cags

China Australia Geological Storage of CO_2

中 澳 二 氧 化 碳 地 质 封 存

二氧化碳捕集、输送、驱油封存过程的环境监测

Environmental Monitoring for CO_2 capture, transportation, enhanced oil recovery and storage

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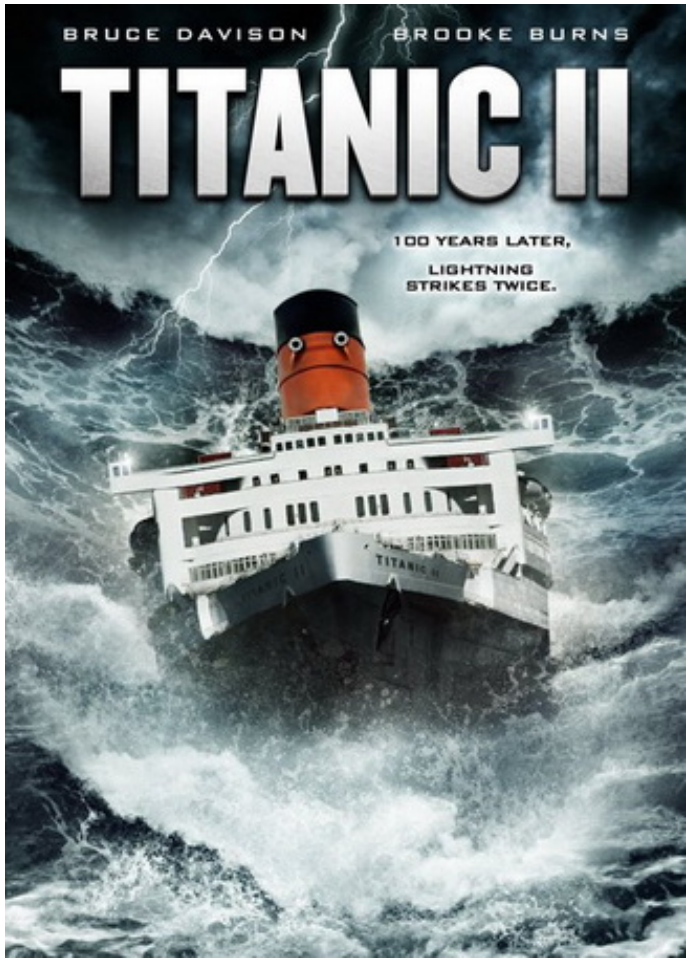
中石化石油设计有限公司

ZHANG Yuanyuan
Sinopec petroleum engineering & consulting corporation

两部电影Two Films



两部电影Two Films

Climate change:
Melt of Glaciers

"The largest coronal mass emission CH_4" the Earth's atmosphere to burn

主要内容Outline

一 技术背景

Ⅰ．Background of CCS

二 碳捕集、输送及封存的环境污染识别

Ⅱ．Environmental Pollution during CCS

三 环境监测及环境监管

Ⅲ．Environmental Monitoring and Regulations for CCS

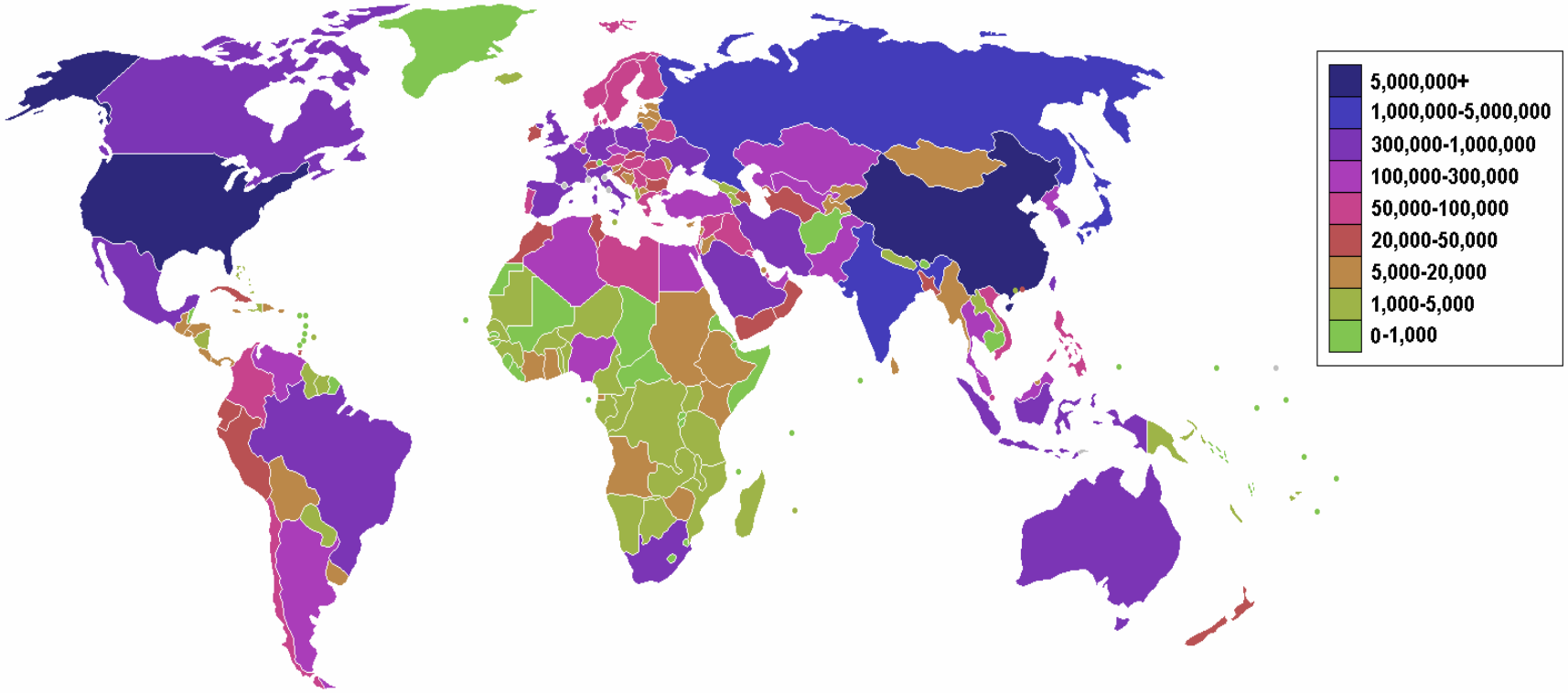
四 案例分析-胜利油田CCUS项目的环境监测

Ⅳ．Introduction of Environmental Monitoring in Shengli

技术背景 Background

全球气候变化问题日益严峻，已经成为威胁人类可持续发展的主要因素之一，削减温室气体特别是CO_2的排放以减缓气候变化成为当今国际社会关注的热点。

Climate change is one of the most significant threats facing the world today. Avoiding the worst consequences of climate change will require large cuts in global greenhouse gas emissions which has been the hot issues in international society.



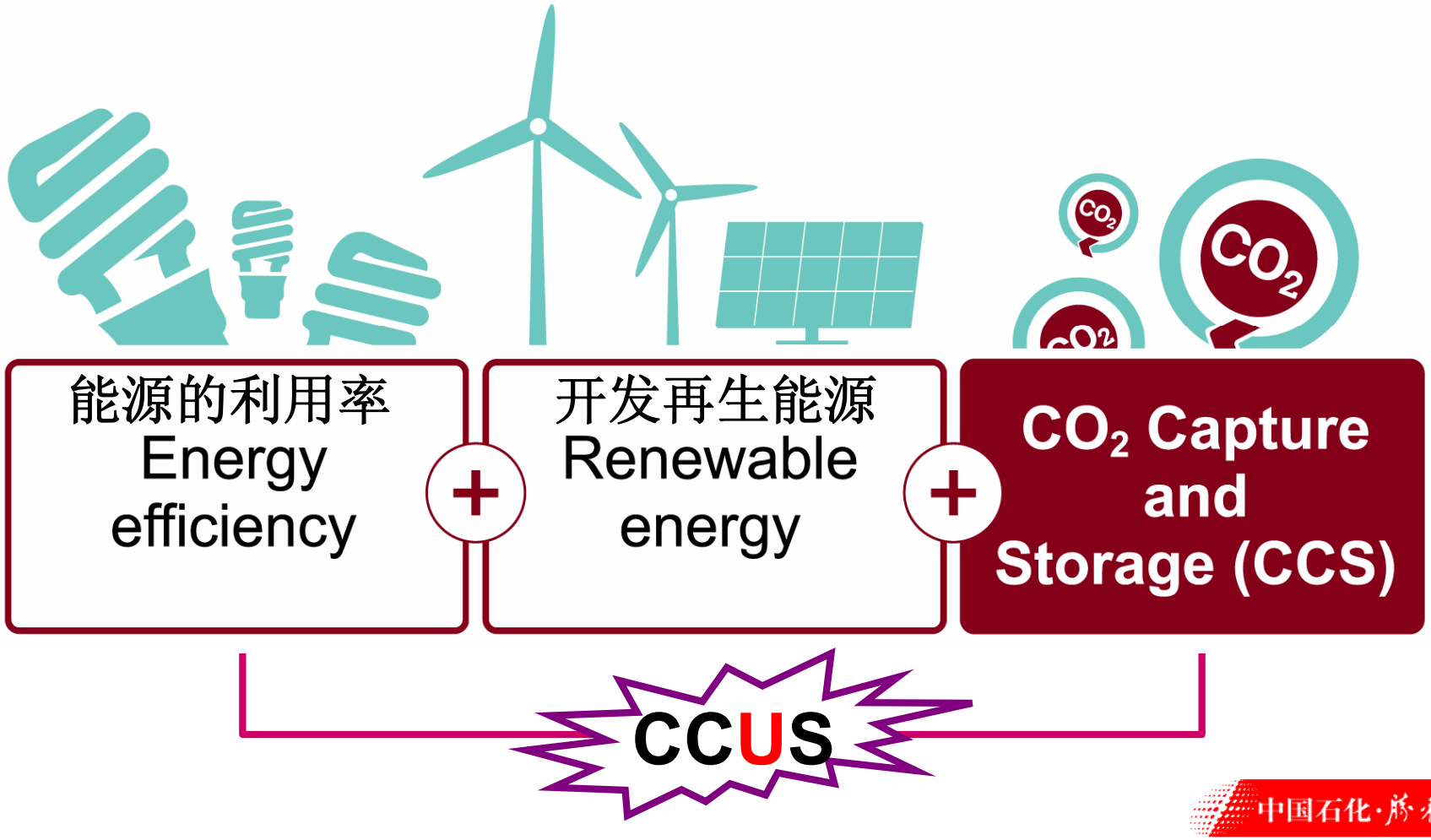
通过燃烧化石燃料产生的二氧化碳排放量的国家

Carbon Dioxide Emissions by Burning Fossil Fuels in the World

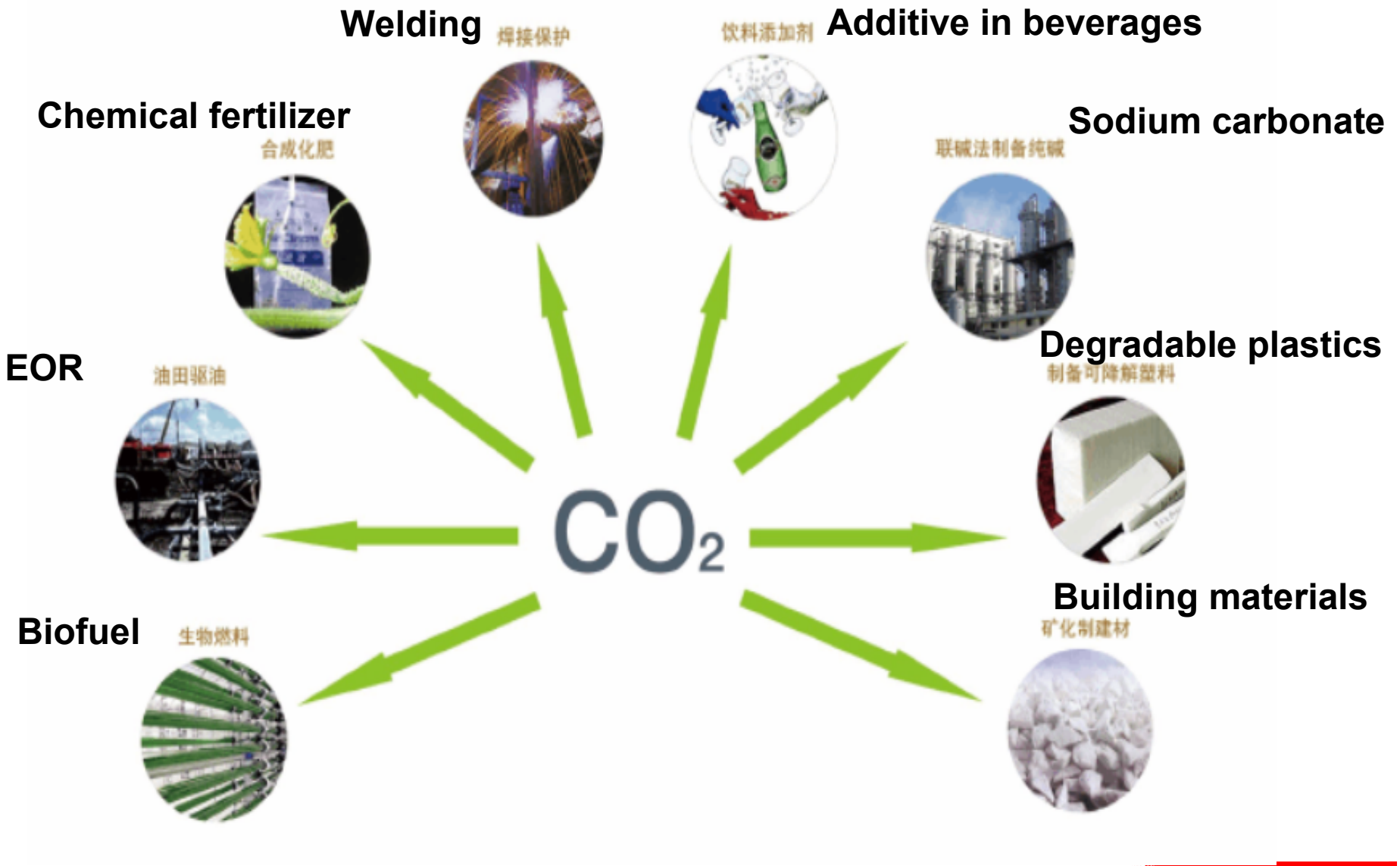
技术背景 Background

碳减排的方法：

Methods for CO_2 mitigation



技术背景 Background



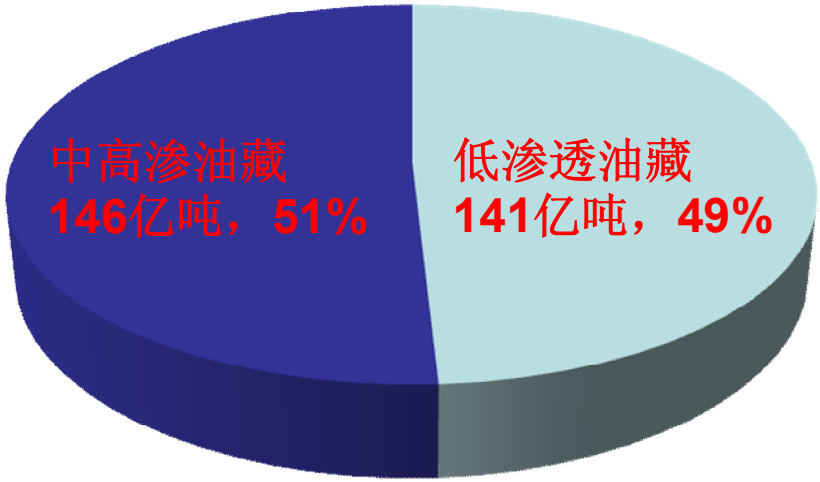
技术背景 Background

CO_2-EOR是中国现阶段规模化CO_2利用封存有效途径

CO_2-EOR is an ideal option for CO_2 geological storage at present

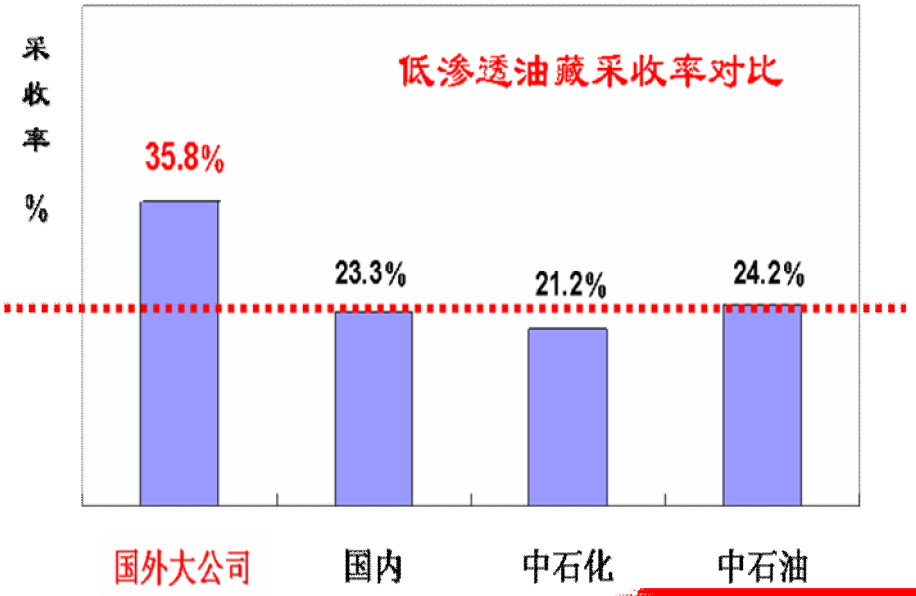
中国低渗透油藏储量规模大、动用率低、采收率低，而超临界CO_2是具有高密度、低粘度、易与原油混相等特性，是优越的驱油剂，可广泛应用于我国低渗透油藏，并大幅度提高其采收率。

Low permeability reserves in China are large-scale with low use and recovery efficiency. Supercritical CO_2 is characterized by high density, low viscosity, easy to mix with crude oil. Thus, CO_2 flooding is excellent, and can be widely used in low permeability reservoirs in China.



中国探明石油地质储量品位分布饼状图

（2008年）



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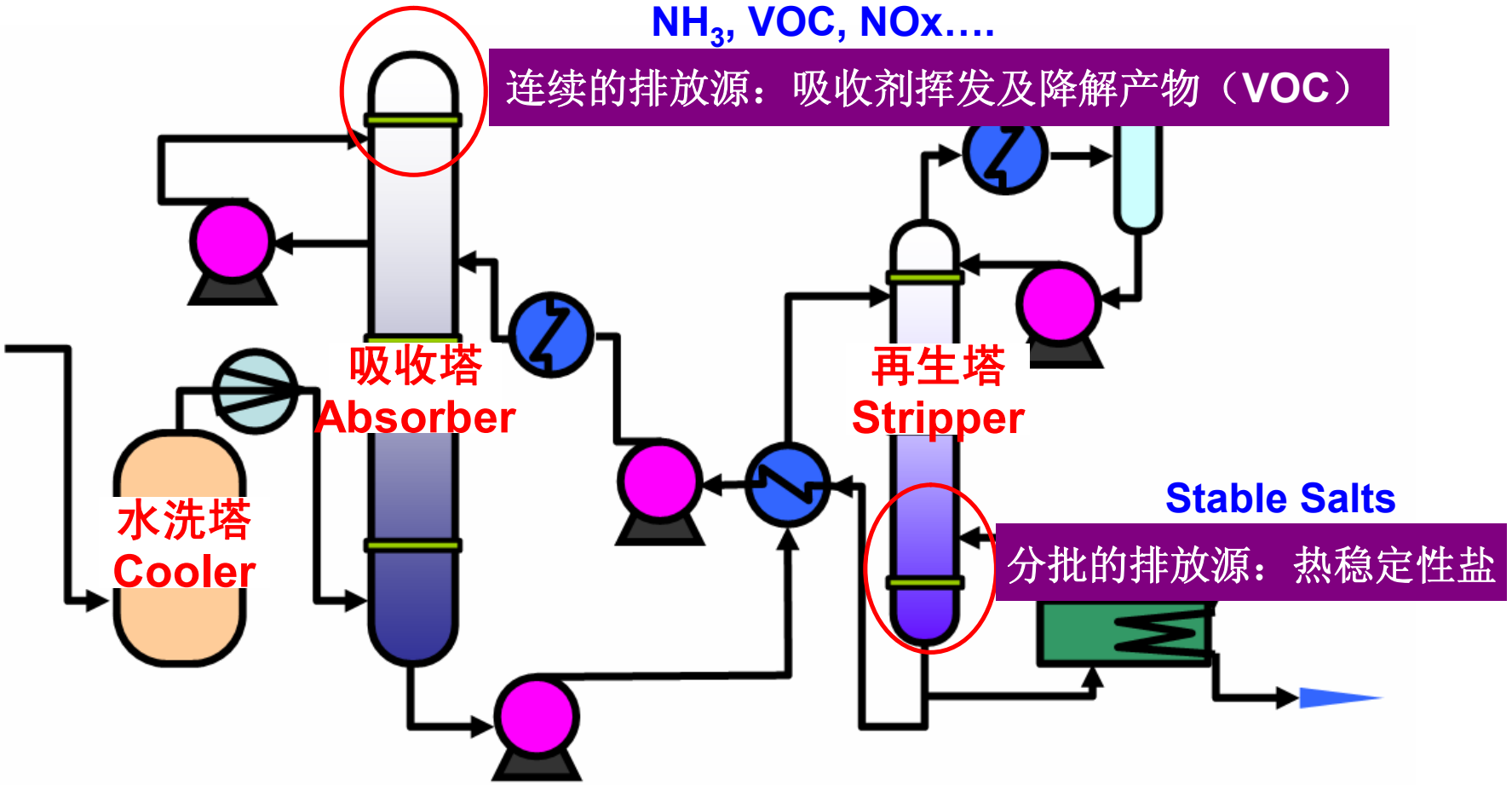
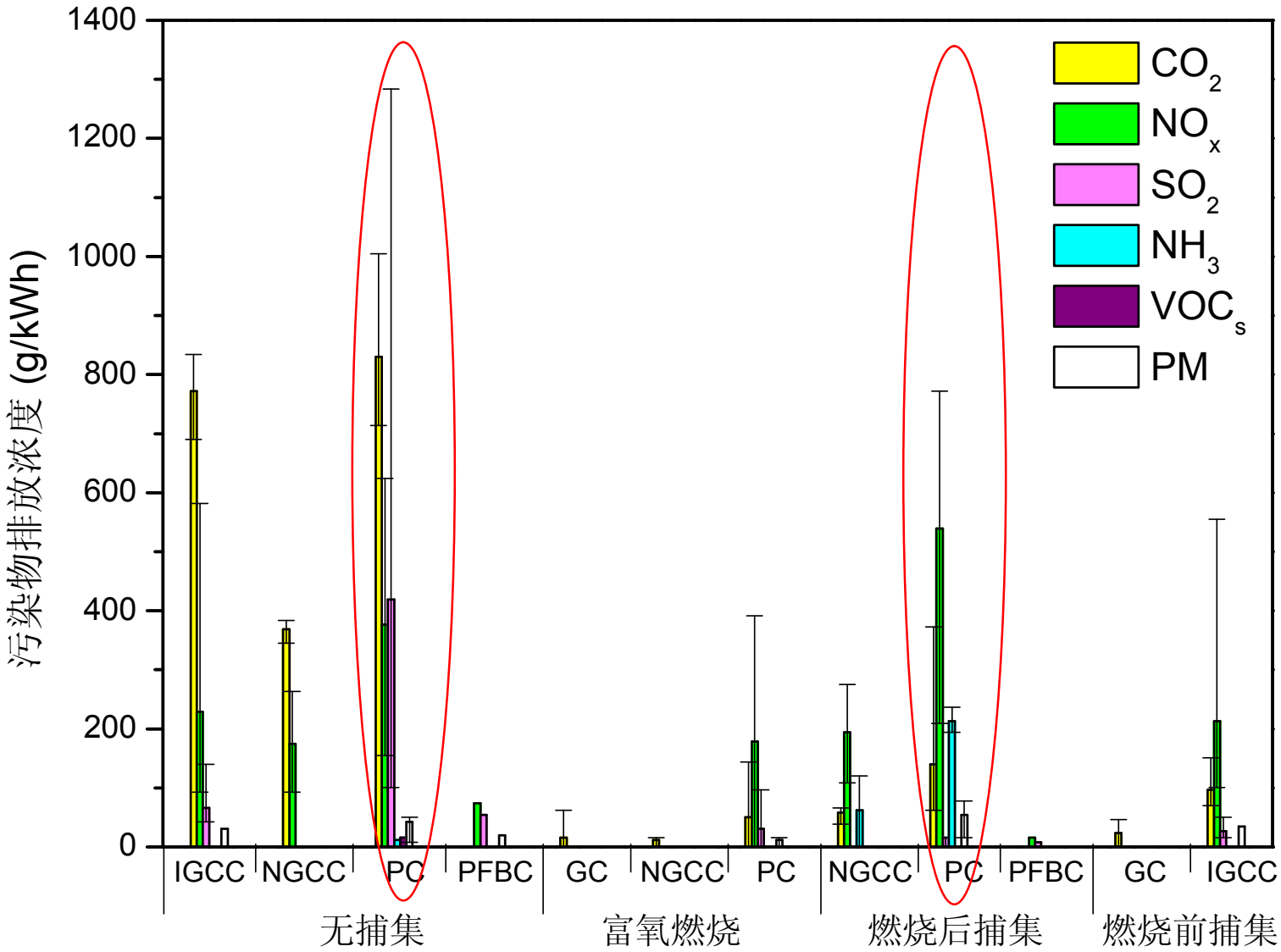
捕集阶段 Capture Stage

污染物：气体和液体

Pollutants gas and liquid



捕集阶段 Capture Stage



Koornneef, J., et al. (2010). The impact of CO_2 capture in the power and heat Sector on the emission of SO_2, NOx, Particulate Matter, Volatile Organic Compounds and NH_3 in the European Union. Atmospheric Environment 44, 1369~1385.

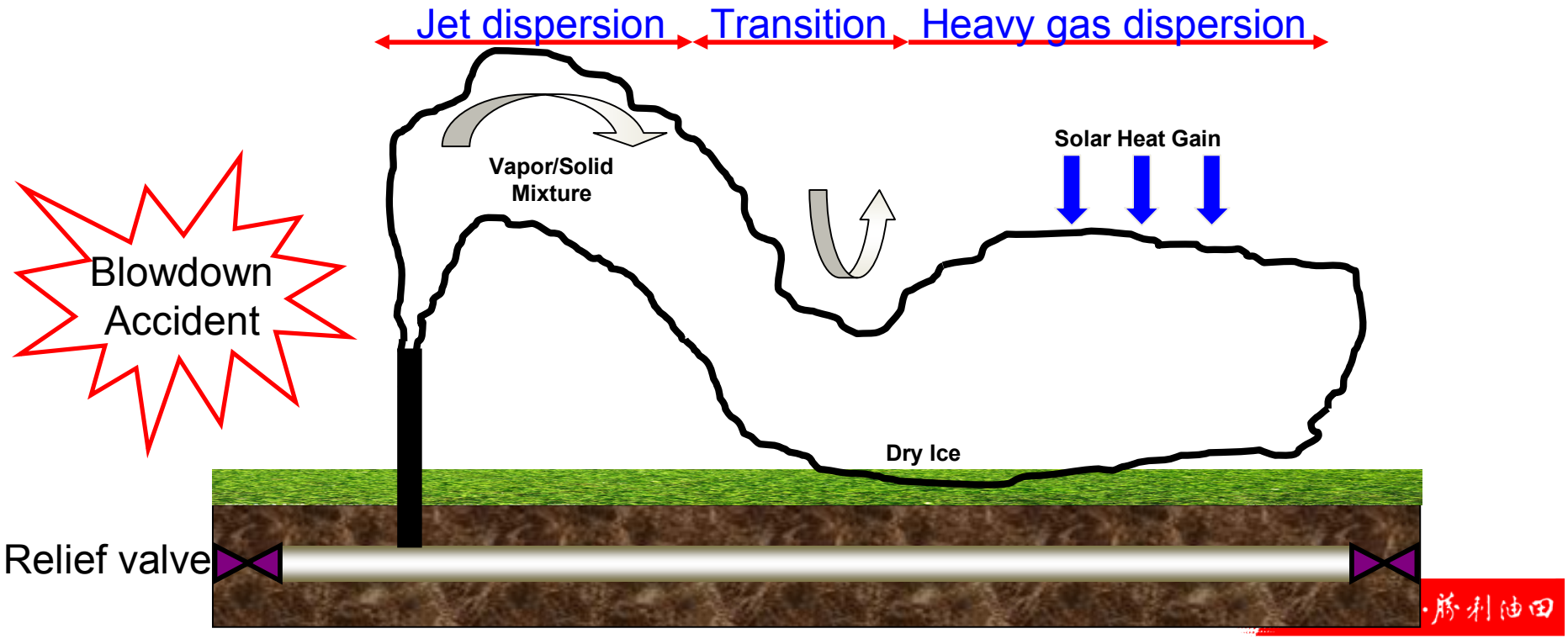
输送阶段 Transportation Stage

当CO_2浓度高于10%时，人在短时间内将失去意识，存活率很低。管道一旦发生泄露，周围大气中CO_2浓度将迅速升高，可能危机人体健康。

At concentrations higher than 10%, CO_2 gas can cause severe injury or death due to asphyxiation.

In case of accidental leakage/ release of CO_2 from a pipeline (typically containing several Mt of inventory), the released CO_2 dense gas cloud:

- could accumulate to potentially dangerous concentrations in low-lying areas,
- could cover an area of several square kilometers

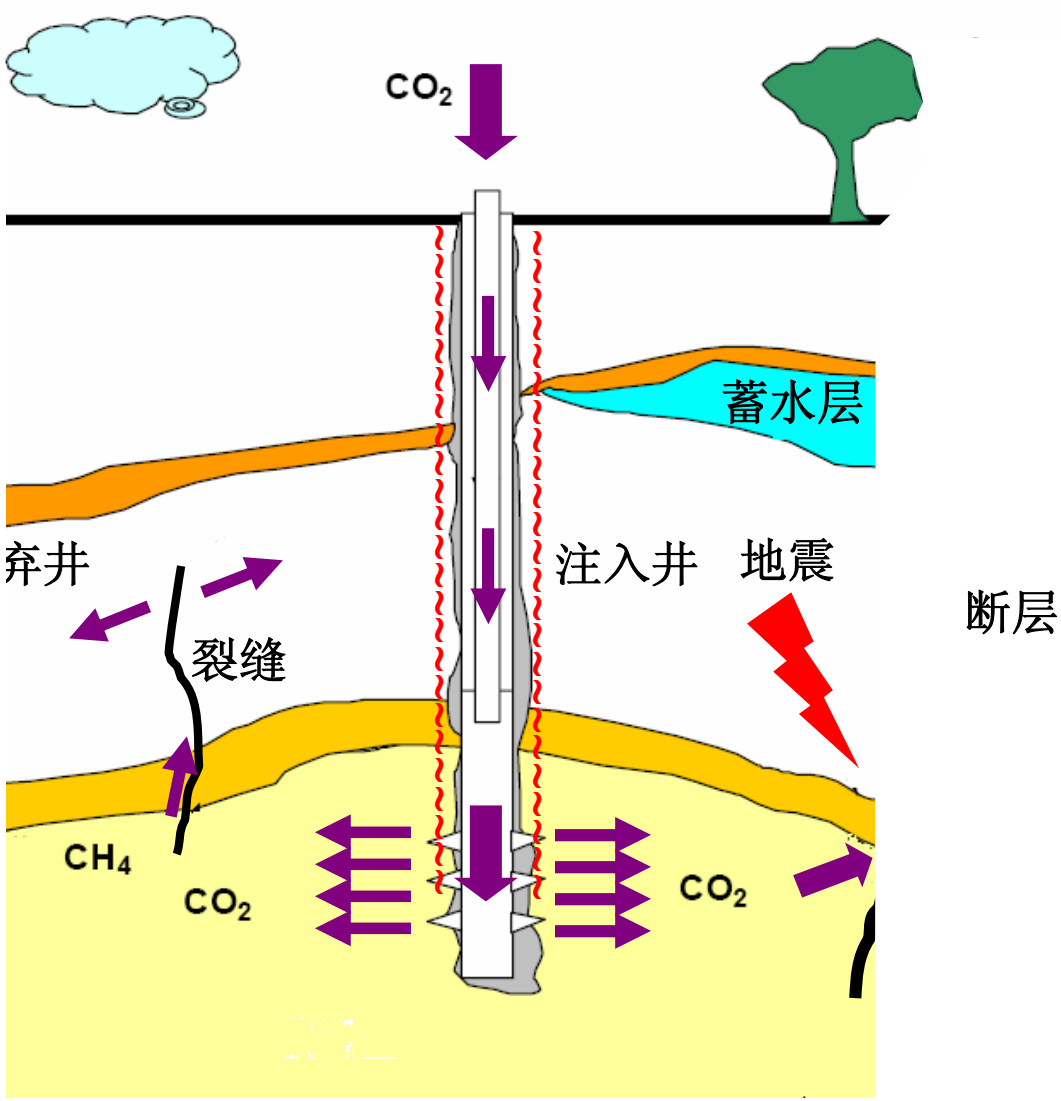


输送阶段 Transportation Stage

In 2006 and 2010, BP and Shell conducted field experiments on CO_2 release and dispersion during transmission to conduct industrial-scale validation tests of theoretical models, respectively.

驱油封存环节 EOR and storage stage

- **注入井**
  injection well
- **废弃井**
  abandoned well
- **裂缝**
  crack
- **断层**
  fault



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监管经验 Regulations for CCS

- **国际监管经验**（监测结果影响封存执照的签发/撤销）
  - 澳大利亚：CO_2地质封存环境指南
  - 欧　　盟：CO_2地质封存指令
  - 美　　国：CO_2捕集运输封存指南
  - 英　　国：二氧化碳储存许可法令
  - 挪　　威：CO_2地质封存选址指南
  - 日　　本：海洋污染防治法的修订
  - 中　　国：CO_2封存环境管理的技术标准正在进行中

Developed countries, including Europe, Australia, US, Japan, and UK, have provided regulations for carbon storage and emphasized the importance of environmental impacts during the life cycle of CO_2 storage (Directive 2009/31/EC, 2009; Australian Environment Protection and Heritage Council, 2009; US EPA, 2010; Marine Pollution Prevention Law, 2007; UK Parliament, 2010). In China, CO_2-EOR is still in the early research stage (development and demonstration phase), and the present CO_2-EOR projects are focused mainly on oil recovery efficiency.

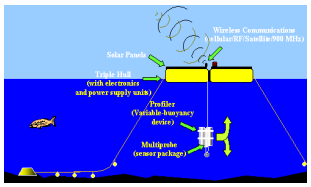
监测方法 Monitoring methods

静态箱

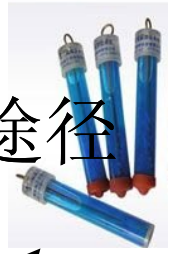
探空

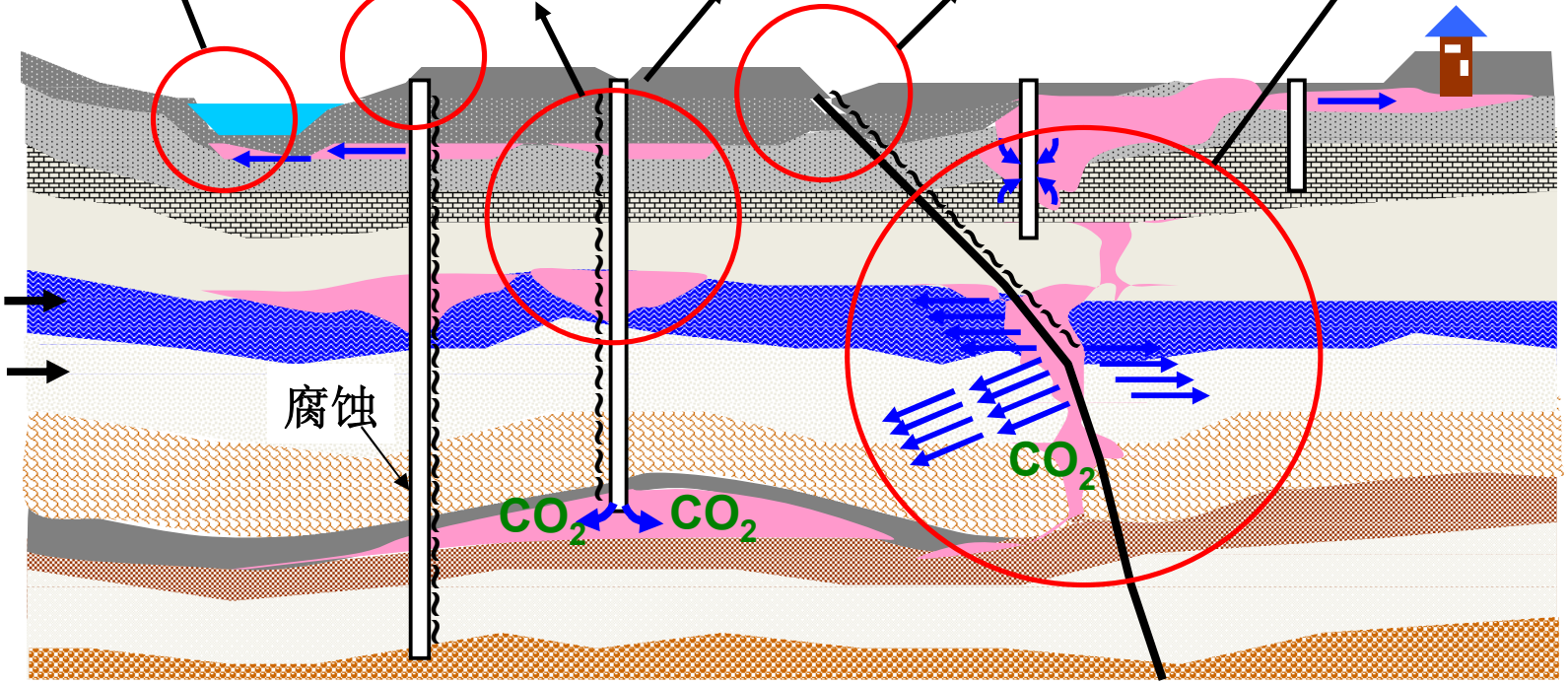
判断途径

水质



判断途径





监测方法 Monitoring methods

- **国外CO_2-EOR及咸水层封存多采用地震法确定羽状流位置，但地震法的应用受埋存深度的影响较大。**

  Seismic method to simulate CO_2 plume. Height of CO_2 injection affects the feasibility of this method.

埋存越深地震获取信号越弱该方法的可行性越差

		浅地层监测									地表和近地表监测					
		4D地震	3D地震	2D地震	VSP	微地震	电磁测量	重力	倾斜仪	井液	水体	土壤气	大气	植被	地面沉降	微生物
CO_2-EOR	Weyburn	■	■		■	■				■		■				
	Pembina Ca	■			■											
	吉林油田		■								■	■				
	胜利油田	■								■	■	■	■	■	■	
	延长油田		■								■	■				
CO_2咸水层封存	神华		■		■						■	■	■	■		
	Aquistore		■		■				■		■	■			■	
	In Salah	■			■	■		■	■	■		■	■	■	■	
	Sleipner	■		■		■	■	■			■			■		
	Snohvit	■														
	Lacq	■				■					■	■		■		
	Otway	■			■	■				■	■	■	■			
	CO_2SINK	■	■	■	■		■					■	■			■
	Frio	■	■		■		■				■	■	■			

4500m

2000m

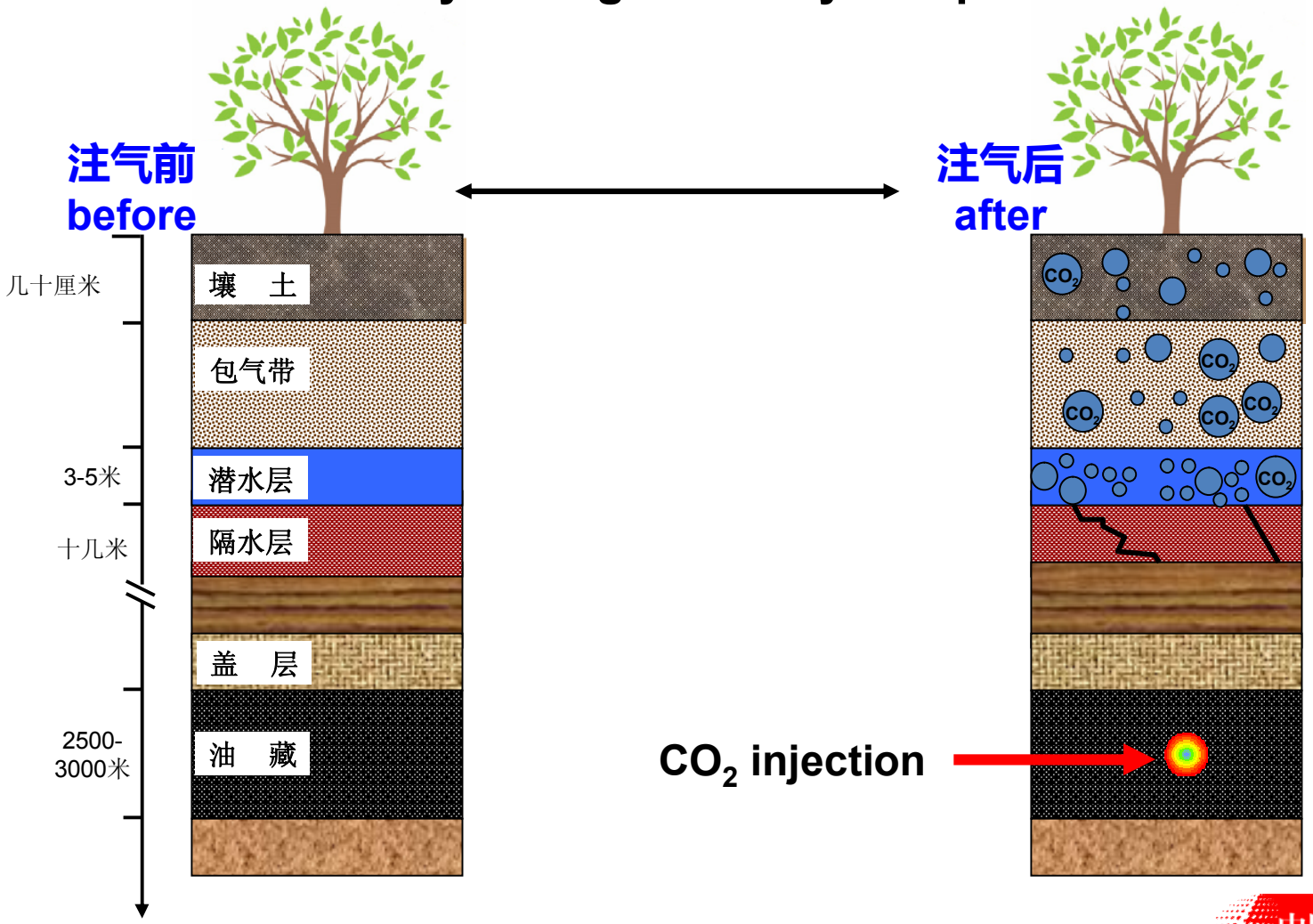
监测方法 Monitoring methods

- **国外CO_2-EOR及咸水层封存近地面监测关注水体和土壤气较多。Ground water and soil gas**
  - 水体：可参考水质标准（饮用、工业用水）进行约束，便于监管
  - 土壤气：直接影响植物、动物的生长，方便监测

		浅地层监测									地表和近地表监测					
		4D地震	3D地震	2D地震	VSP	微地震	电磁测量	重力	倾斜仪	井液	水体	土壤气	大气	植被	地面沉降	微生物
CO_2-EOR	Weyburn	■	■		■	■				■		■				
	Pembina Ca	■			■											
	吉林油田		■								■	■				
	胜利油田	■								■	■	■	■	■	■	
	延长油田		■								■	■				
CO_2咸水层封存	神华		■		■						■	■	■	■		
	Aquistore		■		■				■		■	■			■	
	In Salah	■			■	■		■	■	■		■	■	■	■	
	Sleipner	■		■		■	■	■			■			■		
	Snohvit	■														
	Lacq					■					■	■		■		
	Otway				■	■				■	■	■	■			
	CO_2SINK	■	■	■	■		■					■	■			■
	Frio	■	■		■		■				■	■	■			

监测方法 Monitoring methods

通过对比识别泄露风险
Identify leakage risks by comparison



监测方法 Monitoring methods

Developed online software tool to present monitoring techniques

Monitoring Selection Tool

HIDE PANEL | You are not logged-in | LOGIN | Enter scenario name here ... | NEW | RUN

Reservoir location	Reservoir depth	Reservoir type	Landuse at site	Monitoring phase	Monitoring aims		Tool package
(•) Onshore	( ) 0.5-1.5 km	( ) Aquifer	( ) Settled	(•) Pre-injection	[ ] Plume	[ ] Calibrate	( ) Core
( ) Offshore	( ) 1.5-2.5 km	(•) Oil	(•) Agricultural	( ) Injection	[ ] Top-seal	[x] Leakage	( ) Extra
( ) Both	(•) 2.5-4 km	( ) Gas	( ) Wooded	( ) Post-injection	[ ] Migration	[ ] Seismicity	(•) All
	( ) >4 km	( ) Coal	( ) Arid	( ) Closure	[ ] Quantify	[ ] Integrity	
			( ) Protected		[ ] Efficiency	[ ] Confidence	

35 Injection rate (Mt/year) | 5 Duration (years) | PRINT PAGE | CREATE CSV | TOOL CATALOGUE | HELP

Scenario name	Enter scenario name here ... [2013-09-30 02:20:59]
Location	Onshore
Depth	2500 to 4000 m
Type	Oil
Quantity	175.000 Mt (35.000 Mt/yr for 5.0 yrs)
Package	Agricultural+Pre-injection+All

Tool	Rating %	Leakages
Soil gas concentrations	100	4.0
Bubble stream detection	100	4.0
IR diode lasers	75	3.0
Non dispersive IR gas analysers	75	3.0
Bubble stream chemistry	75	3.0
Downhole fluid chemistry	75	3.0
Eddy covariance	75	3.0
Surface gas flux	75	3.0
Airborne spectral imaging	75	3.0
Long-term downhole pH	50	2.0
Fluid geochemistry	50	2.0
Ecosystems studies	50	2.0
Tracers	50	2.0
Tiltmeters	25	1.0

Interactive tool can be found at: **http://www.ieaghg.org/index.php?/Monitoring-Selection-Tool.html**

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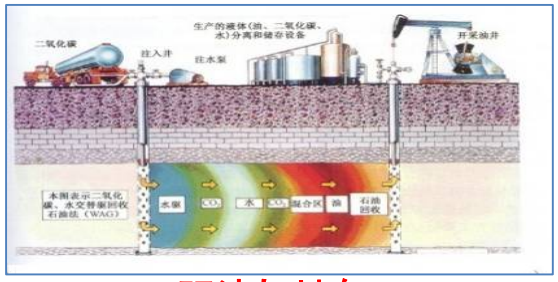
案例分析-Shengli oilfield case study

中国石化胜利油田紧密结合自身企业特点，在国内外率先开展了以燃煤电厂烟气为CO_2捕集气源、CO_2驱油为主要资源化利用及封存方式的CCUS技术研发及应用示范，实现了原油开采的“绿色无碳*”。

In light of the characteristics of our enterprise, and giving full play to the strength of integration stragety, Sinopec has laid strong emphasis on CCUS technology research and application demonstration, which adpots CO_2 flooding as the major method of resource utilization and storage, achieving “Green Oil”.

燃煤电厂烟气CO_2捕集



驱油与封存

CO_2减排—绿色低碳 环境生态效益

Emission Reduction
---Social & Environmental Benefits

CO_2驱油—提高采收率 经济效益

Enhanced Oil Recovery
---Financial Benefits

* 经概算，消耗1吨原油产生约3.02吨CO_2，在低渗透油田应用CCUS技术，每注入封存4-5.6吨CO_2，可以增产原油1吨，消耗这部分原油CO_2净产生量为负值。

案例分析-Shengli oilfield case study

- 建成了4万吨/年燃煤电厂烟气CO_2捕集纯化成套装置
  Sinopec 100 t/d CCUS Project on Coal-fired Power Plant Flue Gas

将胜利电厂烟气中的CO_2捕集出来，经过压缩、干燥、液化及存储后，通过罐车输送至油区用于CO_2驱油与封存。

Process: capture and purify in Shengli Power plant, compress, dry, liquefy, store and CO_2 flooding





捕集纯化 Capture & Purify Shengli Power Plant	压缩 Compress	干燥 Dry	液化 Liquefy	储存装车 Store,Load
MSA化学吸收工艺	往复式三级压缩	硅胶吸附	R-22氟利昂制冷剂	真空绝热储罐
捕集率：80% 纯度：99.5%	出口压力：2.5MPa 出口温度：40℃	水露点 ≤－40℃	液化温度：-20℃	储存压力：2.2MPa 储存温度：-20℃

案例分析-Shengli oilfield case study

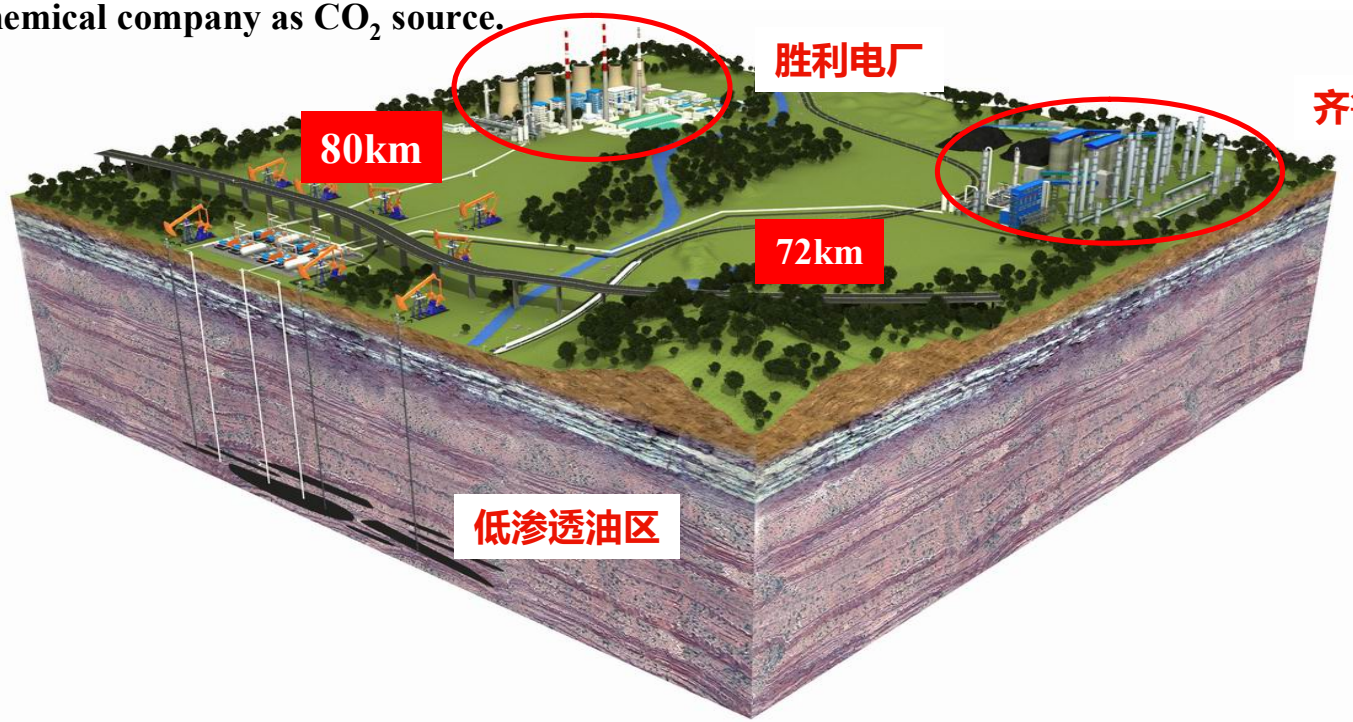
依托现有技术，中国石化建成了4万吨/年燃煤电厂烟气CO_2捕集纯化成套装置和高89低渗透油藏封存驱油场地，目前开展两项大规模CCUS示范工程的研究开发与施工建设：

（1）齐鲁石化50万吨/年煤制气尾气CO_2捕集、输送及驱油封存示范工程；

（2）胜利电厂100万吨/年燃煤烟道气CO_2捕集、输送及驱油封存示范工程。

Sinopec has built up 100 t/d CCUS Project on Coal-fired Power Plant Flue Gas, and now there are two ongoing CCUS projects:

One is 1 million tons/year CO_2-EOR project with flue gas from Shengli coal-fired power plant as CO_2 source, and the other one is for 0.5 million tons/year CO_2-EOR project with coal gas from Sinopec Qilu Petrochemical company as CO_2 source.



中国石化·胜利油田

案例分析-Shengli oilfield case study

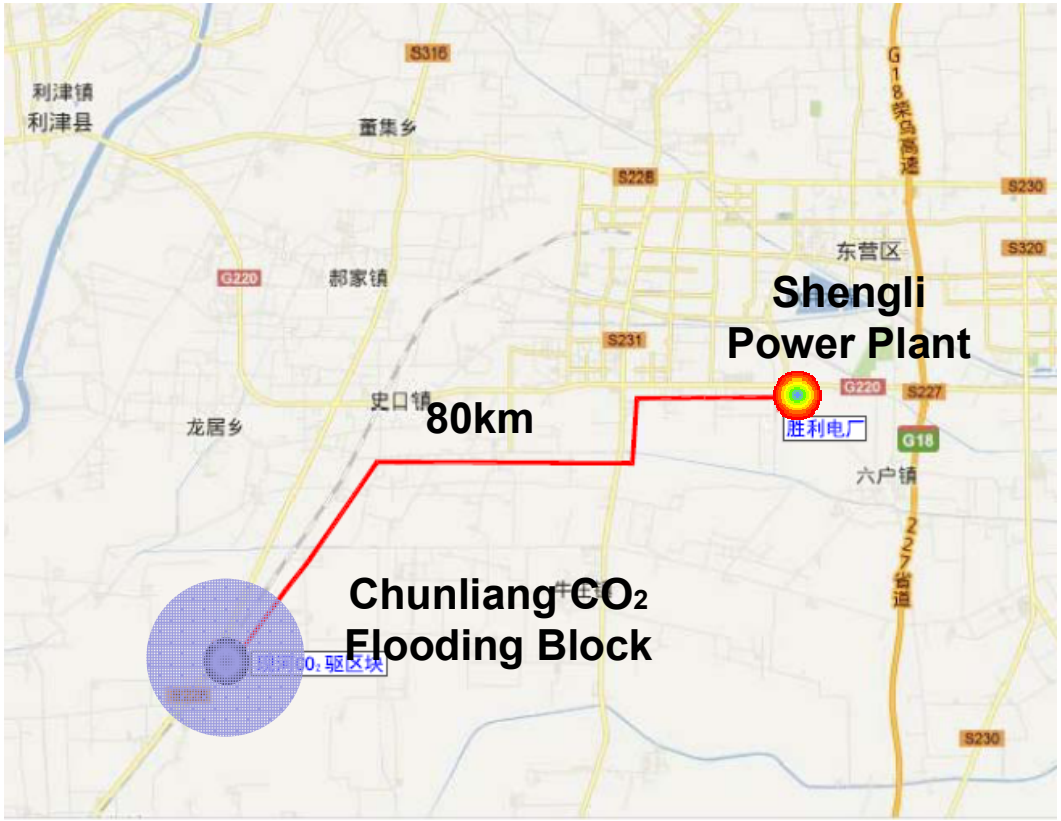
Shengli Power Plant Phase III,
Rarefied CO_2
(CO_2 14%)

↓

Chemical Absorption Process

↓ 1 Mt/a

Chunliang Oil Region
Flooding



Jan. 2012~Jun. 2013: Research

Dec. 2014: Project construction

2015: Project operation, monitoring and evaluation

案例分析-Shengli oilfield case study

QPEC Coal Gas, elevated CO_2 (CO_2 90%)

↓

Cryogenic Distillation Process

↓ 0.5 Mt/a

Chunliang Oil Region Flooding

Dec. 2012: Project plan and feasibility study completed

Dec. 2013: Project construction and commissioning completed

案例分析-Shengli oilfield case study

CO_2长输管线 CO_2 pipeline

输送的煤制气尾气中CO_2含量91.454%，采用气相输送，起输压力4MPa，管径DN400。

管线输送全线途经临淄区、桓台县和高青县，位于淄博市境内，管线全长约72.0km，是中国第一条CO_2长输管道。

Initial Pressure: 4.0MPa

CO_2 Phase: Gas

CO_2 content: 91.454%

Diameter of pipe: DN400mm

Length: 72 km

二氧化碳安全与环境监测技术
CO_2 safety and environmental monitoring

与清华大学、中科院武汉岩土力学所、中国矿业大学等研究机构联合开展了CO_2驱油封存的环境监测及评价方法开发，开发了胜利油田CO_2驱油示范区本底环境监测方案，确定对驱油示范区土壤气、地下水、植被、大气、地面变形等方面开展环境监测。

CO_2 environmental monitoring and impacts assessment will be studied cooperated with Tsinghua University, Institute of Rock and Soil Mechanics of Chinese Academy of Sciences, and China Mining University. Environmental monitoring plan for baseline has been finished, including soil gas, underground water, vegetation, air, and ground deformations.

结合会 2012年6月23日 设计院
初步确定本底监测方案的参与单位

论证会 2013年1月13日 武汉岩土所
本底环境监测方案汇报及研讨

商讨会 2013年3月6日 设计院
统一本底监测方案

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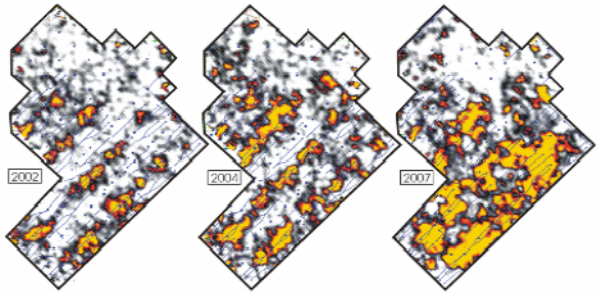
二氧化碳安全与环境监测技术
CO_2 safety and environmental monitoring

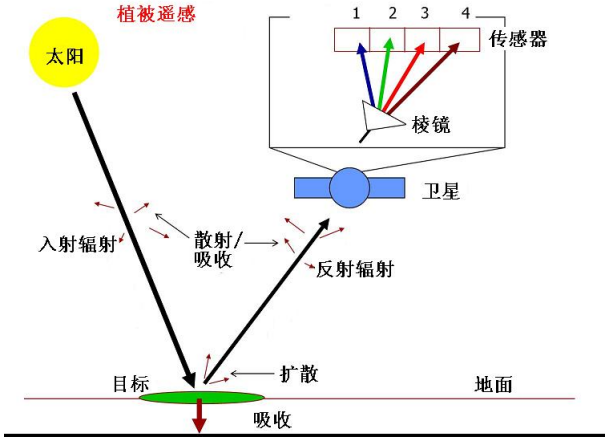
监测方法 Monitoring Methods

4D seismic



soil gas

Vegetation



ground deformations

GPS示意图

Ground water

便携式水质分析仪

离子色谱

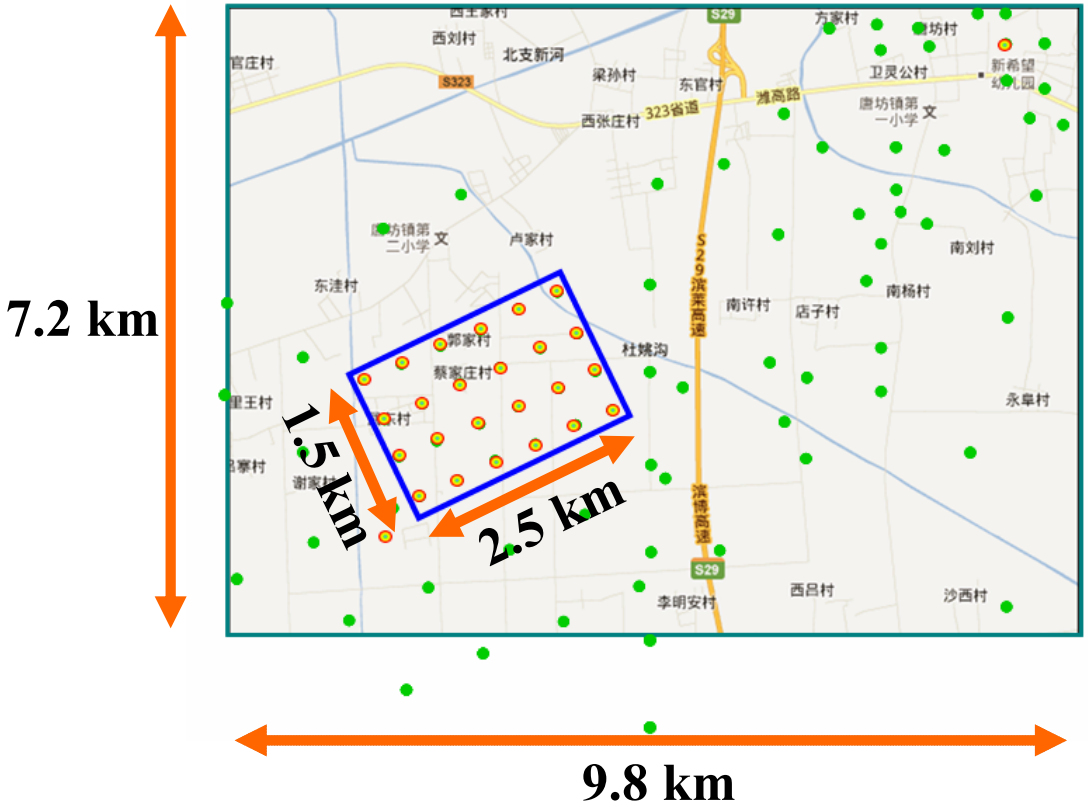
Air

土壤气监测 soil gas

土壤气CO_2通量 Soil gas CO_2 flux

拟注气区域(9.8km×7.2km)布设了86个监测点，其中已注气区域(2.5km×1.5km)含20个监测点。便携式GPS导航仪确保监测点的精确位置，选择EGM-4 CO_2呼吸仪监测土壤气CO_2通量。

There are total 86 monitoring points for soil gas CO_2 flux, in which 20 points are set up in injection area. Portable GPS is used to ensure the accurate position of monitoring points. EGM-4 is used to monitor soil gas CO_2 flux.



GPS

EGM-4

地表水监测 surface water

地表水


胜利高原公司制造


后维修保养
先停机断电

谢 谢！

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