq/kg	33	36		PAG
contaminated soil(upper layer 20 cm) in Baotou		Bq/kg		80-200,or>400 near tailing pond		PAG

*PAG- data after the Programme of Aero survey and ground measurements

**MIMRE- data after the results of Monitoring by Inner Mongolia Radioactive Environment Management Institute

5. dataset -cont.

Building material with ferrous slags (2007)

Factories	Major products	Ra-226	Th-232	K-40
		Bq/kg	Bq/kg	Bq/kg
A brick factory	paving bricks house bricks	51	212	123
Cement factory 1	Cement	83.6	330.9	429.2
Cement factory 2	425# cement 325# cement	24.6	240.1	371.9

Indoor radiation level

Type of samples	PAEC of ^{222}Rn progeny	PAEC of ^{220}Rn progeny	Gamma dose rate
	(nJ/m^3)	(nJ/m^3)	(E-8Gy/h)
BS	212.5	186.25	16.12
BNS	60.86	37.78	12.63

BS-the buildings made of slag bricks.

BNS-the normal buildings not containing slag

5. dataset -cont.

mining workers

8 h per day, or 251 days per year

Special workers- on the tailing pond or ferrous slag dump

2 h per day, or 251 days per year

6. Radiological assessment

Bayan obo

- Most of workers receive 0.24-0.7 mSv/a of additional external exposures
- But some workers may receive more than 1.0 mSv/a
- Public in the Bayan Obo city area receives additional external exposure about 0.044 mSv/a

6. Radiological assessment-cont.

Baotou

- The additional external exposures for workers are in range of 0.3- 0.6mSv/a
- The additional external exposure is 0.043mSv/a for members of the public living in the soil contaminated area.
- The indoor effective dose for the buildings containing no slag is 1.86 mSv/a in Baotou City area (similar to other places in China), but the dose becomes higher than 2.0 mSv/a for most of the buildings made of slag bricks.

7. Questions

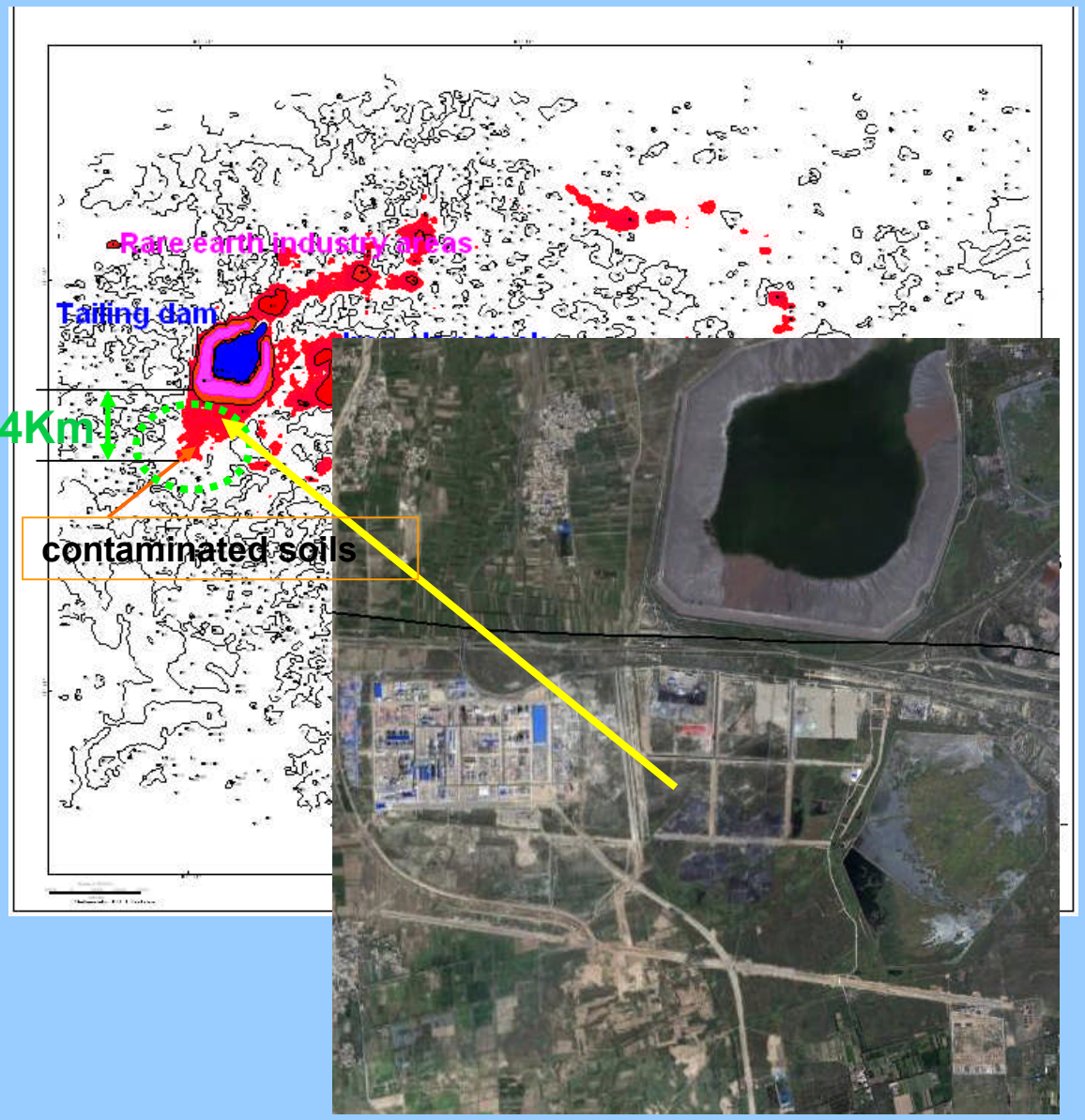
- **Need to perform a dose assessment**

(case1)Legacy sites
risk and safety assessments in support to decision making for remediation

abandoned plants

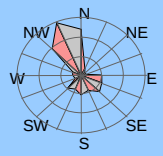
The closed plant for other uses, but rare earth slag left

7. Questions



- **Need to perform a dose assessment**

(case2)Estimate exposure of the public for the current situation in contaminated area.
internal dose may be significant and mainly result from dust and aerosols of ^{220}Rn progenies transported from tailing pond



wind direction: NNW

wind speed : 3.4 m/s

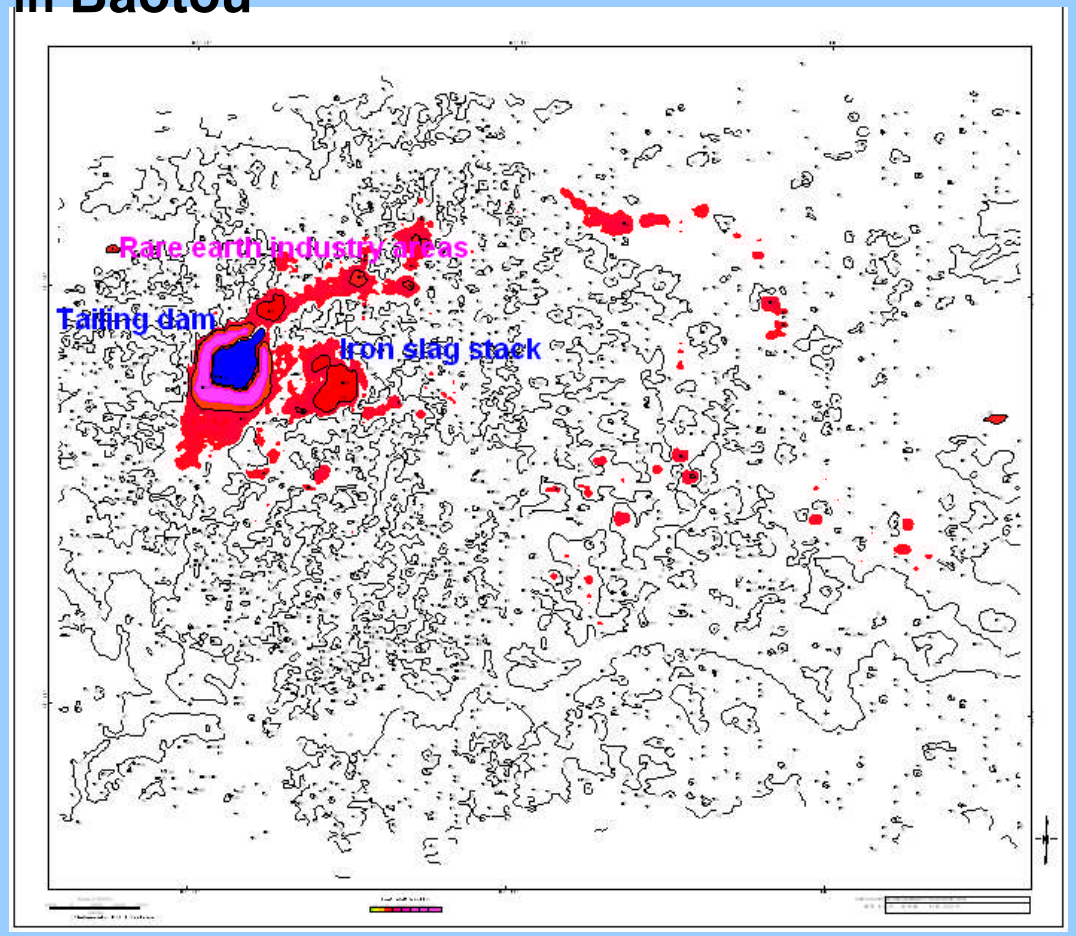
TSP:0.44mg/m^3

PM10(in tailings): 11.6%

7. Questions

- **Need to perform a dose assessment**

  (case3)Estimate exposure of the Public in an area of 42.5Km×30 Km in Baotou



ACKNOWLEDGEMENTS

- **EMRAS II WG2 ,IAEA**
- **Institut de Radioprotection et de Sûreté Nucléaire (IRSN)**
- **Department of Nuclear Safety Management of Ministry of Environment Protection of China**
- **China Aero Geophysical Survey & Remote Sensing Center for Land and Resources**
- **Mr Liu Hua and Mr. Pan Ziqiang**
- **Ms Astrid Liland**
- **Ms Virginia Koukouliou**
- **Mr Thierry.DOURSOUT**
- **Mr C. Yu**
- **Mr/Ms…….**

OTHER CONTRIBUTORS OF THE RESEARCH PROGRAMME

Mr. Pan Su, Mr. Feng Youcai and Mr. Li Rujun

Dept. of Nuclear Safety Management of MEP

Mr. Cheng Jianping, Mr. Qin Zhangjian, Mr. Jin Ge

Dept. of Engineering Physics of Tsinghua University

Mr.Yang Bin, Mr. Ma Yongfu, Mr. Yang Weigeng, Song Jianfeng, Xiang Yuanyi, Zheng Guodong,

Zhejiang Province Environmental Radiation Monitoring Center

Mr. Sui Wenli, Ms. Liu Guifang, Ms. Wang Xiaoqing and Mr. Li Xiansheng

Inner Mongolia Radioactive Environment Management Institute.

Mr. Luo Jianjun, Mr. Liu Xinhua

Nuclear and Radiation Safety Center of MEP

Thank you!