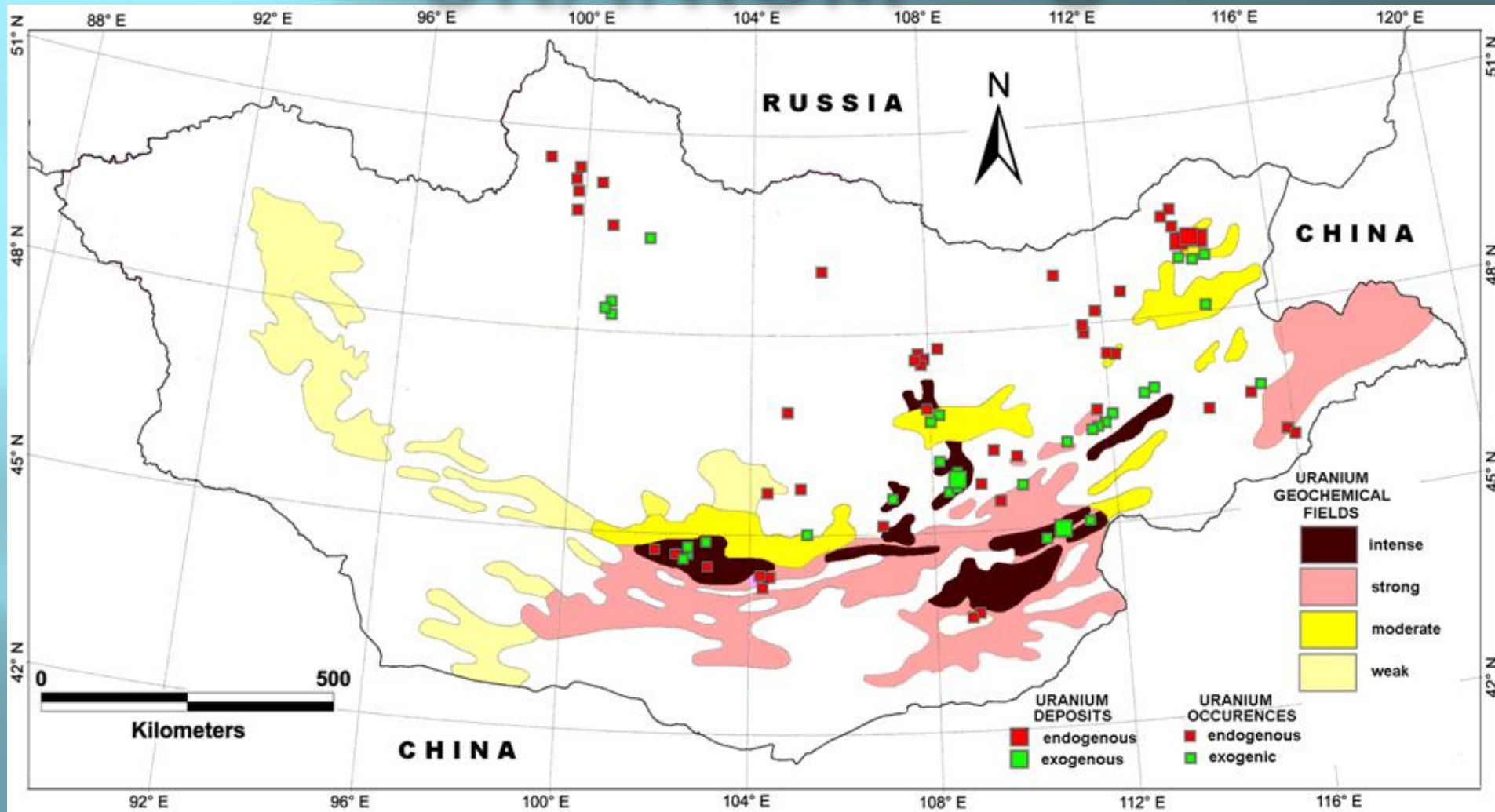




Robin Grayson and Baatar Tumenbayar
26 October 2016

**Health risks from
URANIUM and FLUORIDE
in Ulaanbaatar and
Rural Mongolia**

URANIUM – U



Conventional Uranium occurrences

URANIUM – U

- ❖ **Conventional U resources**
 - ❖ **Targets for mining**
 - ❖ **Strict regulations**
- ❖ **Unconventional U resources**
 - ❖ **Not targets for mining**
 - ❖ **MAJOR health risks**
 - ❖ **U in COAL**
 - ❖ **U in SODA LAKES**

URANIUM – U

UNCONVENTIONAL URANIUM DEPOSITS AND OCCURENCES Soda Lakes

Map	Reference		UNCONVENTIONAL URANIUM DEPOSITS AND OCCURENCES Soda Lakes							
		province	name	latitude	longitude	major commodity	U concentration	status	source	
Uraniferous Soda Lakes										
M50	SB-L	DORNOD	Shar Burdiin Lake	48°19'6.96"N	114°31'18.66"E	U	14,877 µg/L	occurrence	Linhoff et al. (2011)	
	GY2-L		Gurvany-2 Lake	48°19'42.24"N	114°30'44.22"E	U	10,164 µg/L			
M46	-	-	NW Mongolia	-	-	U	1,000 µg/L		Isupov et al. (2011a)	
M50	SB-L	DORNOD	Gurvany-1 Lake	48°11'8.34"N	114°25'40.02"E	U	271 µg/L		Linhoff et al. (2011)	
	GY2-L		Tsaidam-2 Lake	48° 7'3.18"N	114°24'7.14"E	U	140 µg/L			
	SB-L		Tsaidam-1 Lake	48°27'31.86"N	114°49'42.18"E	U	57 µg/L			
	GY2-L		Gurvany-1 Stream	48°11'38.22"N	114°25'30.54"E	U	50 µg/L			
World Health Organisation guidelines for drinking water						U	15 µg/L		WHO (2011a)	

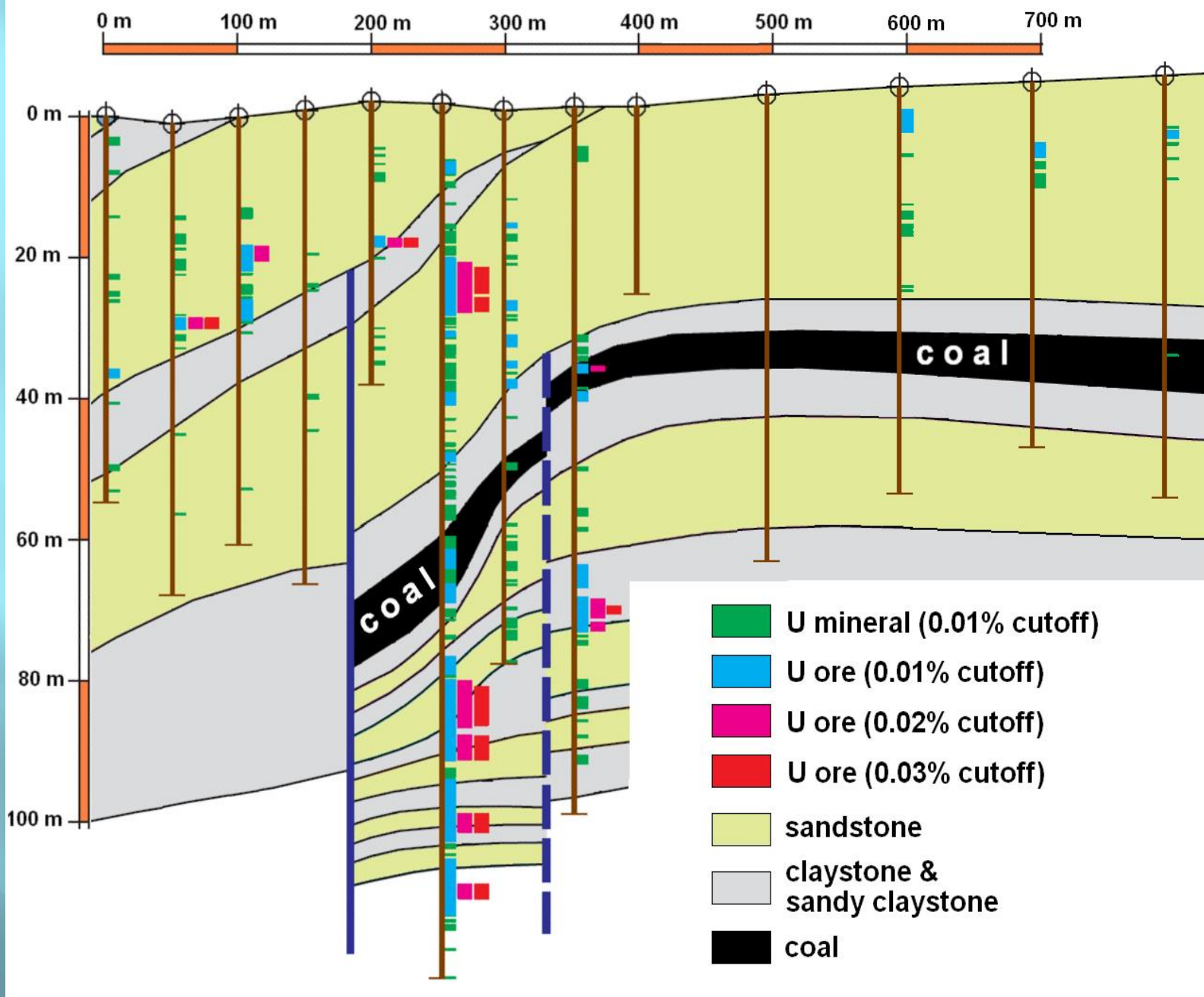
Uraniferous Dry Soda Lakes

Uraniferous Dry Soda Lakes										
L48	UL-3	TOV	Jirmin Tsagaan Lake	47°55'52.20"N	106° 5'21.00"E	U	350	mg/kg	occurrence	Markwitz et al. (2008) determined by PIXE
Canadian Soil Quality Guidelines — industrial						U	300	mg/kg		CCME (2007)
L48	UL-3	TOV	Jirmin Tsagaan Lake	47°55'52.20"N	106° 5'21.00"E	U	176	mg/kg	occurrence	Markwitz et al. (2008) determined by PIGE
	UL-2			47°55'51.78"N	106° 5'19.32"E	U	70	mg/kg		
Canadian Soil Quality Guidelines — commercial						U	33	mg/kg		CCME (2007)
Canadian Soil Quality Guidelines — residential and agricultural						U	23	mg/kg		CCME (2007)

Unconventional Uranium in SODA LAKES

UNCONVENTIONAL URANIUM DEPOSITS AND OCCURENCES													
Map	Reference	Passport	Uraniferous Coal						Coal Ash	Lusannandan, 2012 MS)	Duganay, (2005)		
			name	Deidmaa et al. (2001)		major commodity	status	minor commodity					
				latitude	longitude								
Uraniferous Jurassic-Cretaceous Coals													
L48	702	P	Nalaikh	47 44 50	107 17 0	Brown Coal	deposit	U	1 g/t U	7 g/t U	✓		
	825	P	Tevshiin Govi	45 59 59	105 59 59	Brown Coal		-	1 g/t U	5 g/t U	✓		
	937	-	Talyn Bulag	45 43 00	106 6 00	Brown Coal		-	4 g/t U	20 g/t U	✓		
L49	131	P	Sharyn Gol	46 10 10	108 27 34	Brown Coal		-	3 g/t U	22 g/t U	✓		
	459	P	Baganuur	47 44 00	108 23 00	Brown Coal		U	7 g/t U	29 g/t U	✓		
								4.1 g/t U	22 g/t U		✓		
	482	P	Chandgana	47 23 15	110 01 00	Brown Coal		-	<1 g/t U	<5 g/t U	✓		
	584	P	Shivee Ovoo	46 10 10	108 27 34	Brown Coal		U	5.1 g/t U	7.9 g/y U		✓	
	586	P	Nogoon Toirom	46 06 00	108 38 00	Brown Coal	occurrence	U	-	-			
	601	P	Alag Togoo	46 10 30	109 02 20	Brown Coal	deposit	-	4.5 g/t U	18 g/t U		✓	
627	P	Uelziit	46 24 00	111 36 00	Brown Coal	U		-					
L50	630	P	Khalzan Ovoo	46 15 00	111 24 00	Brown Coal	occurrence	U	-				
	653	P	Ereen Soum-1	45 51 00	108 29 00	Brown Coal		U	-				
	654	P	Ereen Soum-2	45 51 00	108 31 00	Brown Coal		U	-				
	120	P	Bayan Us	47 50 30	115 35 30	Brown Coal		U	-				
	122	P	Us Nuur	47 47 00	115 33 00	Brown Coal		U	-				
	147	P	Arjar Oelziit	47 13 00	114 46 00	Brown Coal		U	-				
	151	P	Hoeot	46 58 00	114 30 00	Brown Coal	deposit	U	-				
	164	P	Zuen Bulag	46 57 00	115 17 30	Brown Coal		U	-				
		166	P	Nuur Hooronduin Heseg	46 52 00	115 32 00	Brown Coal	occurrence	U	-			
	M46	447	P	Khar tarvagatai	49 32 48	91 40 45	Black Coal	deposit	-	2 g/t U	15 g/t U	✓	
M50	207	P	Aduunchuluun	48 08 06	114 31 30	Brown Coal	deposit	U, Ge	66 g/t U	300 g/t U	✓		
Uraniferous Permian Coals													
K48	116	P	Tavan Tolgoi	43 37 00	105 28 30	Black Coal	deposit	-	2 g/t U	10 g/t U	✓		
									1.1 g/t U	6.4 g/t U		✓	
Uraniferous Carboniferous Coals													
L46	430	P	Olonbulag	45 10 00	91 18 00	Black Coal	deposit	-	1 g/t U	5 g/t U	✓		
L47	429	P	Bayanteeg	45 42 00	101 34 00	Black Coal		-	4 g/t U	20 g/t U	✓		

Unconventional Uranium in COAL



Unconventional Uranium occurrences 6

URANIUM – U

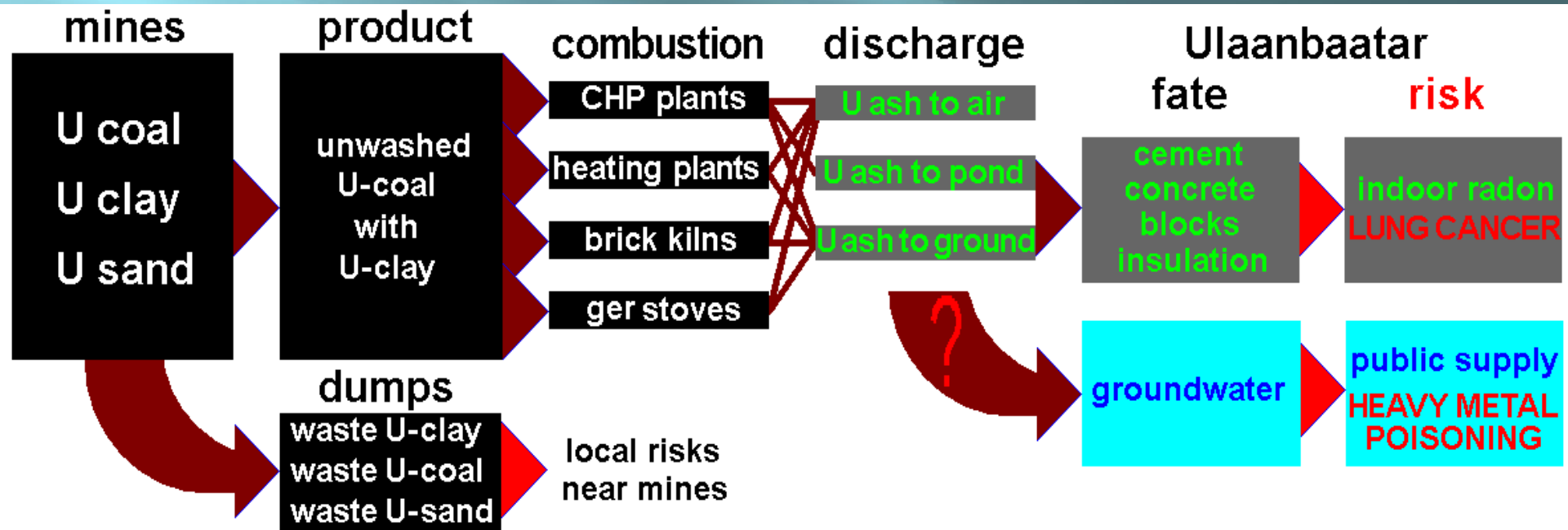
blue sky of Mongolia

Combustion of uraniferous coal

Photochemical smog blanketing Ulaanbaatar

URANIUM – U

Photo: Nick Grayson



URANIUM – U



Uranium in Ash

URANIUM – U

MONGOLIA	<u>Dornod</u> : BW Background Well	7 µg/L	<u>Linhoff et al. (2011)</u>
MONGOLIA	Ulaanbaatar: average 7 Districts	7 µg/L	<u>Nriagu et al. (2012)</u>
MONGOLIA	Ulaanbaatar: average 11 wells in <u>Khan Uul</u> District	6.7 µg/L	
MONGOLIA	<u>Dornod</u> : TS2-2 well near Tsaidam-2 soda lake	5.0 µg/L	<u>Linhoff et al. (2011)</u>
USA	average in 55,000 groundwater samples	4.8 µg/L	Irwin (1997)
MONGOLIA	Ulaanbaatar: average 55 wells in <u>Soningo Khairkhan</u> District	4.6 µg/L	<u>Nriagu et al. (2012)</u>
MONGOLIA	Ulaanbaatar: average 129 wells in 7 Districts	4.6 µg/L	
MONGOLIA	Ulaanbaatar: average 19 wells in <u>Bayanzurkh</u> District	3.7 µg/L	
USA	average in over 28,000 domestic water samples	2.5 µg/L	
MONGOLIA	Ulaanbaatar: average 27 wells in UB <u>Sukhbaatar</u> District	2.4 µg/L	<u>Nriagu et al. (2012)</u>
EUROPE	average in 5,474 tap water samples	2.2 µg/L	
GERMANY	guideline for waters used in preparing infant food	2.0 µg/L	
MONGOLIA	Ulaanbaatar: average 9 wells in <u>Chingeltei</u> District	1.6 µg/L	<u>Nriagu et al. (2012)</u>
MONGOLIA	Ulaanbaatar: minimum detected in 129 wells in 7 Districts	<0.01µg/L	

Uranium in Water

URANIUM – U

Country	details	micrograms per litre	source
MONGOLIA	Ulaanbaatar: labels on <u>Ar Janchivlan</u> bottled water	1,800 µg/L	this paper
USA	maximum in 55,000 groundwater samples	946 µg/L	Irwin (1997)
MONGOLIA	<u>Dornod</u> : TS-1-1 well near Tsaidam-1 soda lake	102 µg/L	<u>Linhoff et al. (2011)</u>
MONGOLIA	<u>Dornod</u> : SB-1 <u>Shar Burdiin</u> Well	86 µg/L	
MONGOLIA	Ulaanbaatar: maximum in 129 wells in 7 Districts	57.2 µg/L	<u>Nriagu et al. (2012)</u>
USA	maximum contaminant level for naturally occurring uranium	30 µg/L	EPA rule
WORLDWIDE	Recommended revised WHO guideline for U in drinking water	30 µg/L	<u>Hirose & Fawell (2012)</u>
USA	979 water supplies	≥20 µg/L	
MONGOLIA	Ulaanbaatar: average 4 wells in <u>Bayangol</u> District	18.6 µg/L	<u>Nriagu et al. (2012)</u>
WORLDWIDE	WHO guideline limit for U in drinking water	15 µg/L	WHO (2011a)
USA	2,228 water supplies	≥14 µg/L	
MONGOLIA	<u>Dornod</u> : TS2-1 well near Tsaidam-2 soda lake	12 µg/L	<u>Linhoff et al. (2011)</u>
MONGOLIA	Ulaanbaatar: average 4 wells in <u>Bagakhangai</u>	11.3 µg/L	<u>Nriagu et al. (2012)</u>
GERMANY	maximum permitted for natural mineral waters	10 µg/L	
GERMANY	maximum permitted for spring waters	10 µg/L	
GERMANY	maximum permitted for table waters	10 µg/L	

Uranium in Water

Since 1821
MS 3651-2004

Natrium + Kalium	118.4 mg/L
Calcium	154.3 mg/L
Natri	230.21 mg/L
Magnesium	4.9 mg/L
Chloride	13.84 mg/L
Sulphate	33.62 mg/L
Ferrium	-
Radi	10-18.5 mg/L
Ammoni	1.0 mg/L
Cuprium	1.0 mg/L
Mangani	0.5 mg/L
Florid	1.5 mg/L
Selen	0.05 mg/L
Uran	1.8 mg/L
Fenol	0.01 mg/L
Other organic elements	15 mg/L



Bottled by Soft Trade

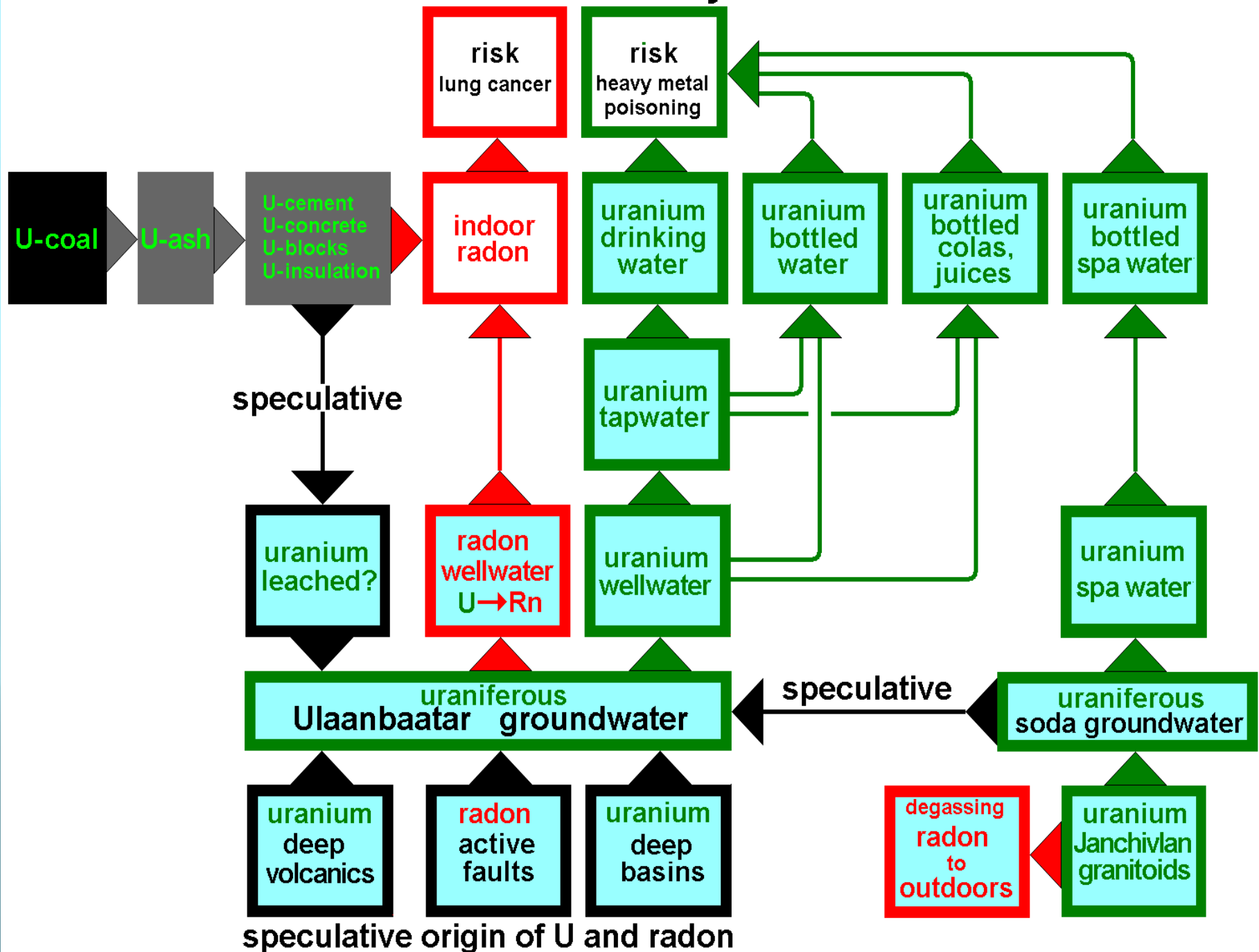
Утас: 976-11-351044

www.armineral.mn

Хадгалах хугацаа 4 сар
Хадгалах нөхцөл +5 - /+20/ гр.цельс

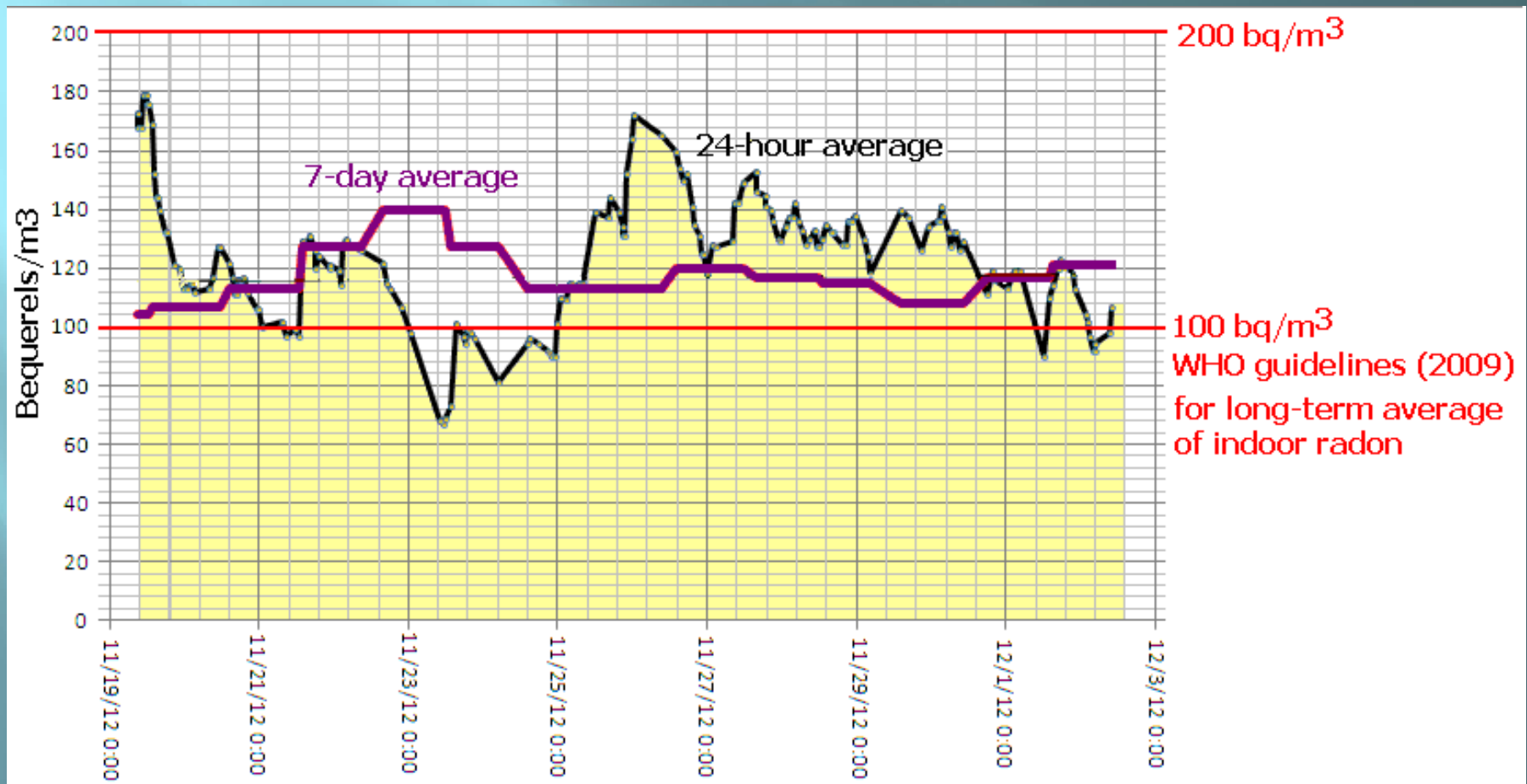


Ulaanbaatar city



RADON IN AIR

❖ Apartment near Nomin Store, Ulaanbaatar



RADON IN WATER

- ❖ **High levels in Ulaanbaatar**
- ❖ **UB water is RADON SPA !**

Location	spring / spa	longitude	latitude	Radon min	Radon max	Source
Mongolia	Khalzan in 1955	108 34 30	45 49 00	-	3,478 Bq/L	Oyunchimeg et al. (2002)
	Khalzan in 1957			444 Bq/L	555 Bq/L	
	Bayanzurkh	97 20 00	49 07 00	-	518 Bq/L	GIC (2003)
	Tsagaan gol	88 00 00	48 53 00	7.4 Bq/L	518 Bq/L	
	Janchiyvan	107 37 00	47 36 00	400 Bq/L	430 Bq/L	Oyunchimeg et al. (2002)
	Khalzan in 2000-2001	108 34 30	45 49 00	159 Bq/L	261 Bq/L	
	Urtgad	99 50 00	51 39 00	3.6 Bq/L	222 Bq/L	GIC (2003)
	Bulgan	91 23 00	46 35 00	3.6 Bq/L	222 Bq/L	
	Tsetsuukh	99 02 00	48 21 00	3.6 Bq/L	222 Bq/L	
	Zaart	98 46 00	48 21 00	11.1 Bq/L	177 Bq/L	
	Khukh nuden	114 49 00	49 40 00	44 Bq/L	159 Bq/L	
	mineral spring water				110 Bq/L	Oyunchimeg et al. (2006)
Japan	provisional (emergency) standard for infants – applicable to drinking-water used to prepare baby food				100 Bq/L	WHO FAQ (2011)
World	guideline of Codex Alimentarius for infant food				100 Bq/L	
World	guidelines for radon limit before treatment of water				100 Bq/L	WHO (2011a) Table A6.1
Ulaanbaatar	apartment tapwater from public supply pump houses				75 Bq/L	Oyunchimeg et al. (2006)
World	above this limit, classified as radon mineral water				74 Bq/L	Zdrojewicz et al. (2006)
Mongolia	drinking water in some province and soum centres				53 Bq/L	Oyunchimeg et al. (2006)
USA	maximum of over 28,000 domestic water supplies				24 Bq/L	Irwin (1997)
World	“Screening levels for drinking-water below which no further action is required”				0.50 Bq/L	WHO (2011a)
USA	average of 55,000 ground waters				0.12 Bq/L	Irwin (1997)
USA	average of 35,000 surface waters				0.04 Bq/L	

SODA LAKES

- ❖ Several thousand in Mongolia
- ❖ Very high pH (alkaline)
- ❖ Dissolve heavy metals
- ❖ Uranium, Selenium, Arsenic...
- ❖ Fluoride also



Ca/Mg CARBONATES IN SOIL

**URANIUM
SOURCE ROCKS**

sequestration as geopetal crusts

infiltrate

leaching

calcium
bicarbonate
waters

sodium
bicarbonate
waters

sodium
bicarbonate
waters

sodium
bicarbonate
waters

**PARENT
ROCKS**

Na^+
 Ca^{2+} dominant
 HCO_3^-
 $\text{SO}_4^{=}$
 Cl^-

Na^+ dominant
 Ca^{2+} lessened
 HCO_3^-
 $\text{SO}_4^{=}$
 Cl^-

Na^+ dominant
 Ca^{2+} depleted
 HCO_3^-
 $\text{SO}_4^{=}$
 Cl^-
U(VI) complex

Na^+ dominant
 Ca^{2+} eliminated
 HCO_3^-
 $\text{SO}_4^{=}$
 Cl^-
U(VI) complex

Main Controlling Factors

ice crystallization
ice fractionation
ice melting
ice sublimation
evaporation
desiccation

extremophiles
aridity-humidity
rainfall-snowfall
frost
wind erosion
inflow-outflow

reduction

oxidation

reduction

U(IV)

URANINITE UO_2

U(IV)

FLUORSPAR > FLUORIDE



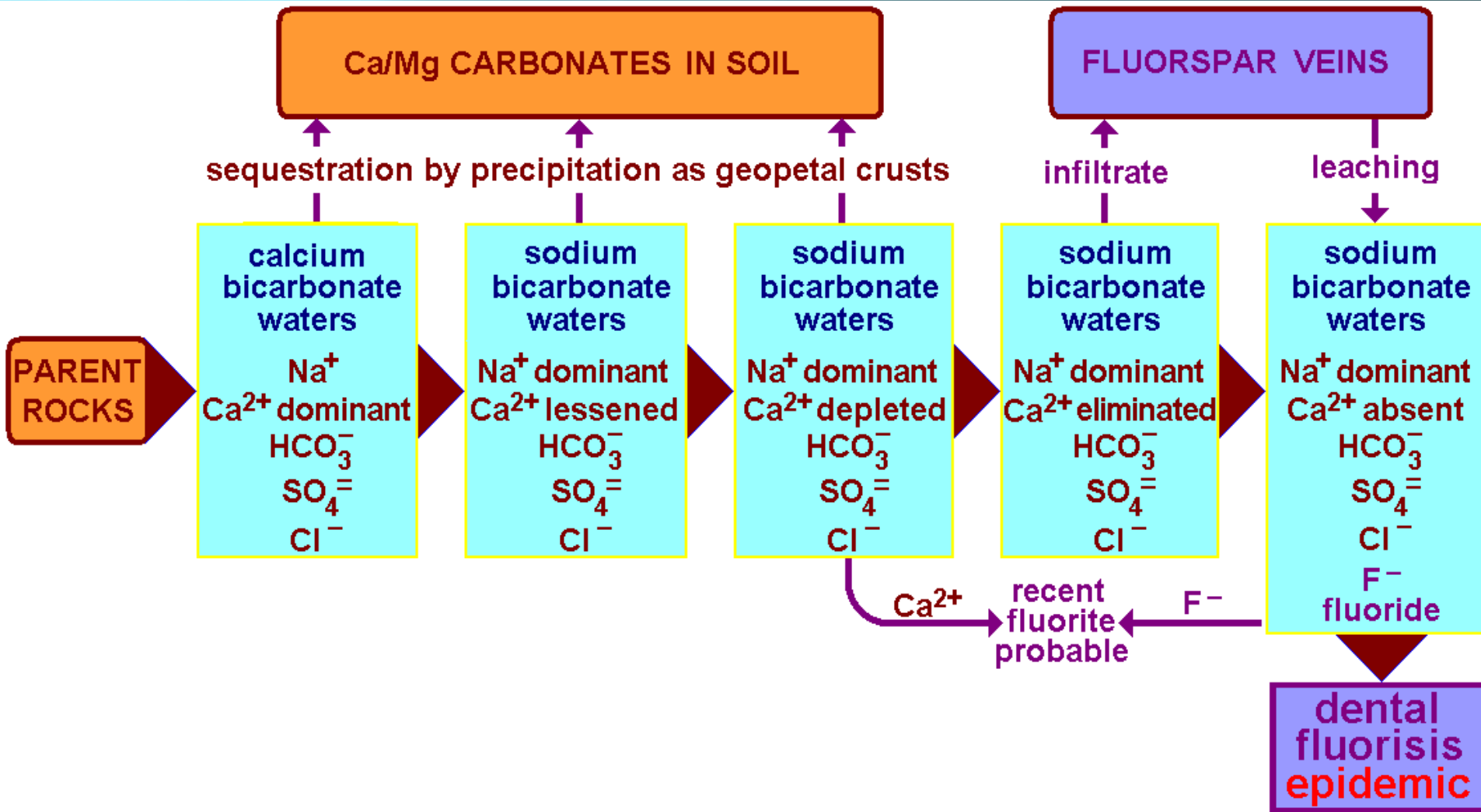
FLUORSPAR



FLUORSPAR CITY – Bor Undur



FLUOROSIS



LOW FLUORIDE

WORLDWIDE	WHO Guidelines – risk of dental fluorosis if fluoride in drinking-water above this level	1.5 mg/L	WHO (2006)
MONGOLIA	MNS drinking water standards – HIGHEST permitted	1.5 mg/L	MNS 3900:1986
	<u>Ar Janchivlan</u> bottled water	1.1 mg/L	
	<u>Dornod Aimag</u>	1.1 mg/L	<u>Zolboo et al. (2001)</u>
	<u>Khirjirt</u> bottled water	1.0 mg/L	
	<u>Terelj</u> bottled water	0.8-1.0 mg/L	
	MNS drinking water standards – LOWEST permitted	0.7 mg/L	MNS 3900:1986
MONGOLIA	<u>South Gobi Aimag</u>	0.57-0.91 mg/L	<u>Zolboo et al. (2001)</u>
	<u>Gobisumber Aimag</u>	0.52 mg/L	
	<u>Gobi-Altai Aimag</u>	0.26 mg/L	
	<u>Arkhangai Aimag</u>	0.24 mg/L	
	<u>Bayan Olgii Aimag</u>	0.16 mg/L	
	<u>Bulgan Aimag</u>	0.14 mg/L	
	<u>Ulaanbaatar</u>	0.06 mg/L	

LOW Fluoride in Water

HIGH FLUORIDE

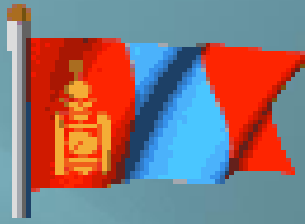
Country	Details % children with dental fluorosis	fluoride micrograms per litre	source
KENYA	Lake Nakuru	2,800 mg/L	WHO (2006)
	Lake Elmentaita	1,640 mg/L	
TANZANIA	Momella soda lakes	690 mg/L	
MONGOLIA	Tsenker Hot Spring	25 mg/L	Gendenjamts (2005).
WORLDWIDE	WHO Guidelines – risk of crippling skeletal fluorosis if fluoride in drinking-water above this level	10 mg/L	WHO (2006)
MONGOLIA	Sukhbaatar Soum, Sukhbaatar Aimag	2.0-3.5 mg/L	Dorj (2007)
	Sukhbaatar Aimag	1.63-2.17 mg/L	Zolboo et al. (2001)
	Ulaan-Uul railway station – 50%	2.05 mg/L	Bayarmaa, Norjmaa and Bolormaa (2006)
	Sainshand railway station – 40%	1.97 mg/L	
	Zuunbayan railway station – 75%	1.96 mg/L	
	Airag railway station – 36.3%	1.95 mg/L	
	Dornogobi Aimag	1.41-1.94 mg/L	Zolboo et al. (2001)
WORLDWIDE	WHO Guidelines – risk of dental fluorosis if fluoride in drinking-water above this level	1.5 mg/L	WHO (2006)
	MNS drinking water standards – HIGHEST permitted	1.5 mg/L	MNS 3900:1986

HIGH Fluoride in Water

TANNERIES

A photograph of a large industrial tannery. In the foreground, there are massive piles of animal skins, some appearing wet and glistening. Several workers in dark clothing are visible, standing near the piles. The background shows the interior of a large building with a high ceiling and a series of bright windows. Large industrial drums or vats are visible on the right side of the image.

HEXAVALENT CHROMIUM



THANK YOU



Robin Grayson and Bataar Tumenbayar

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