The global drain
International dimensions of China’s groundwater pollution crisis

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China and groundwater: a very long story

Hemudu well: ~5700 years old

井 = ‘well’

Importance of groundwater in China

- Groundwater accounts for about one third of total water use in China
- Source of drinking water for ~70% of the population; about two thirds of cities/towns rely on groundwater for some or all of their drinking supply.
- Particularly important in northern China as rainfall is low (~150 to 700 mm/yr) and highly seasonal
- Supports huge irrigated agriculture sector (maize, wheat, cotton)
- Drinking water for hundreds of millions of Chinese people.
China’s groundwater challenges: Quality

Approximately 300 million people in China are using unsafe drinking water sources & 190 million each year fall ill due to water quality problems (although, improvements seen in recent years)

3 major water quality issues:
1. **Industrial pollution**: Responsible for increased incidence of cancers, especially gastro-intestinal cancers
2. **Agricultural pollution**: Has caused widespread pollution of China’s groundwater with Nitrate, ammonia, phosphorous & pesticides (human and ecological health issues)
3. **Geo-genic toxic elements (particularly arsenic)** causes chronic arsenicosis, skin lesions & skin cancer in many semi-arid regions of China
Pollution in China: front page news
2016 ‘Groundwater status bulletin’ from MWR

• This report made the international news. Estimated that in the northern plains, over 80% of shallow groundwater polluted, falling into the worst two water quality grades (IV and V)

• Large sample size: over 2500 wells sampled
图 1 地下水动态月报监测站网分布图
How is water quality measured and rated in China?

- China uses a 5 grade water quality rating system in national standards for Groundwater, surface water and marine water.

- Under the rating system, ~30 indicator pollutants are measured. If all pollutants are less than the specified level in the standard, the water is ranked ‘Class I’ (un-polluted).

- If one or more of the indicator pollutants exceed particular levels, quality is ranked in a lower category accordingly.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
<th>Uses</th>
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<tr>
<td>I</td>
<td>Unpolluted</td>
<td>Appropriate as drinking water sources</td>
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<tr>
<td>II</td>
<td>‘Light’ pollution</td>
<td>Non-preferred drinking water (but used with treatment)</td>
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<tr>
<td>III</td>
<td>‘Moderate’ pollution</td>
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<tr>
<td>IV</td>
<td>Polluted</td>
<td>Not fit for drinking/human contact</td>
</tr>
<tr>
<td>V</td>
<td>Seriously polluted</td>
<td>Not fit for any purpose</td>
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<tr>
<td>VI</td>
<td>Worse than serious pollution (‘Off the charts’)</td>
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Groundwater pollution – scale of the problem

Surface water pollution in major basins
What is the scale of water pollution in China?

• Conflicting public statements by government officials make it difficult to assess scale of problem. Water quality data for drinking water sources is not made public: https://www.chinadialogue.net/article/show/single/en/8922-Clear-as-mud-how-poor-data-is-thwarting-China-s-water-clean-up

• Ministry of Environmental Protection produces yearly Environmental Quality Bulletins, but data highly spatially aggregated.

• In 2015 Ministry of Land and Resources indicated that >60% of China’s groundwater is polluted (in Class IV or V) and only 9% in the top category (Class I)

• Ministry of Water Resources recently reported that >80% of groundwater used for urban drinking water supplies meets required standards (Class III or above)

➢ This is because drinking water is usually supplied by deep wells that are less affected by pollution (this is a questionable claim as discussed in Han et al, 2016; Peters et al 2015)
Industrial pollution (ground & surface water)

• Discharge of industrial wastewater into China’s rivers (both legal and illegal) has been a chronic problem for the last 2-3 decades

• ~80% of petrochemical plants and other major polluting industries located along rivers and most discharge directly into them

• Total annual wastewater discharge (COD) = 23.5 million tons of Chemical Oxygen Demand (COD), cf. estimated ‘bearing capacity’ of aquatic waterways = 7.4 million tons

Image source: China Dialogue
Mechanisms of groundwater pollution

1. Pollution discharge to surface water bodies → leakage of surface water to aquifers
   (e.g., on-site wastewater canals, ponds/waste storage areas or nearby streams)

2. Leaching of contaminated soils and open storage of solid waste materials by infiltrating rainfall

3. Leakage of underground storage tanks

4. (Illegal) pollution ‘disposal’ wells?
‘Disposal’ wells scandal

- In 2014 there were reports in Chinese and international media that many industries had been illegally paying for ‘disposal’ wells, and pumping wastewater directly underground through wells or illegal ‘seepage pits’.
- Whistle-blower drilling contractors claimed this practice was widespread throughout the country.
Tengger Desert scandal

https://www.youtube.com/watch?v=_q6hhWB1ixQ


- Petro-chemical companies in northwest China constructed huge wastewater disposal pits in the Tengger Desert.
- Wastewater seeped into groundwater and/or left toxic evaporated residues at the surface, which were buried underground.
  - Exposed by Chen Jie, Beijing-based photo journalist.
  - Huge response in Chinese media and government; Xi Jinping issued memos, State Council formed an investigation team and local officials punished.
Agricultural pollution (surface and groundwater)

- Fertilizer usage rates are 2-3 times the world average in China

- A combination of agricultural, industrial and domestic pollution is responsible for groundwater and surface water pollution in most areas.
- Industrial/agricultural sectors overlap geographically much more in China than Australia (e.g. ‘rural’ China has many industrial enterprises)
Cancer villages: the product of ‘break-neck’ economic growth?

**TABLE 1. Cancer villages in 2009 and GDP per capita in 2007 by province, China**

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Total: 459, 223, 241, 117, 218, 106, 238

The ‘Cancer Village Belt’: Huai/Hai River basins in North China

Cancer villages

- Defined as population centres in China where cancer rates (morbidity and/or mortality) exceed national averages
- The most common cause of cancer villages in China is water pollution
- Particular cancers are far above average rates in villages suffering extreme water pollution, particularly Stomach, Liver and Oesophageal cancer (World Bank, 2007; Ebenstein, 2012; Yang and Zhuang 2014):
International trade and pollution in China

Did western countries ‘offshore’ their pollution to China during trade ‘liberalisation’ of the 1990s and early 2000s?

Major events:

• China’s Market reforms (late 1970s and 1980s 改革开放）
• 1990s: Trade agreements negotiated with IMF, World Bank & Clinton administration
• China’s entry into WTO in 2001.

➢ Supercharged China’s economic growth on the back of manufacturing cheap goods for global markets
➢ Volume of China’s exports grew by 390% between 2000 and 2007
International trade deals and China’s pollution crisis


- Explores the behind scenes discussions about US-China trade deals in the 1990s
- Cautionary voices in Clinton administration (e.g. Gore) warned the deals would create incentives for multinationals to exploit lax safety and environmental regulations in China
- However trade deal architects (‘Walmart model’) resisted making any stipulations about environmental standards
WTO entry: Supercharging China’s economy, and pollution emissions

Lin et al., 2014:

• Rapid growth in air pollution emissions 2000 to 2008

• Large proportion related to goods for export (e.g. EET = Emissions embodied in net trade)

➢ What about water pollution?

International trade and pollution ‘havens’

- Cole et al, 2008; Cole et al 2011: empirical data on industrial output, foreign investment and pollution intensity in China

- Found correlations between certain pollutant classes (e.g. petroleum matter in water) and foreign direct investment during China’s economic boom

- Some support for the pollution ‘haven’ hypothesis

### TABLE 7: Linear and Quadratic Log Estimation Results with Fixed-Effects for Industrial Wastewater and Petroleum-Like Matter

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<th>Variables</th>
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Is deep groundwater (e.g. most drinking water) safe from pollution?
Nitrate in China’s groundwater: deeper understanding of the extent and nature of this problem

- Nitrate is ubiquitous throughout China’s groundwater systems.
- Great ‘indicator pollutant’ as it is highly soluble and present in contaminant mixtures from many sources (both agricultural and industrial)
- We compiled data from as many studies as we could find (research literature) ~70 studies, covering 52 groundwater systems:
Groundwater nitrate pollution – scale of the problem
Nitrate in groundwater: Scale of problem

- All shallow, deep and karstic aquifers (except 1) had some samples with nitrate concentrations above natural background levels (~1 mg/L NO₃-N, or 4.5 mg/L nitrate as NO₃)

- In four of the 37 deep aquifers for which data were available, more than half of samples exceeded WHO max. safe drinking water level (50 mg/L nitrate as as NO₃ or ~11mg/L NO₃-N)

- Isotopic data (δ¹⁵N and δ¹⁸O of NO₃) indicate a variety of sources, including urban wastewater, fertilizer and animal manure:
Groundwater pollution - scale of the problem

• Serious groundwater pollution is not just found in unconfined, shallow groundwater aquifers: Depth vs. Concentration relationship (?)

• Also significant contamination of deep groundwater (>100m), including confined/semi-confined aquifers
The Beijing Tap Water study:

- Random sample of tap water from sites around Beijing
- Most tap water plants pump from deep wells then treat and provide water to different parts of the city
- High percentage (46%) had nitrate concentrations above 20mg/L
- Strong indication that deep aquifers below Beijing are contaminated due to ‘bypass flow’.
Deep groundwater: how has it been contaminated?

Mechanism:

- Intensive groundwater development: thousands of wells per aquifer
- High pumping rates, increasingly from deep groundwater (as shallow groundwater quality deteriorates)
- If wells are not 100% cemented and/or natural fractures are present, shallow contaminants have a ‘short-circuit’ and reach deep aquifers.

Data (Han et al, 2016; Han et al, 2014; Currell et al, 2010; 2012) indicate this is common throughout northern China
Government response to the challenge

Chinese government has created ambitious new policies for improving water quality nationally:

• 2011: National Groundwater Pollution Prevention & Control Plan (for details: https://www.sciencemag.org/content/334/6057/745.full)

Solutions to the challenge?

Since 2013, China’s new leaders (Xi Jinping, Li Keqiang) have overseen China moving away from a ‘big engineering’ approach to environmental problems, and tackling other aspects of the problem, including:

1. Official corruption (e.g. links between polluters and government officials)

2. Lack of enforcement power and adequate penalties for pollution

3. Institutional overlap (‘who’s job is it to look after water quality and what about when this conflicts with other priorities?’):

   ➢ “环保不下水，水利不上岸”
## Government agencies with a role in water & pollution management

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<td>Ministry of Agriculture</td>
<td>Management of agricultural pollution (non point-source); fisheries &amp; wildlife conservation</td>
</tr>
<tr>
<td>Ministry of Water Resources</td>
<td>Protection of water resources; flood control and drought relief; water withdrawal licences; trans-boundary water conflicts</td>
</tr>
<tr>
<td>Ministry of Land and Resources</td>
<td>Monitoring and protection of groundwater resources</td>
</tr>
<tr>
<td>Ministry of Environment Protection</td>
<td>Pollution control, water quality monitoring; wastewater discharge monitoring; environmental impact assessment</td>
</tr>
<tr>
<td>National Development and Reform Commission</td>
<td>Governance of major river basins</td>
</tr>
<tr>
<td>State Oceanic Administration</td>
<td>Supervision, monitoring and control of marine pollution</td>
</tr>
<tr>
<td>Ministry of Transport</td>
<td>Marine pollution control (shipping)</td>
</tr>
<tr>
<td>Ministry of Industry and Information Technology</td>
<td>Prevention and control of industrial water pollution</td>
</tr>
</tbody>
</table>
China’s Bold 10-point plan

- Part of China’s ‘War on Pollution’
- A new ‘10 point plan’ for China’s water

**Aims & Targets (By 2020)**
- Increase % of surface water in water quality grades I, II and III to 70% of total water by
- Decrease % of groundwater in lowest class (V) to 15% of national total
- Additional improvements by 2030 & 2050.

- League tables: best and worst performing districts, best and worst performing industries, ‘yellow card’ and ‘red card’ system

- Public disclosure of data on drinking water security from 2016
A sustainable plan for China’s drinking water

Tackling pollution and using different grades of water for different tasks is more efficient than making all water potable, say Tao Tao and Kunlun Xin.

Challenges for implementation of the 10-point plan

• Quality, co-ordination and availability of accurate water quality data is still a major hurdle for the successful implementation of the **10-point plan** for water pollution.

• Three different agencies collect and report data on water quality, and each has different monitoring locations and sampling/analysis programs.

• Often, conflicting data is reported in the media, causing confusion and making the public doubt the figures.
Further reading on these topics:

**THE GLOBAL DRAIN:**

Why China’s Water Pollution Problems SHOULD MATTER TO THE REST OF THE WORLD

by Matthew J. Currell and Dongmei Han

Chinese and international media have recently reported that more than 80% of the shallow groundwater in large parts of northern China is affected by pollution, rendering it unsafe for drinking without treatment. This is by no means the first such report. In 2013, China’s largest ever national groundwater quality survey estimated that more than half of the nation’s total groundwater resource, including shallow and deep aquifers, was polluted to some degree. The sources of pollution include industrial waste and agricultural chemical runoff, which enter shallow aquifers predominantly by seepage from the surface, although there is also evidence of illegal waste injection directly underground using “pollution disposal wells.” In both of these widely publicized groundwater quality surveys the data used to determine the overall prevalence of pollution came from thousands of government monitoring wells installed around the country: a large sample size that ensures the data are statistically significant over a wide range of geographic areas. These data and other recent reports indicate...
References (for this presentation) & Further reading:


