



Environmental risk management of red mud contaminated land

Katalin Gruiz, Viktória Feigl, Orsolya Klebercz,
Attila Anton and Emese Vaszita
Gruiz@mail.bme.hu http://enfo.agt.bme.hu/drupal/en/gallery/2472

Ajka
Hungary
October 2010

The failure of the NW corner of the Ajka alumina plant red mud depository resulted in the release of 800 000 m^3 of highly caustic red mud suspension, which engulfed the downstream villages of Kolontár, Devecser, Somlóvásárhely.

10 people have died, 150 were injured.
400 houses were destroyed.
Ecosystem of creeks, rivers, wetlands
and terrestrial areas was damaged.
10 000 ha agricultural land was impacted.

Characteristics of the dam: statics problems

The material of the dam: fly ash with puzzolanic-activity, forming a concrete-like material, stabile but not flexible (low tensile strength).

Layered bedrock: Triassic carbonates (dolomite) overlain by a fluvial sequence of marls, clays (prone to slipping when swollen) and interbedded fine sands.

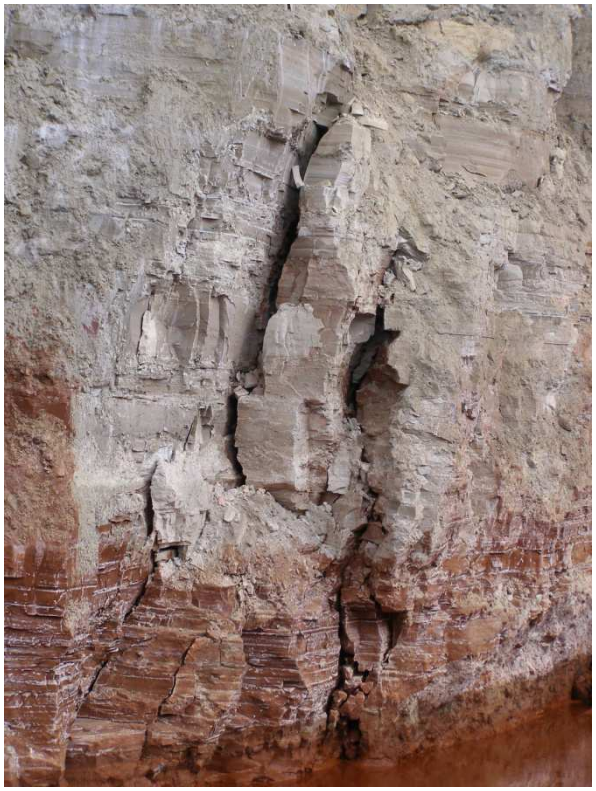
An exterior non-permeable subsurface dam/wall was build in the 90's as a barrier to protect surface and subsurface waters from alkaline leachate. The second dam retained alkaline leachate wetting the marl and clay layers permanently.

Retrospective characterization of the dam statics

Method

InSAR: Synthetic Aperture Radar Interferometry

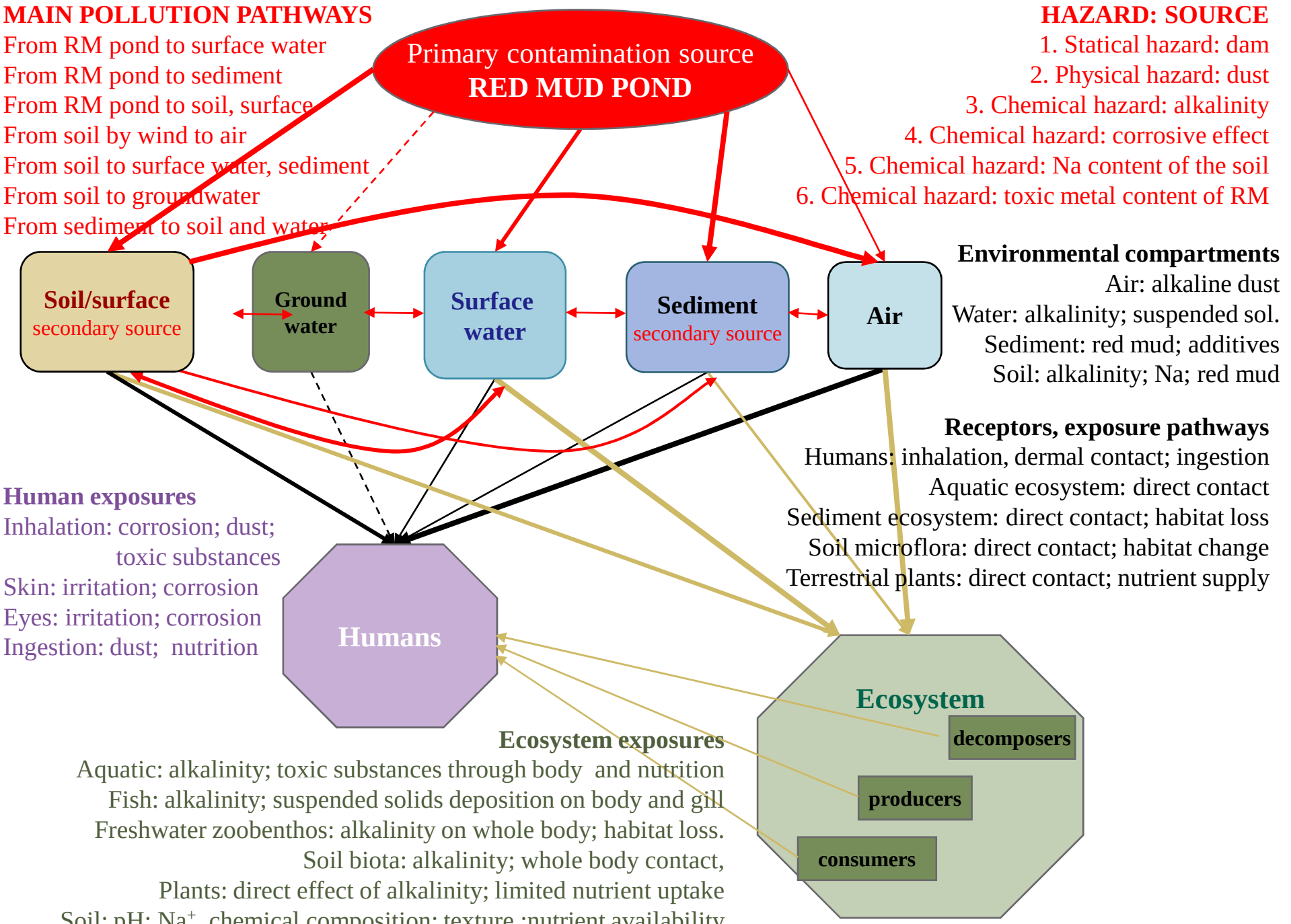
Results: 2003–2010 ENVISAT data were processed and the rate of the vertical movement calculated. The broken corner submerged 12–15 mm/year (violet), while the surrounding was stabile (green).



Environmental risk management

1. Catastrophe response:
   Protecting human life,
   animals and other values

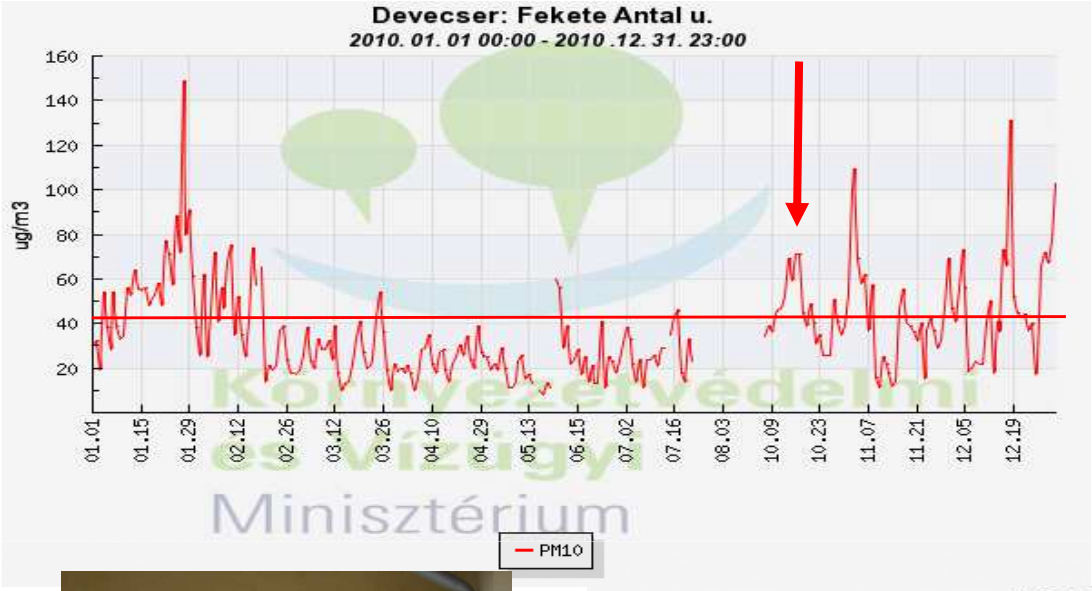
2. Risk mitigation by rapid measures
3. Final risk reduction
   - Creating the conceptual risk model
   - Site assessment
   - Preliminary risk assessment: scoring
   - Detailed risk assessment: quantitative
   - Evaluation of the risk reduction options
   - ERA, SEA
   - Implementation of the RRMs
   - Monitoring on the long term
   - Verification
   - Risk communication


MAIN POLLUTION PATHWAYS
From RM pond to surface water
From RM pond to sediment
From RM pond to soil, surface
From soil by wind to air
From soil to surface water, sediment
From soil to groundwater
From sediment to soil and water
Primary contamination source
RED MUD POND
HAZARD: SOURCE
1. Statical hazard: dam
2. Physical hazard: dust
3. Chemical hazard: alkalinity
4. Chemical hazard: corrosive effect
5. Chemical hazard: Na content of the soil
6. Chemical hazard: toxic metal content of RM
Soil/surface
secondary source
Ground water
Surface water
Sediment
secondary source
Air
Environmental compartments
Air: alkaline dust
Water: alkalinity; suspended sol.
Sediment: red mud; additives
Soil: alkalinity; Na; red mud
Receptors, exposure pathways
Humans: inhalation, dermal contact; ingestion
Aquatic ecosystem: direct contact
Sediment ecosystem: direct contact; habitat loss
Soil microflora: direct contact; habitat change
Terrestrial plants: direct contact; nutrient supply
Human exposures
Inhalation: corrosion; dust; toxic substances
Skin: irritation; corrosion
Eyes: irritation; corrosion
Ingestion: dust; nutrition
Humans
Ecosystem
decomposers
producers
consumers
Ecosystem exposures
Aquatic: alkalinity; toxic substances through body and nutrition
Fish: alkalinity; suspended solids deposition on body and gill
Freshwater zoobenthos: alkalinity on whole body; habitat loss.
Soil biota: alkalinity; whole body contact,
Plants: direct effect of alkalinity; limited nutrient uptake
Soil: pH; Na+, chemical composition; texture,;nutrient availability

Risk scores of some selected scenarios

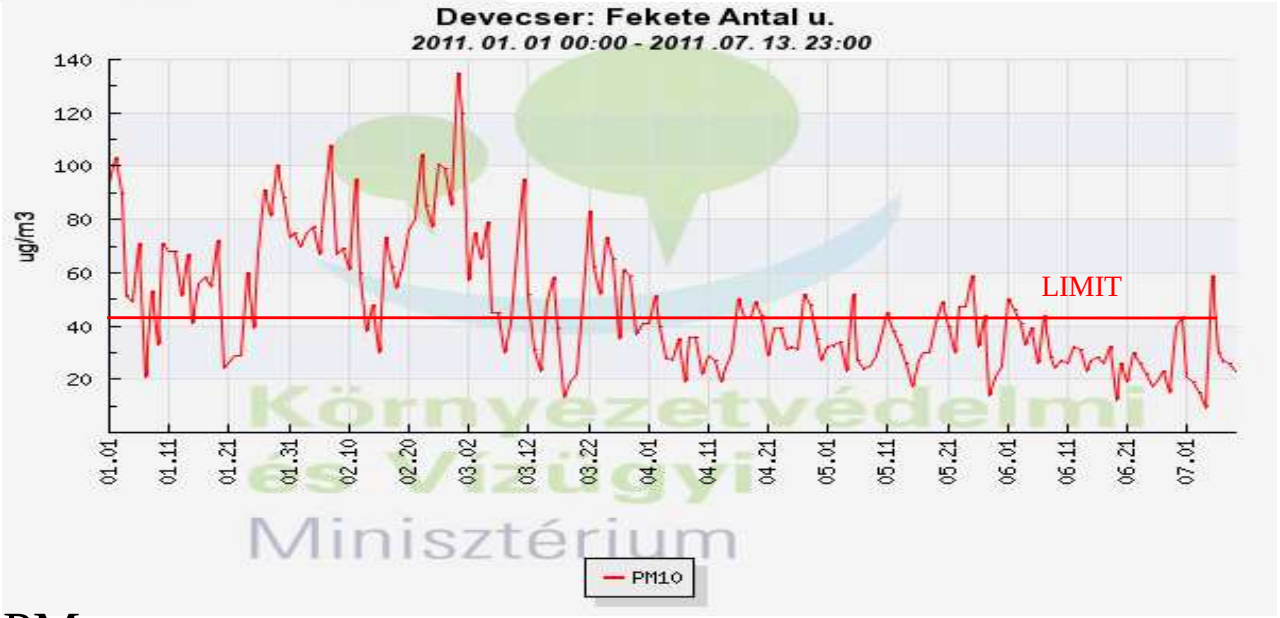
Evaluated risk scenario		Risk score max.100	Risk characterization	Action necessary?
1. Red mud layer on soil: infiltrated alkaline solution, desiccated red mud				
1.1.	Below 5 cm thick red mud layer	63	High risk	Action required
1.2.	5–10 cm thick red mud layer	74	Very high risk	Action required
1.3.	10–20 cm thick red mud layer	85	Very high risk	Action required
1.4.	Above 20 cm red mud layer	91	Very high risk	Action required
2. Red mud removal: caustic solution infiltrated, solid red mud layer removed				
2.1.	Below5 cm thick red mud layer	14	No risk	No action required
2.2.	5–10 cm thick red mud layer	19	No risk	No action required
2.3.	10–20 cm thick red mud layer	38	Low risk	Not likely required
2.4.	Above 20 cm red mud layer	44	Medium risk	Likely required
3. Red mud incorporated into soil				
3.1.	Below5 cm thick red mud layer	16	No risk	No action required
3.2.	5–10 cm thick red mud layer	25	Low risk	Not likely required
3.3.	10–20 cm thick red mud layer	41	Medium risk	Likely required
3.4.	Above 20 cm red mud layer	49	Medium risk	Likely required
4. Soil with planted vegetation				
4.1.	Removed red mud layer >10 cm	21	No risk	No action required
4.2.	Mixed in red mud layer <5 cm	14,5	No risk	No action required
4.3.	Mixed in red mud layer 5–10 cm	20,5	Low risk	Not likely required
5. Disposal of the removed red mud		78	Very high risk	Action required

Quantitative risk assessment



Dust inhalation

Prognosis was: no increased risk for the summer of 2011. Mesured data validated the prognosis: PM10 is under the Hungarian screening value



13 monitoring stations for PM

Caustic effect on humans

Inhaled NaOH was calculated in a worst case scenario, assuming the highest dusting rate and 10% NaOH content in the fugitive dust.
RCR_{inh} = 1/200 compared to the 2 mg/m^3 occupational exposure limit.
RCR_{inh} = 1/1000 compared to the acute inhalation limit of 10 mg/m^3.

Dermal irritation and corrosion

Red mud /risk scenario	Maximum pH	RCR_{dc}	Verbal risk characterization
Freshly discharged red mud	>13	**RCR_{dc}>10**	Significant
Red mud on soil: after 5 months	12.5	**RCR_{dc}=5**	Significant
Red mud on soil: after 10 months	12.3	**RCR_{dc}=3**	Significant
Red mud removal from soil surface	8.0	RCR_{dc}~0	Negligible
Red mud incorporation, max. 10%	8.8–9.9	RCR_{dc}=0.001–0.01	Negligible
Disposal of removed red mud	11–12.3	**RCR_{dc}=0.1–3**	Moderate–signif.

Risk of pH and Na on soil quality and function

Alkalinity: risk of reduced soil life

Red mud removal on the field: pH 8.00±1.0, negligible risk.
Incorporating 5% RM: pH 8.8±0.5, moderate risk.
Revegetation lowered the pH with a value of 1.7 in lab experiments.
Plant growth is inhibited by a pH above 9.5
Incorporation of 10% red mud is at the boundary of the acceptable risk.

Na-content: risk of sodification

Red mud / scenario	Na 7 months	RCR 7 months	Verbal risk characterization	7 month after removal
Red mud on soil	**3100**	**RCR_{Na}=3.4**	High	Not acceptable, remove
Removal from soil	*200*	RCR_{Na}=0.1	Negligible	Unlimited use
Incorporation 5%	*420*	RCR_{Na}=0.2	Moderate	Unlimited use
Incorporation 10%	*800*	RCR_{Na}=0.8	Moderate	Usable
Incorporation 10% low attenuation	**1600**	**RCR_{Na}=1.6**	Significant	Use specific plants, apply monitoring and control
Deposition of red mud with soil	**15 000**	**RCR_{Na}=15**	Very high	Isolate by vegetation, if plants are able to grow
Deposition of RM	**38 600**	**RCR_{Na}=40**	Very high	Encapsulate

Risk posed by toxic metal contamination on soil

Scenario	As mg/kg	Cr mg/kg	Ni mg/kg	Se mg/kg	RCR_{As}	RCR_{Cr}	RCR_{Ni}	RCR_{Se}	Verbal characteriz	Action required
Site spec. soil SC	25	75	40	3						
Sewage sludge SC	75	1000	200	-						
Reference soil av.	11	29	18	1,8	0,44	0,39	0,45	0,6	Small	
RM on top*	38	420	180	not det.	**1,5**	**5,6**	**4,5**	0	Significant	Remove RM or mix into soil
RM mixed in**					0,5	0,4	0,9	0	Moderate	
Removal of RM	14,8	31	25	1,6	0,6	0,4	0,6	0,5	Moderate	Unlimited use
5% RM	9,8	38	19	1,2	0,6	0,5	0,5	0,4	Moderate	Unlimited use
10% RM	11,5	58	29	1,2	0,8	0,8	0,7	0,4	Moderate	Unlimited use
Soil:RM = 2:1	20	157	66	1	0,8	**2,1**	**1,6**	0,3	Significant	Lmtd plant use
Soil:RM = 1:1	25	225	100	0,6	1	**3**	**2,5**	0,2	Significant	Lmtd plant use encapsulation

* Considered as soil ** Considered as sewage sludge

Inhibitory effect of red mud on soil ecosystem members

Test	% red mud in soil causing 10% inhibition	% red mud in soil causing 20% inhibition	% red mud in soil causing 50% inhibition
Soil microorganisms	30	35	40
Seed germination	13	18	25
Plant shoot growth	5	8	18
Plant root growth	6	8	15
Collembolan lethality	15	20	25



Risk reduction