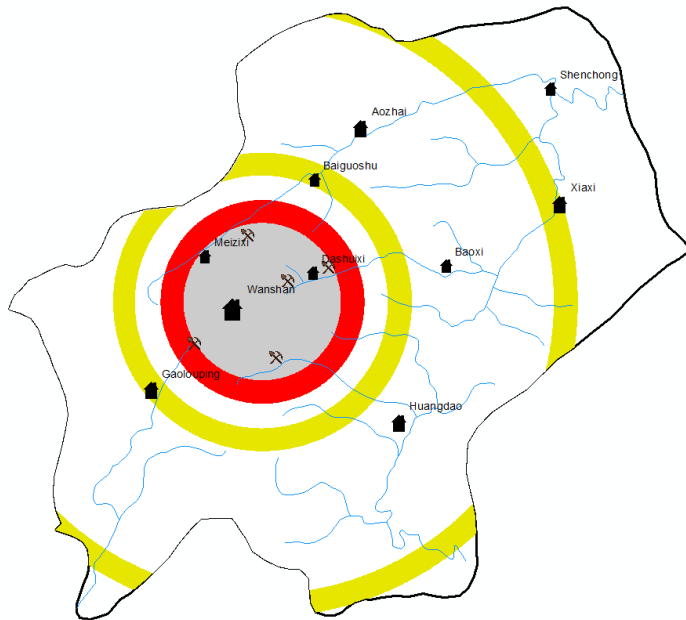


# Quantitative risk assessment of mercury contamination to ecosystems in Wanshan Mercury Mining Area



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Qiu Guangle  
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Thorjørn Larssen

# Scope of the study

- *Goal:*

Specify ecosystem Hg risks in Wanshan Mercury Mining Area (WMMA)

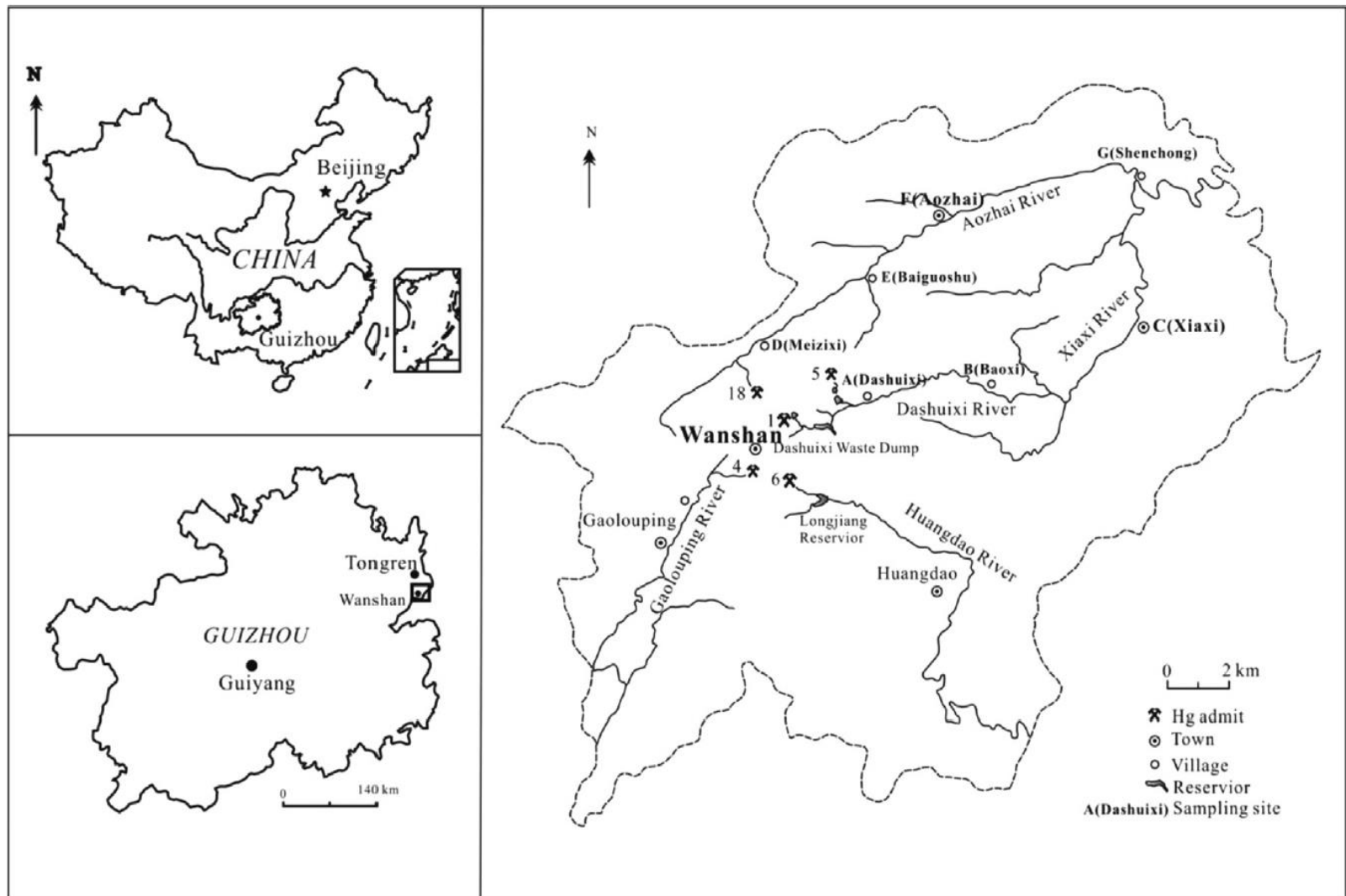
- *Task:*

A quantitative assessment of the Hg risk to different parts of the ecosystem

- *Output:*

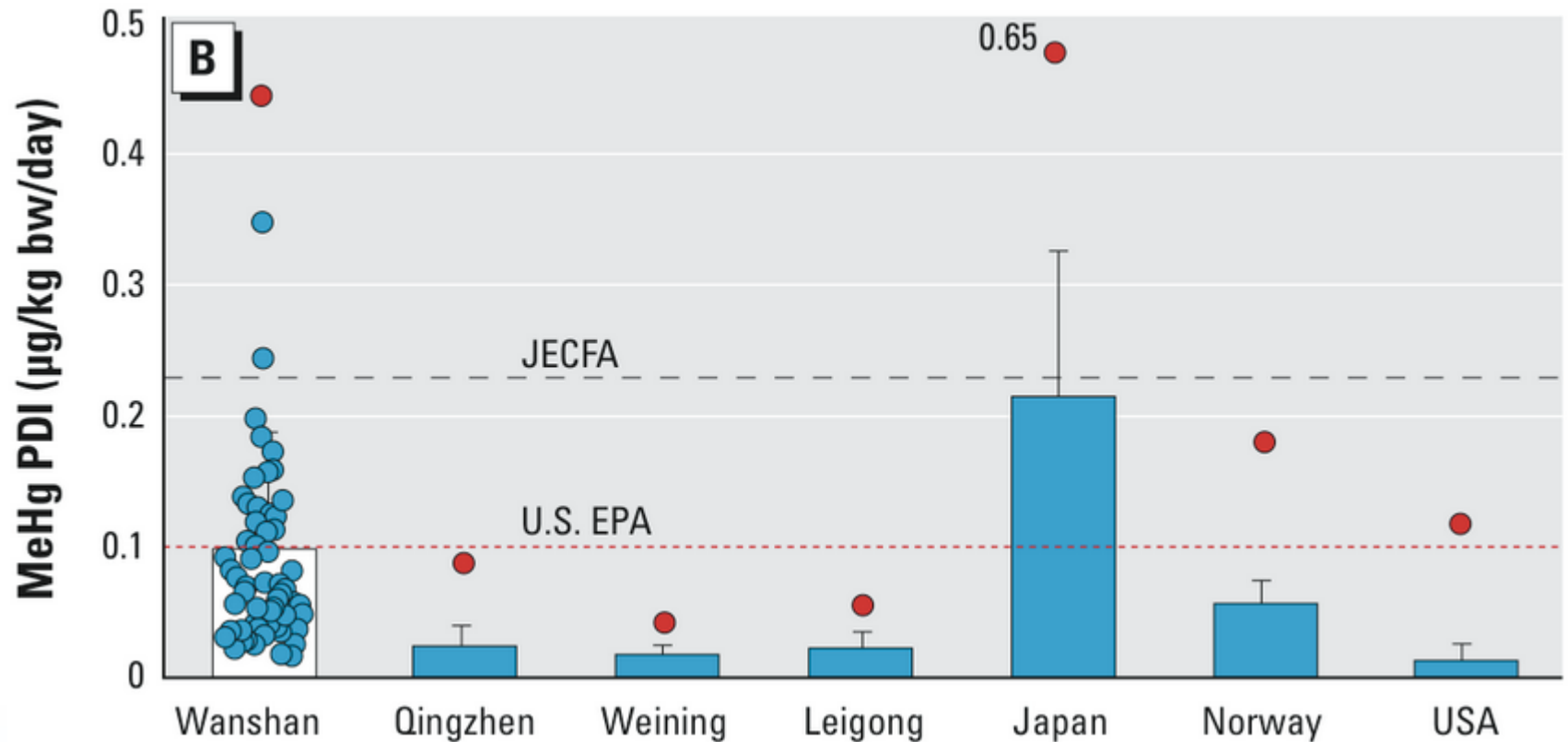
Risk to biota in different ranges from contaminated Hg tailing sites

# Wanshan Mercury Mining Area



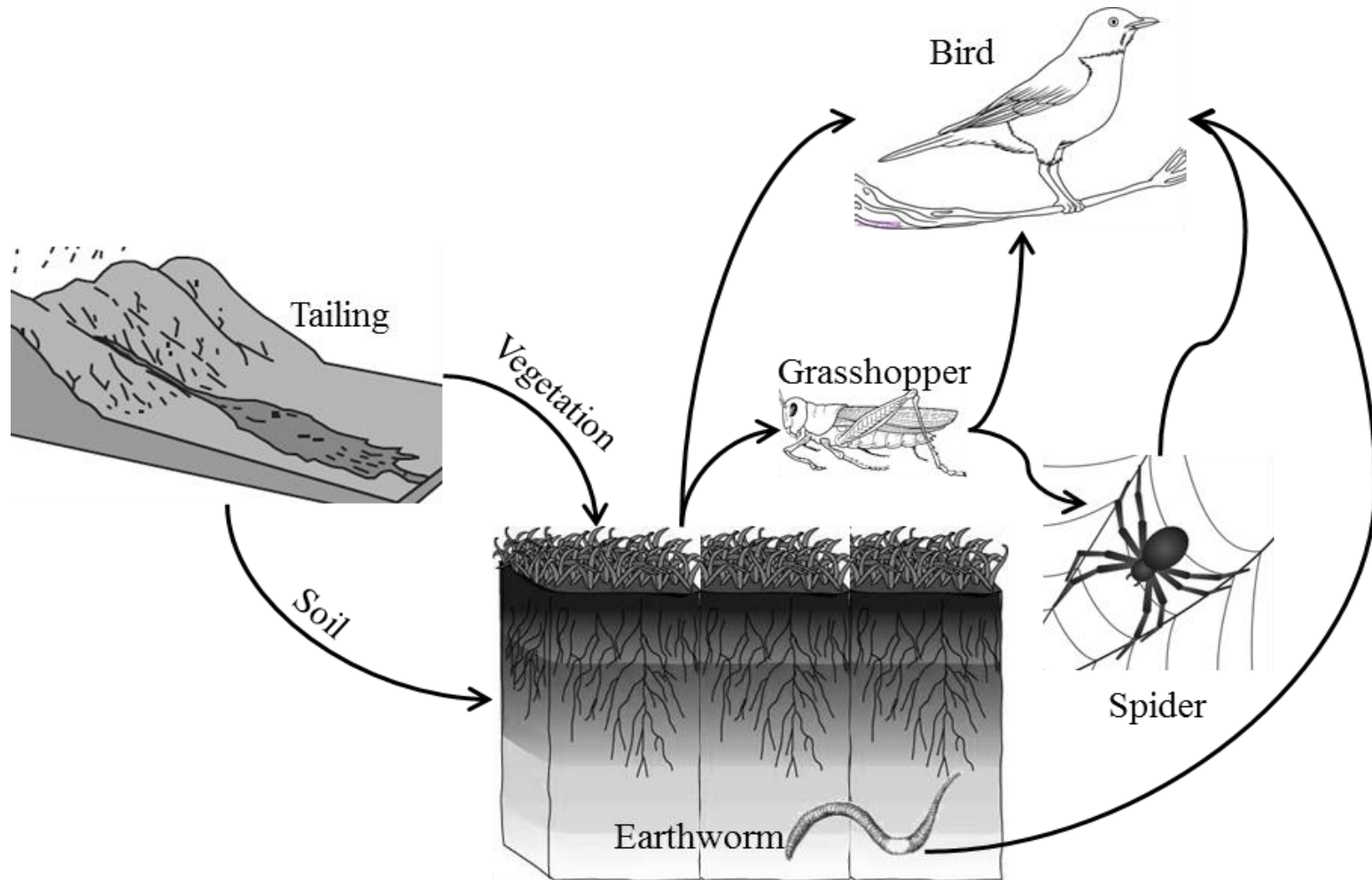
Map source: Li et al. 2015, Environmental Research, 140, 198-204

# Human Hg exposure



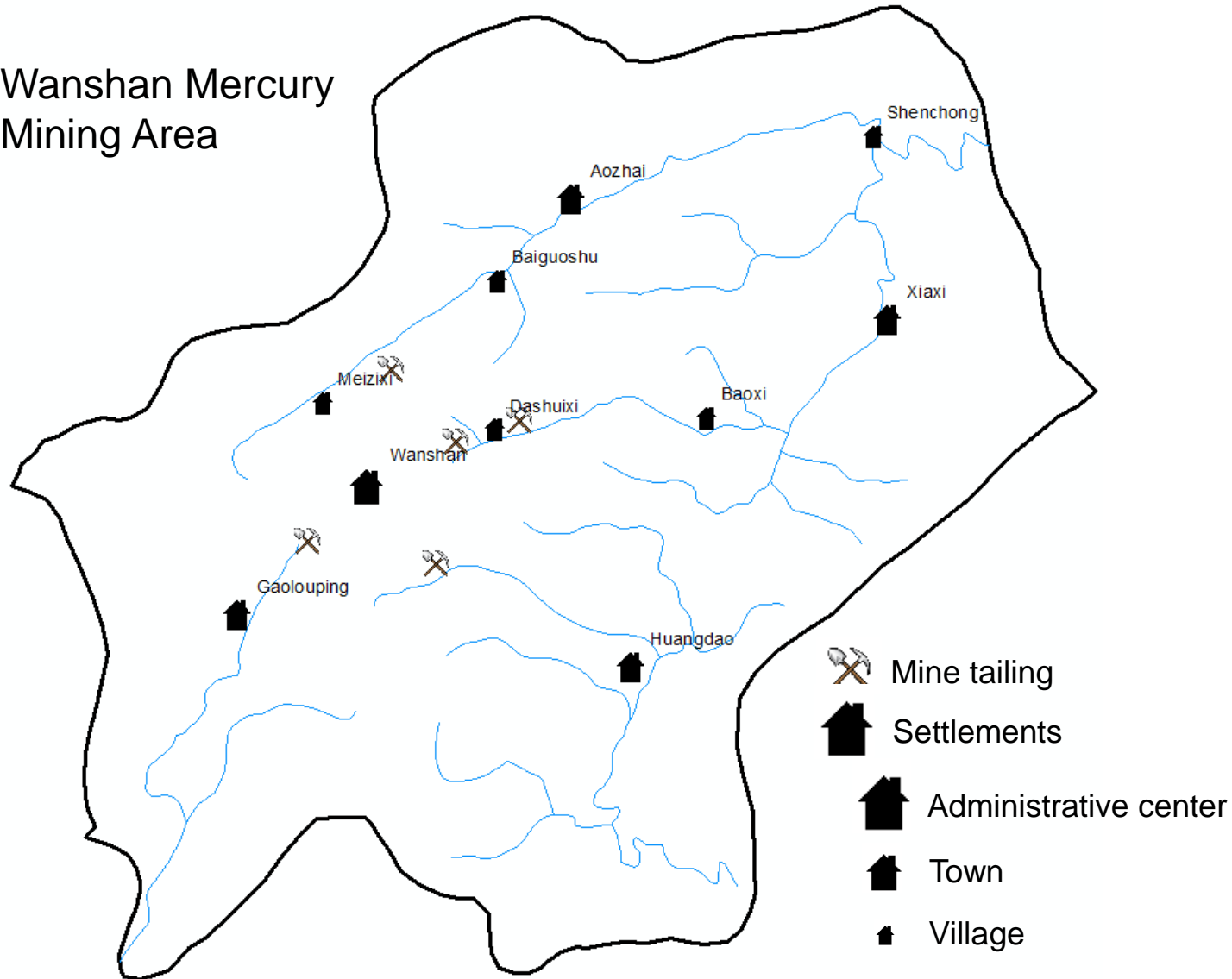
Data from Zhang et al., 2010, Environmental Health Perspectives

# WMMA - bioaccumulation of Hg



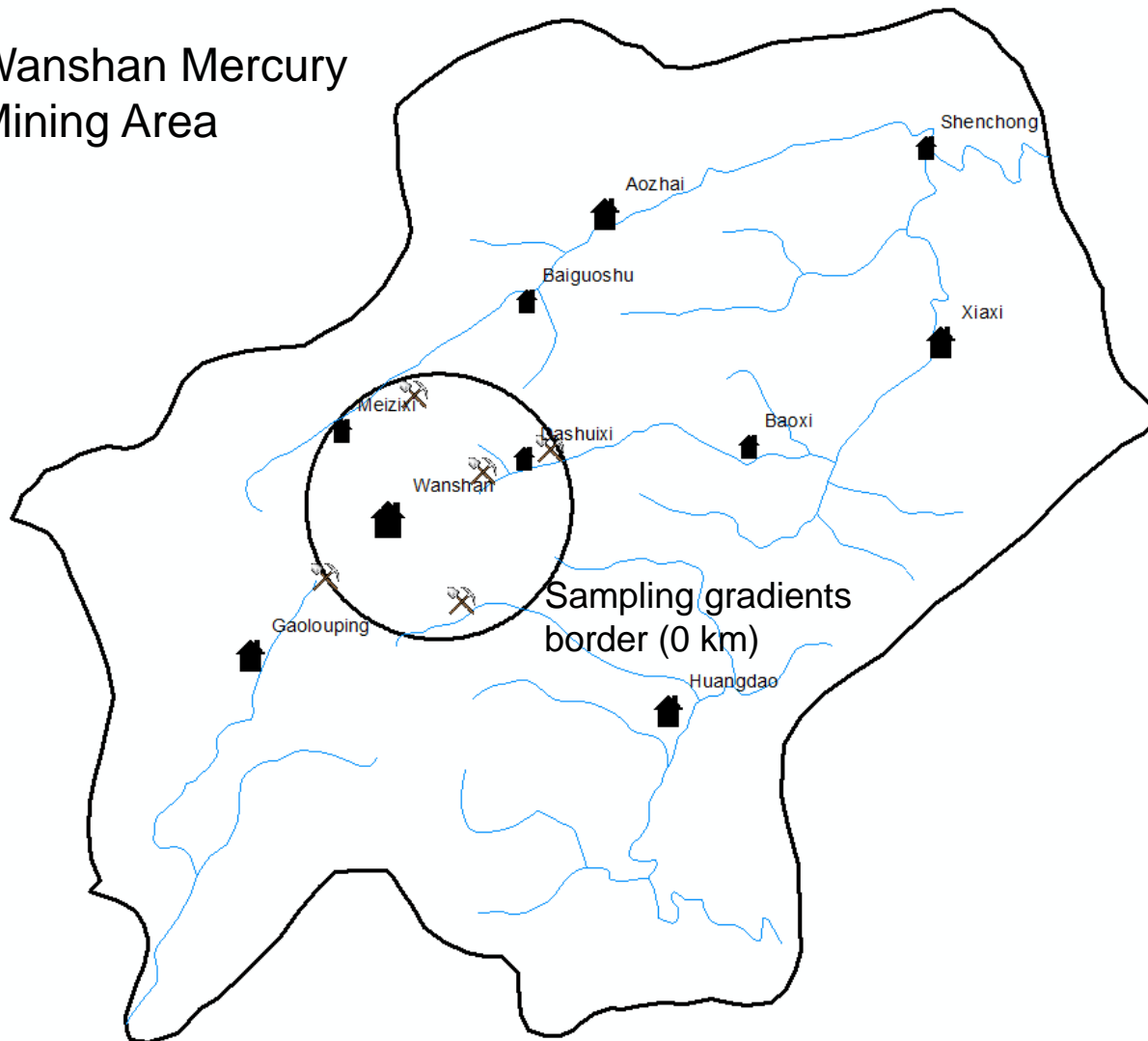
# WMMA sampling

Wanshan Mercury Mining Area



# WMMA sampling

Wanshan Mercury Mining Area

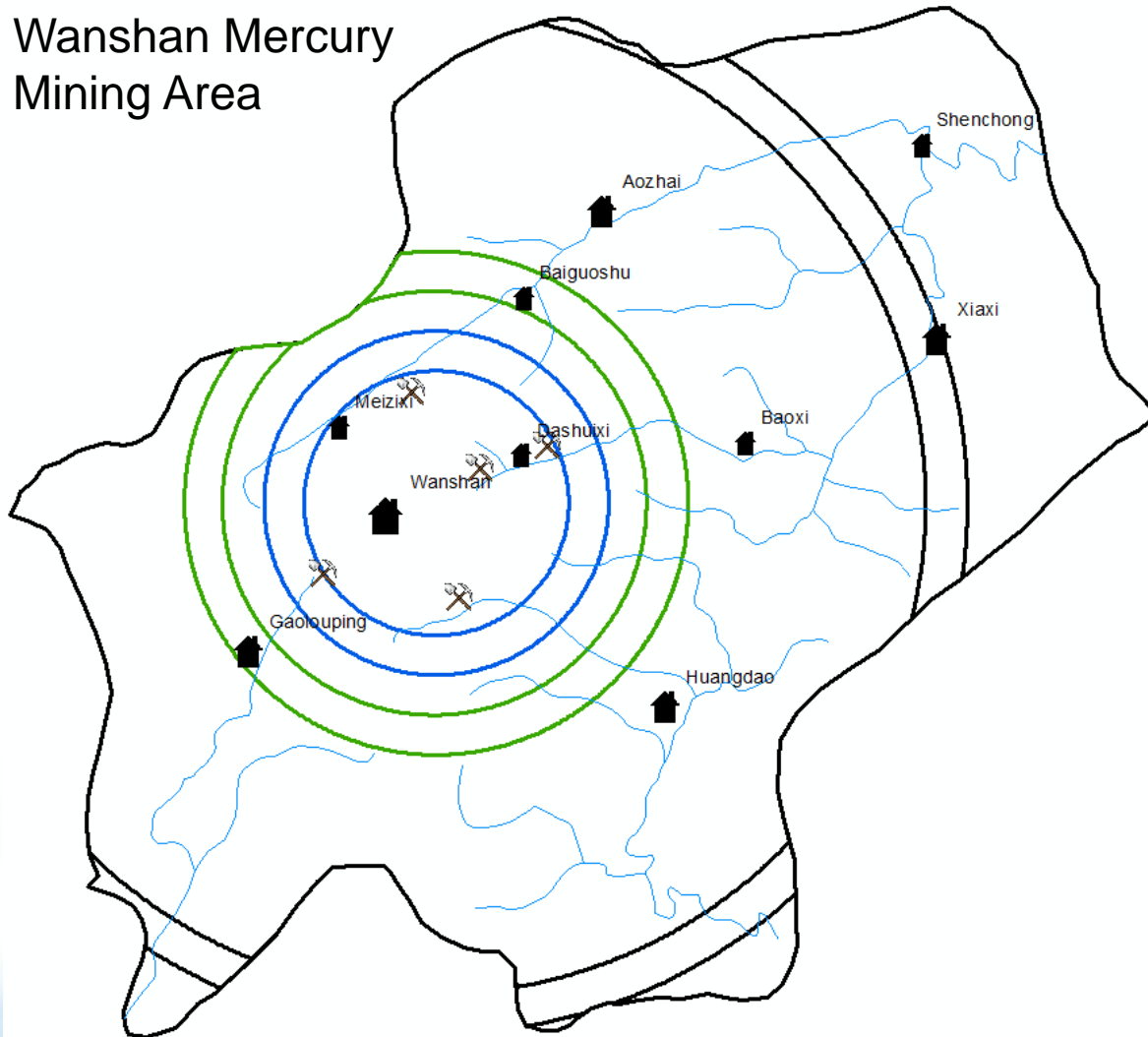


Sampling gradients:

- Starts at border of mine tailing cluster
- Three geographical gradients
  - Xiaxi
  - Aozhai
  - Gaolouping
- One reference site
  - Leishan

# WMMA sampling

Wanshan Mercury Mining Area

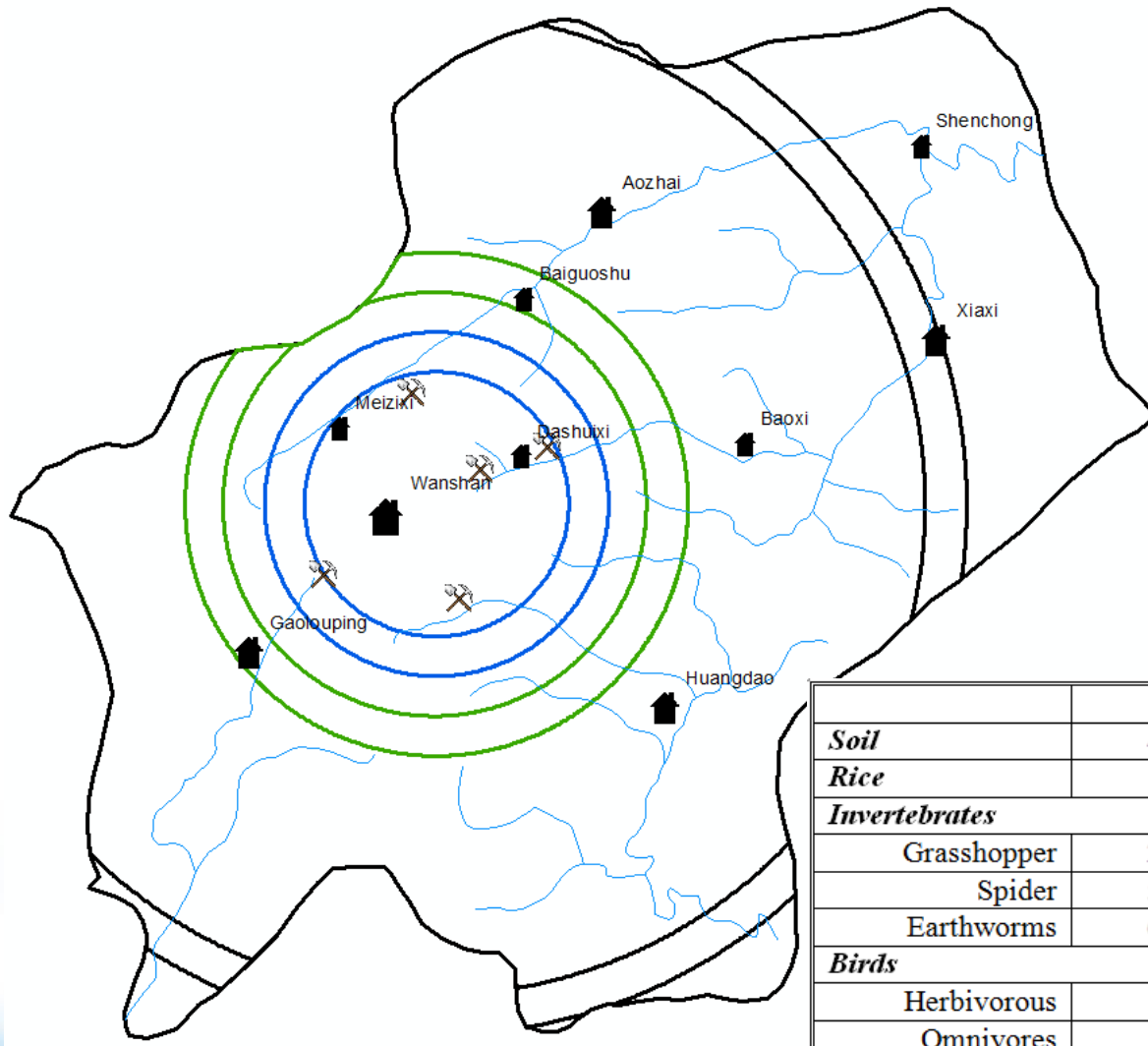


Sampling of terrestrial food web in three areas with increasing distance from mine tailings:

- A: 0-1 km
- B: 2-3 km
- C: 7-8 km



# WMMA sampling



	<b>Leishan</b>
<b>Soil</b>	40/40/40
<b>Rice</b>	10
<b>Invertebrates</b>	
Grasshopper	25/25/25
Spider	50/50/50
Earthworms	60/60/60
<b>Birds</b>	
Herbivorous	42 (1/4)
Omnivores	27 (2/2)
Insectivorous	32 (2/4)

	<b>Xiaxi</b>	<b>Aozhai</b>	<b>Gaolouping</b>
<b>Soil</b>	40/40/40	40/40/40	40/40/40
<b>Rice</b>		19/62/10	
<b>Invertebrates</b>			
Grasshopper	25/25/25	25/25/25	25/25/25
Spider	50/50/50	50/50/50	50/50/50
Earthworms	60/60/60	60/60/60	60/60/60
<b>Birds</b>			
Herbivorous		132 (4/6)	
Omnivores		176 (6/8)	
Insectivorous		143 (8/12)	

# Environmental Risk Assessment

## 1. Risk formulation

- Measurement end points
- Ecological or toxicological

## 2. Risk analysis

- Benchmark concentrations
- Observed concentrations

## 3. Risk characterisation

- Levels of ecosystem risk

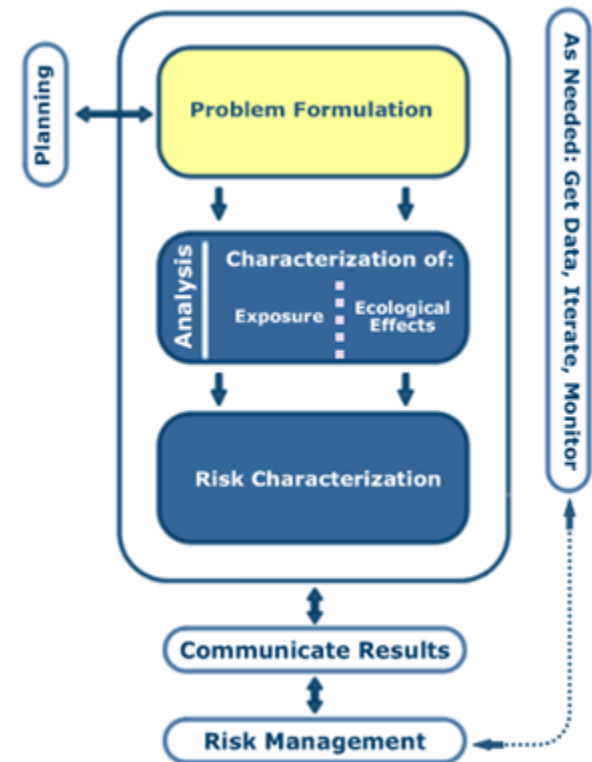


Figure from USEPA  
<http://www2.epa.gov/risk/conducting-ecological-risk-assessment>

# Risk formulation

- Measurement end points
  - Ecological or toxicological
  - Vary depending on specie and habitat of interest

Ecological endpoint	Toxicological endpoint
Survival	Survival Mortality
Growth	Growth Body mass
Reproduction	Productivity Egg hatching success
Behavioral	Altered behavioral patterns Altered activity budgets Impaired motor co-ordination
Subclinical	Altered glutathione metabolism Oxidative stress Antibody suppression Lymphoid depletion Altered neurochemical receptor levels Altered corticosterone

Depew et al. 2012, Environmental Toxicology and Chemistry 31.

# Risk analysis

- Screening benchmarks

1. *No Observable Adverse Effect Level (NOAEL)*

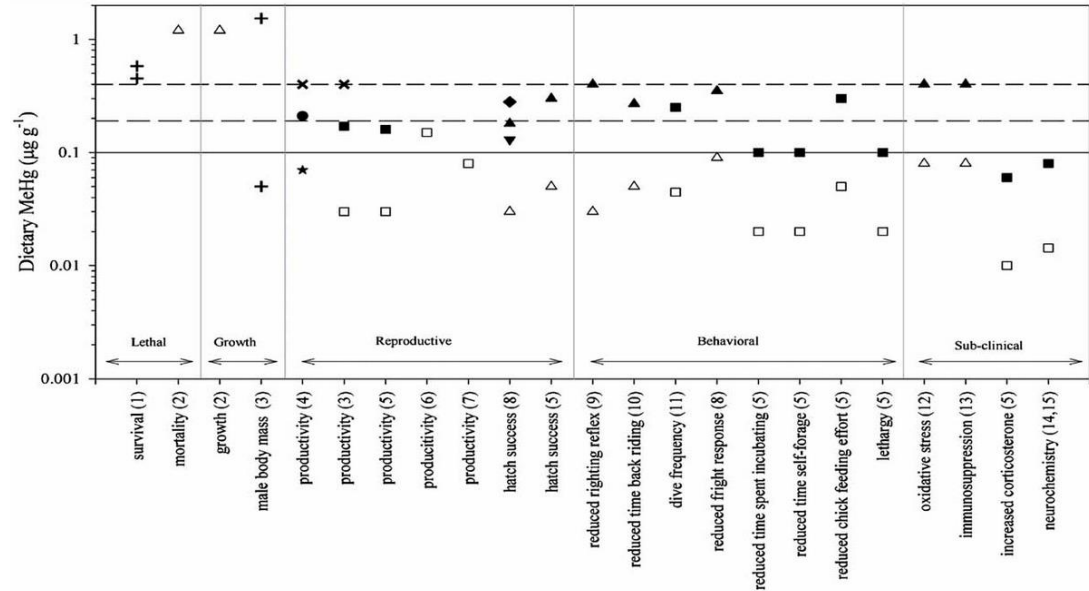
2. *Lowest Observable Adverse Effect Level (LOAEL)*

3. *Effective concentration (EC)*

- *Specific effects seen on e.g. reproduction, growth etc.*

4. *Lethal concentrations (LC)*

- *Specific concentration where e.g. 50 % of population is dead*



Depew et al. 2012, Environmental Toxicology and Chemistry 31.

# Chosen benchmark concentrations

Receptor	Benchmark type	Benchmark	Unit	Reference
<i>Plants</i>				
	Soil concentration	10	mg kg <sup>-1</sup> d.w.	(Cocking et al., 1995)
	Tissue concentration	3	mg kg <sup>-1</sup> d.w.	(Lipse, 1975)
<i>Insects</i>				
	Plant concentration	0.1	mg kg <sup>-1</sup> d.w.	(Scheulhammer et al., 2007)
	Prey concentration	0.08	mg kg <sup>-1</sup> w.w.	(Scheulhammer et al., 2007)
	Tissue concentration	6	mg kg <sup>-1</sup> w.w.	(Zaman et al., 1994)
<i>Earthworm</i>				
	Soil concentrations	1	mg kg <sup>-1</sup> d.w.	(Beyer et al., 1985)
	Tissue concentration	27	mg kg <sup>-1</sup> w.w.	(Beyer et al., 1985)
<i>Birds</i>				
	Plant concentration	0.1	mg kg <sup>-1</sup> d.w.	(Scheulhammer et al., 2007)
	Prey concentration	0.08	mg kg <sup>-1</sup> w.w.	(Scheulhammer et al., 2007)
	Blood concentration	4	mg kg <sup>-1</sup> w.w.	(Evers et al., 2004)

# Observed concentrations in WMMA

	Aozhai	Xiayi	Gaolouping	Leishan
<b>Soil (<math>mg\ kg^{-1}\ d.w.</math>)</b>				
0-1 km	83.11	129.35	92.35	0.65
2-3 km	55.60	52.01	34.43	
7-8 km	17.64	38.12	5.54	
<b>Rice (<math>mg\ kg^{-1}\ d.w.</math>)</b>				
0-1 km		0.12		0.005
2-3 km		0.02		
7-8 km		0.01		
<b>Grasshopper (<math>mg\ kg^{-1}\ w.w.</math>)</b>				
0-1 km	0.40	0.61	0.63	0.13
2-3 km	0.38	0.41	0.46	
7-8 km	0.21	0.22	0.35	
<b>Spider (<math>mg\ kg^{-1}\ w.w.</math>)</b>				
0-1 km	12.12	14.76	12.11	1.52
2-3 km	11.19	13.74	10.67	
7-8 km	3.24	6.08	2.65	
<b>Earthworm (<math>mg\ kg^{-1}\ w.w.</math>)</b>				
0-1 km	52.00	59.78	35.22	0.68
2-3 km	26.94	28.63	17.82	
7-8 km	8.44	21.13	3.88	
<b>Birds (<math>mg\ kg^{-1}\ w.w.</math>)</b>				
Birds-Herbivorous		3.40		0.11
Birds-Omnivores		6.72		0.47

# Risk characterisation

## Level 1 Background

HQ < 1  
*and*  
observed [Hg] <  
reference site [Hg]

## Level 2 Minimal risk

HQ < 1

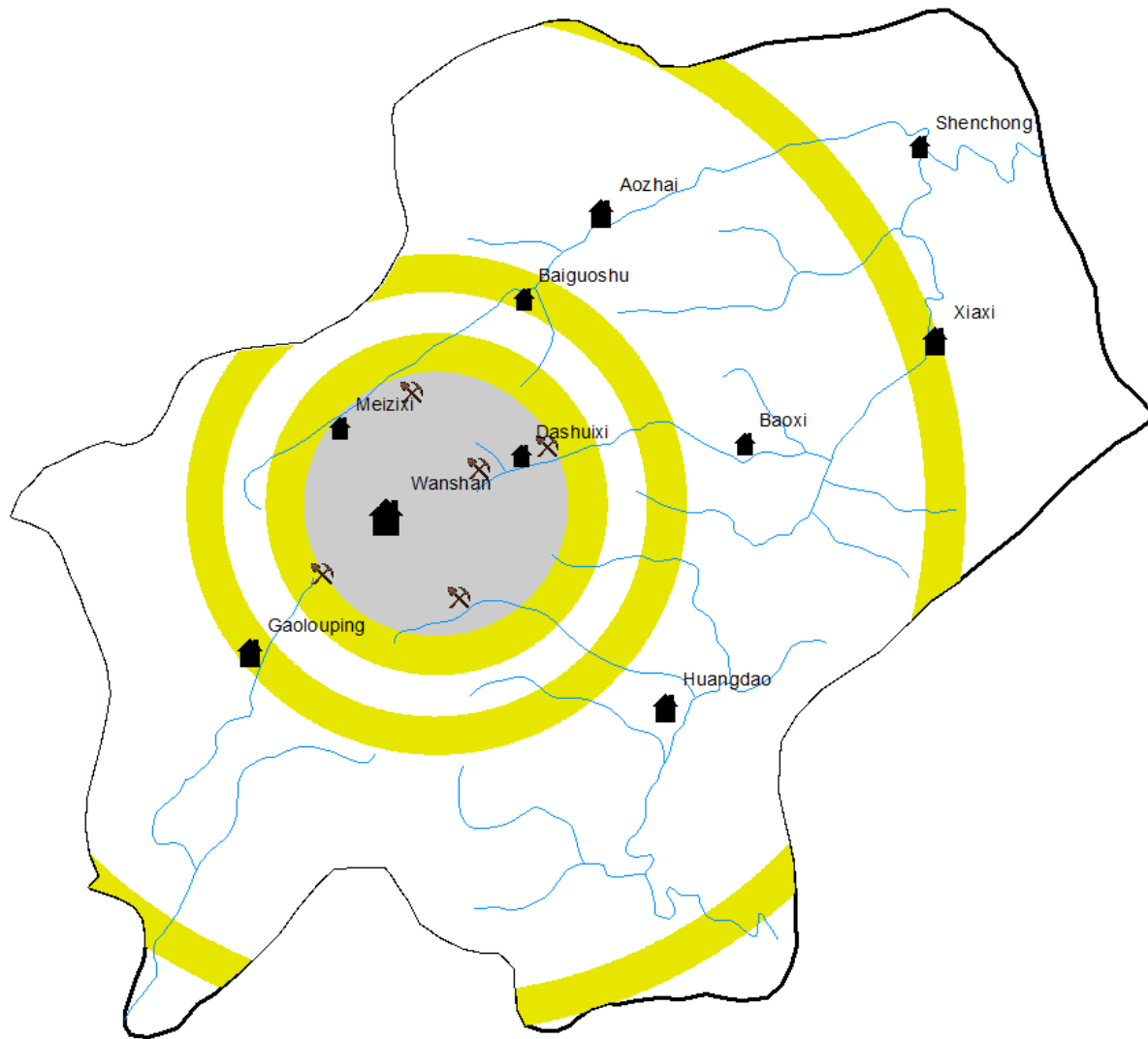
## Level 3 Moderate risk

HQ in diet > 1

## Level 4 High risk

HQ > 1

# Risk characterisation

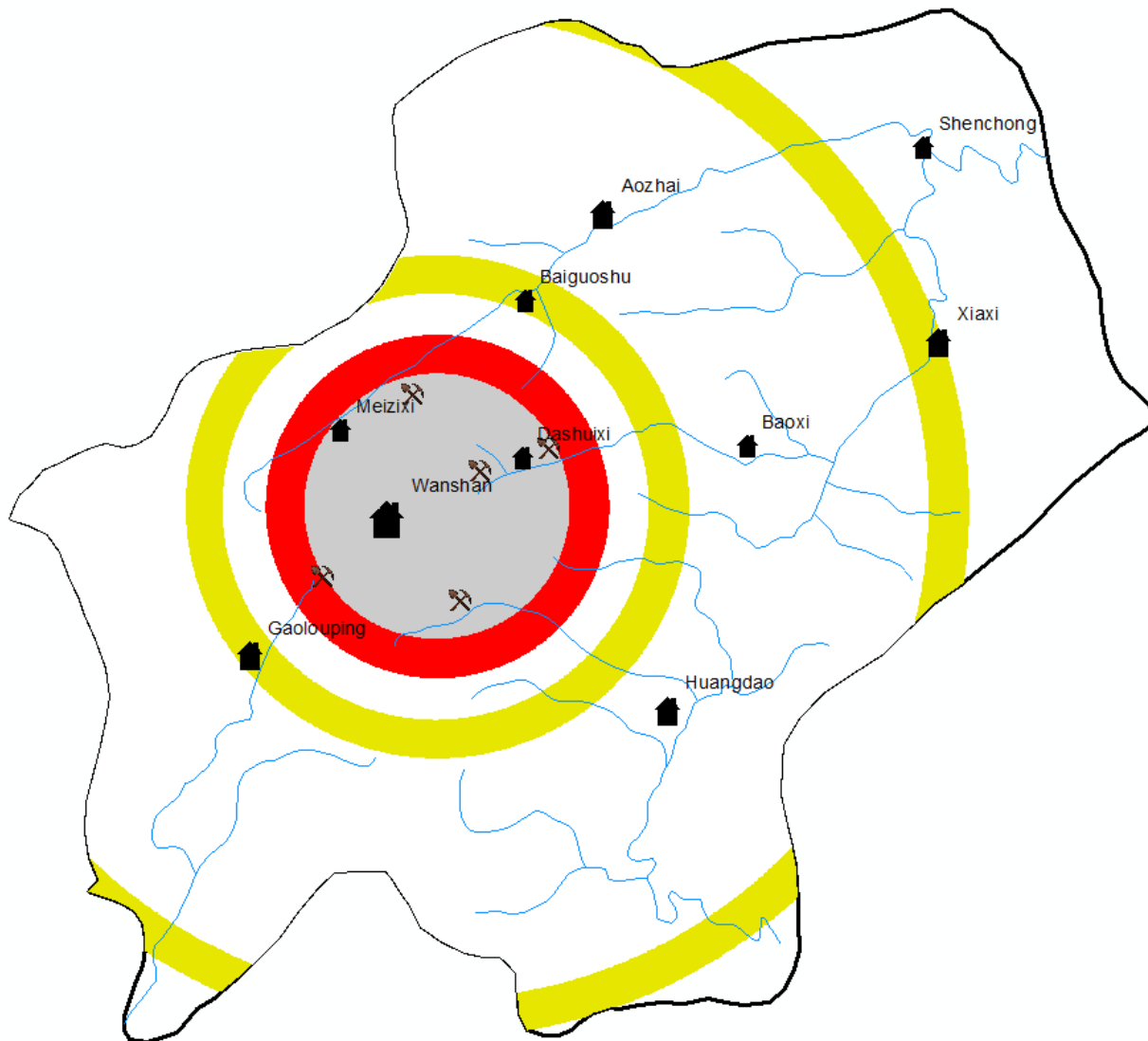


## Rice – WMMA

- **Moderate risk** due to high [Hg] in soil
- Soil HQ values from min. 1.8 to max. 12.9
- All soil [Hg] at least 10-fold higher than at reference site



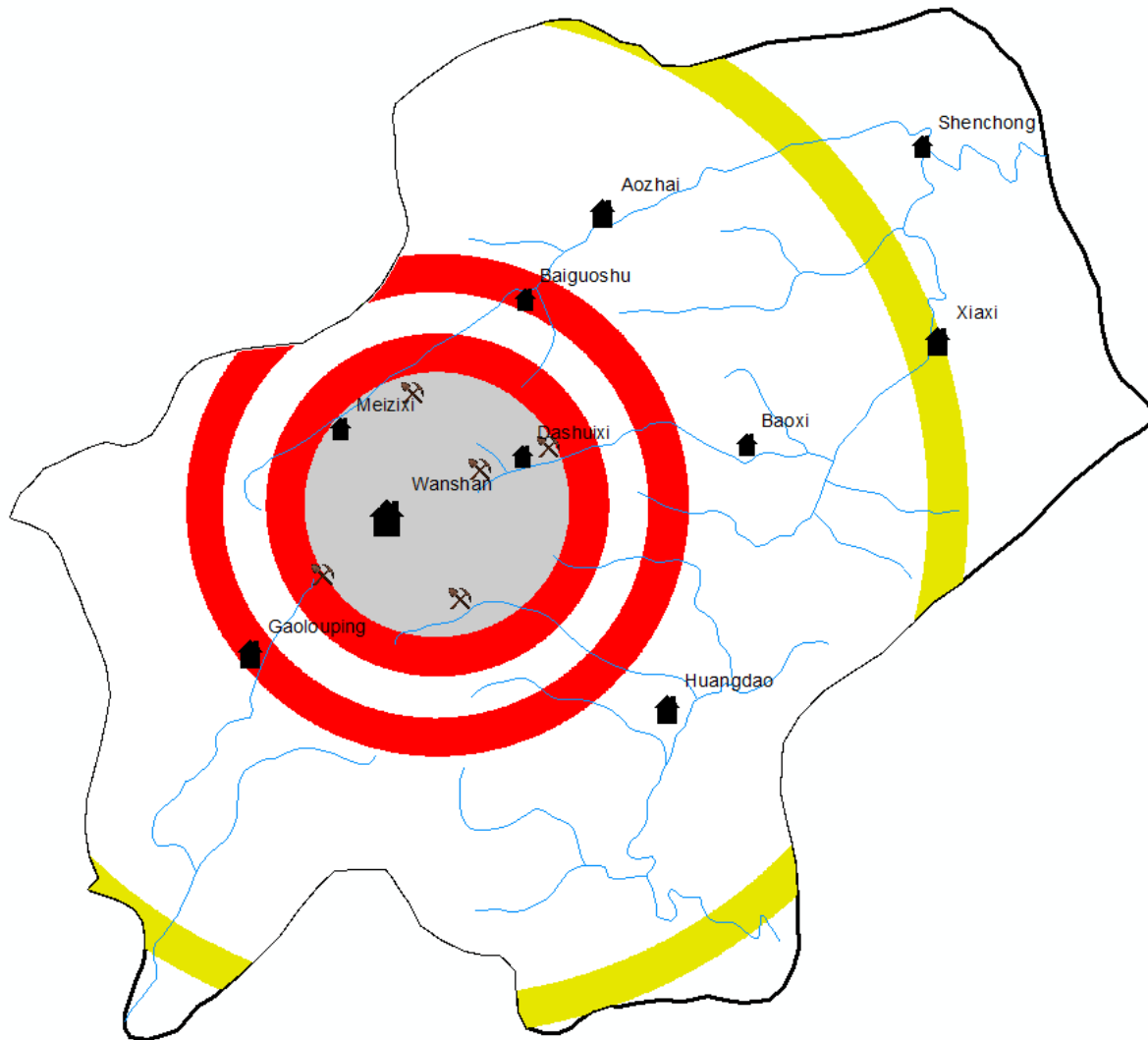
# Risk characterisation



## Earthworms – WMMA

- **High risk** due to high tissue [Hg]
- **Moderate risk** due to high [Hg] in soil
- Mine tailings leads to high [Hg], decreases with distance from site
- Tissue HQ values from min. 1.1 to max. 2.2

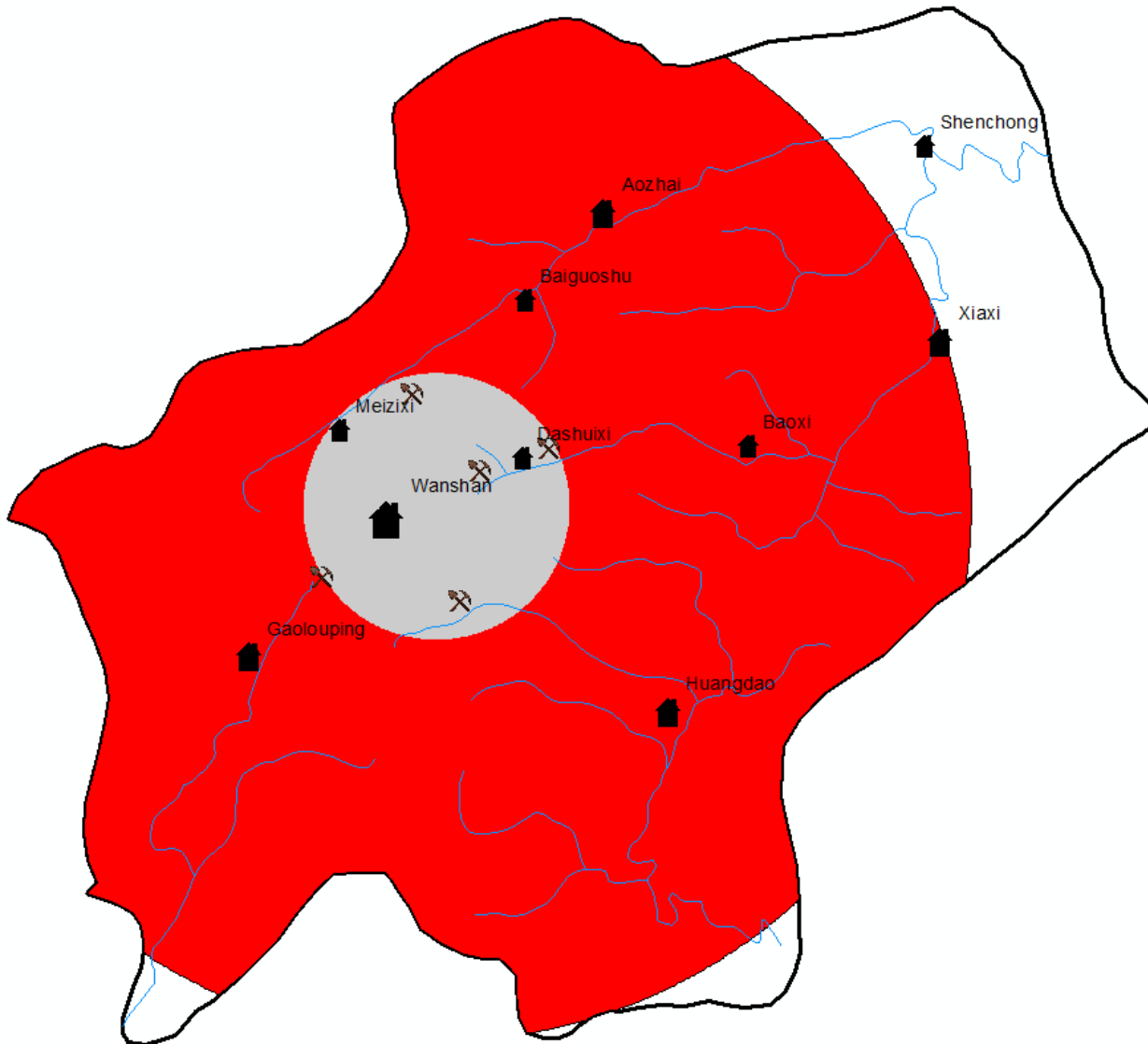
# Risk characterisation



## Spiders – WMMMA

- **High risk** due to high tissue [Hg]
- **Moderate risk** due to high [Hg] in prey
- Even reference site show **moderate risk**
- Tissue HQ values from min. 1.0 to max. 2.5

# Risk characterisation



## Birds – WMMA

- **High risk** due to high tissue [Hg]
- Map show omnivorous and insectivorous birds
- **Minimal risk** for herbivorous birds due to rice [Hg]
- Tissue HQ values from min. 1.7 to max. 2.9

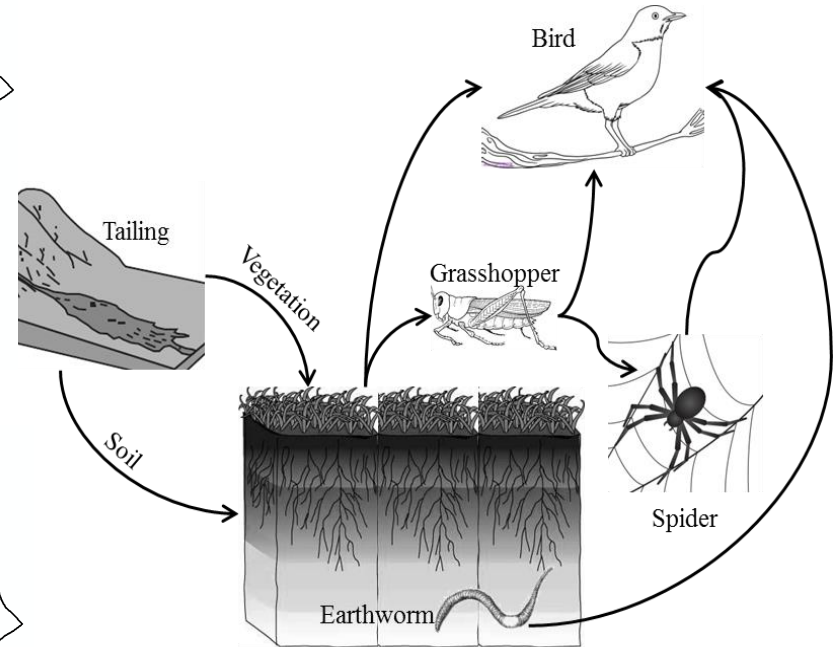
# Risk characterisation

Rice

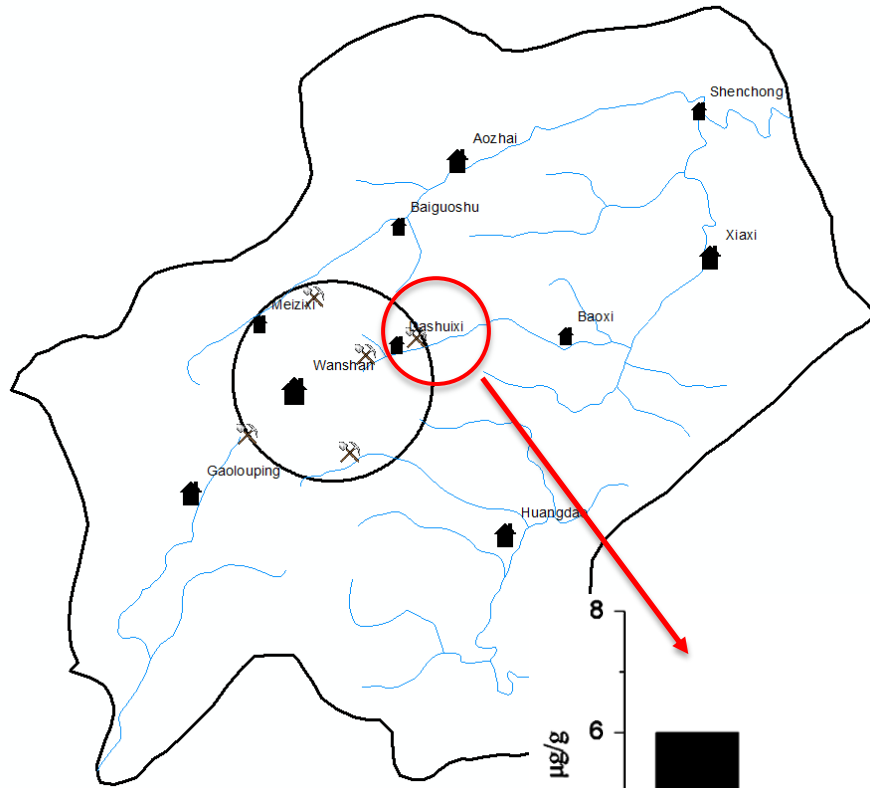
Earthworms

Birds

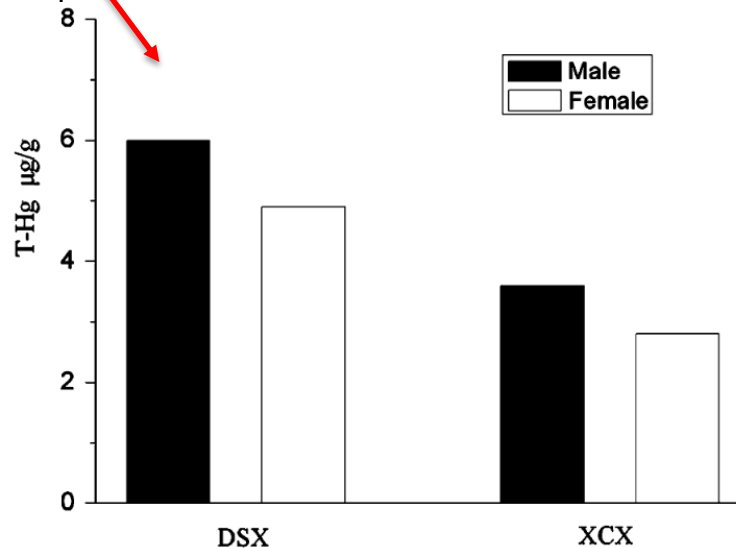
Spiders



# Risk characterisation



From Li et al., 2009. Environmental Geochemical Health 31:683-691



## Human implications

- THg in human hair from WMMA: 2-6 µg/g
- NOAEL: 11 ppm (USEPA); 10 ppm (WHO)
- LOAEL: 52.5 ppm (USEPA); 50 ppm (WHO)
- **Moderate human risk in WMMA:**  
HQ < 1 in hair,  
HQ > 1 in rice

# Study uncertainties

- Benchmark values
  - Based on other biota from other locations
  - Modelled bird blood concentrations
- Conceptual model
  - Representative for WMMA ecosystem?
- Conservative approach
  - NOAEL reduce uncertainty

# Conclusions and suggestions

- Predators (birds, spiders) in WMMA have high risk of Hg exposure
- Herbivorous insects and birds show low risk
- Earthworms high risk close to tailings
- Measure suggestions:
  - Replacing rice paddies
  - No promotion of fruit and dry crops close to tailings
  - No free walking chicken
  - Sign posting high risk areas
  - Risk communication with locals

# Thank you!