Use of artificial tracing (Br\textsuperscript{-} and Cl\textsuperscript{-}) for investigating infiltration processes and their impact on landslide stability.

The case of the Super-Sauze mudslide (04, France)

Outline

1) Context

2) Experimental setup: hydrological and hydrochemical test

3) Results: hydrodynamic concepts on fissure flows

4) Results: hydrochemical concepts on fissure flows

5) Conclusion
1) Context
Financing
This work is granted by the projects ECOU-PREF (Analysis of Fissure flow Systems on Landslides) and TRIGGERLAND (TRIGGERing mechanisms of LANDslides: analysis and modelling) financed by French ANR (National Research Agency)

Objective
To deliver new technologies (experimental prototypes, numerical tools, models) in order to better understand the processes governing landslide failures

Objective of this presentation
Identify the impacts of preferential flows on groundwater dynamics in landslides developed in black marls
2) Experimental setup: hydrological and hydrochemical test
The Super-Sauze mudslide

South French Alps, Department of Alpes-de-Haute-Provence (04, France)

Super-Sauze mudslide

$Z_{\text{min}} = 1740 \text{ m}$

$Z_{\text{max}} = 2105 \text{ m}$

135 m

655 m
1950-1970

Moraine

Before failure

1970-1980

First failures of the gully crests, structural slides on the main scarp
Accumulation of sediment in the torrent

1980-present

Filling up of the gullies and downwards progress of a mudslide

History of the Super-Sauze mudslide (Malet, 2000)
The hydrological and hydrochemical concept (de Montety, 2007)
The experimental area (hydrological tracing test)

Upper part of the mudslide; highly fissured area; Velocity: 1 cm.day$^{-1}$
The experimental equipment

Measurement of overland flow

12 piezometers groups (1, 2 et 3 m)

15 rain gauges

6 sprinklers

Boundaries of the infiltration area

12 piezometers groups

6 sprinklers

15 rain gauges

Boundaries of the infiltration area
The tracing test (artificial rainfall)

KBr
Br⁻ (100 mg/l)

KCl
Cl⁻ (100 mg/l)

3 days

4 days

Rain (mm/h)

Rain (Cl⁻ and Br⁻) mg/l

10/7/07 12/7/07 14/7/07 16/7/07 18/7/07 20/7/07 22/7/07

0 5 10 15 20

10/7/07 19h → 13/7 16h

17/7 11h → 20/7 10h

3 days

4 days

Cl⁻ (mg/l)

Br⁻ (mg/l)
The fissure system characteristics

Zone with no apparent fissures

Near BI-19/BI-20

Near BI-1/BI-2

Near BI-6

Near BI-17/BI-18

Zone with apparent fissures
3) Results: hydrodynamic concepts on fissure flows
Water balance (for the 2 weeks of experimentation)

In: water volume = Rain = 150 m$^3$

Out: water volume = $E + \text{Overland flow} + \text{groundwater flow} = 154.5$ m$^3$

Difference water volume = 4.5 m$^3$ (3.2%)
Groundwater hydrodynamic

Groundwater flow (Piezometers at -1 m)
Average gradient: 34 – 40%

Groundwater flow (Piezometers at -2 m)
Average gradient: 25 – 43%

Groundwater flow (Piezometers at -3 m)
Average gradient: 33 – 34%

Date: 18/7/2007 12h20
Conceptual model of water fluxes: possible connection of macropores
4) Results: hydrochemical concepts on fissure flows
Conceptual model of chemical signature: possible connection of macropores

1. Fissure
   - Macropore
   - Piezometer BI-20

2. Connection of the macropores
Impacts of the superficial fissure system on deep water percolation

Cl and Br (mg/l) (BI-18)

Cl- (mg/l)

Br- (mg/l)

10/7/07 12/7/07 14/7/07 16/7/07 18/7/07 20/7/07 22/7/07 24/7/07

Cl and Br (mg/l) (BI-20)

Cl- (mg/l)

Br- (mg/l)

10/7/07 12/7/07 14/7/07 16/7/07 18/7/07 20/7/07 22/7/07 24/7/07
Impacts of the superficial fissure system on deep water percolation

Cl and Br (mg/l) (BI-2)

Cl- (mg/l)
Br- (mg/l)

Cl and Br (mg/l) (BI-6)

Cl- (mg/l)
Br- (mg/l)

Near Bi6

3 m

Down slope

Up slope

3.4 m
Conclusion

1) Important differences in hydrodynamic and hydrochemical behaviour on very small scale.

2) Fissures increase the groundwater recharge

3) Combination of hydrodynamic and hydrochemical information was useful to show complex hydrological response and development of macropores connectivity

4) Connectivity results in changes of groundwater flow patterns and in such changes the mudslide hydrological structure and influence the overall stability of the mudslide

5) Future work: hydrological numerical modelling
Thanks for your attention