Rainwater harvesting and greywater recovery
- Part 4 -

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Module 2: Resource use from a challenge perspective
Urban Agriculture for resource efficiency and waste management

Course outline

1. Urban water hydrology
- 1.1 Specificities of the urban context
- 1.2 Impacts of the vegetation on water regulation
- 1.3 Soil properties (reminder)

2. Green roof potential for water runoff control
- 2.1 Roles and constitution
- 2.2 Performance

3. Greywater
- 3.1 Origin, collection, treatment
- 3.2 Greywater reuse for irrigation

4. Stormwater basin for road water runoff
- 4.1 Operation
- 4.2 Infiltration performance and clogging process

5. Self-assessment

Course outline

4. Stormwater basin for road water runoff

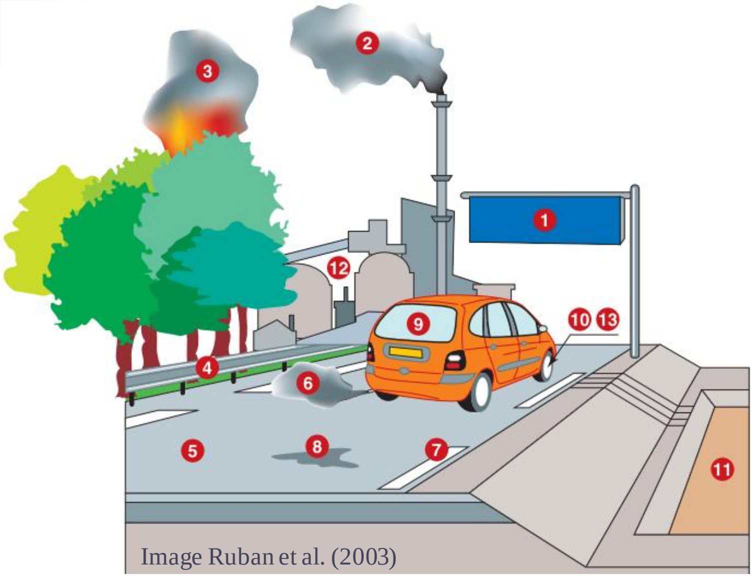
> 4.1 Operation

> Soil sealing and rainwater runoff

Water fluxes in urban areas are different compared to natural areas

=> *see slide n° 6*

Specificity of **road** rainwater runoff = vector of contamination



1: road traffic signs
2: industrial, domestic… combustions
3: Forest fires
4: Safety barriers
5: roads
6: exhaust pipe combustion
7: paints
8: oils
9: car body
10: tyre
11: basin muds
12: roofs
13: brake lining

Hydrocarbon, PAH	(2, 3, 5, 6, 8, 10, 11)	**Copper**	(2, 9, 11, 12, 13)
Cadmium	(1, 2, 8, 10, 11)	**Lead**	(2, 6, 11, 12, 13)
Chromium/Nickel	(2, 7, 9, 11)	**Zinc**	(1, 2, 4, 8, 10, 11, 12, 13)

Road rainwater runoff collection and elimination is a necessity

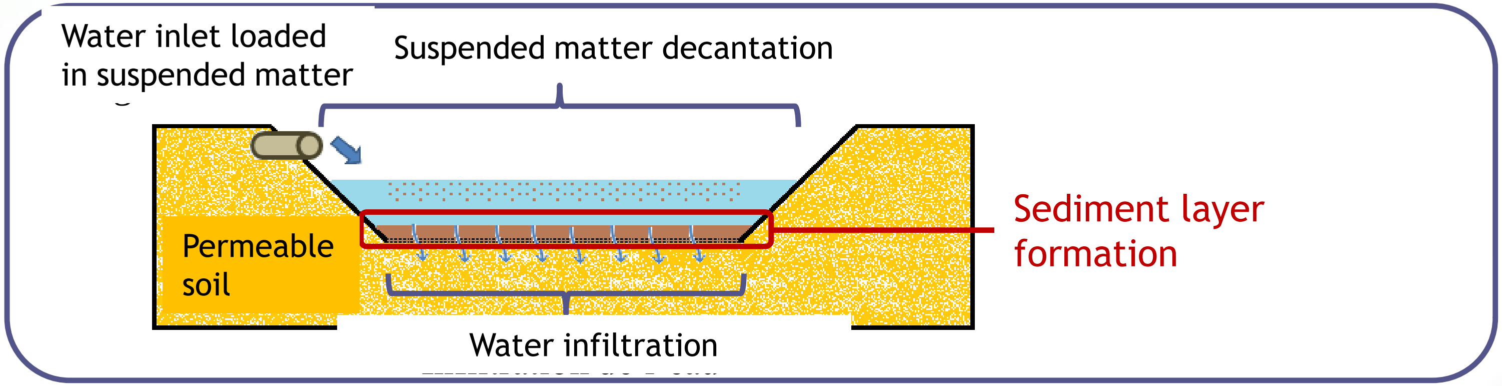
=> One possible solution : **retention-infiltration stormwater basins**

> Stormwater basin working

Cheviré stormwater basin, Nantes, France

Role

- ⇨ Rainwater flow regulation
- ⇨ Groundwater recharge
- ⇨ Epuration



Technical limits

- ⇨ Progressive filling of the soil porosity ➔ Clogging up risk
- ⇨ Infiltration capacity decrease
- ⇨ Epuration efficiency decrease

4. Stormwater basin for road water runoff

> 4.1 Operation

> Main characteristics of the sediment layer

Physico-chemical characteristics

- Fine texture (75% in weight, < 100µm)
- High organic matter content : 4 to 27 % dry weight soil
- Mixed pollution

Hydric properties

- High water retention capacity
- Low infiltration capacity
- Hydrophobic behavior → due to high organic matter content

4. Stormwater basin for road water runoff

> 4.1 Operation

> Organic matter (OM) origin

Natural OM

Spontaneous vegetation development

Example : Cheviré basin

2001

2012

4. Stormwater basin for road water runoff

> 4.1 Operation

> Organic matter (OM) origin

Natural OM

Anthropic OM

Complex mix of natural and anthropic OM

4. Stormwater basin for road water runoff

> 4.1 Operation

> Organic matter (OM) origin

Natural OM

Anthropic OM

Complex mix of natural and anthropic OM

Composition (Durand, 2003)

- **Humic substances** : Biopolymers of plant and microbial origins
- **Lipids** : oil degradation products

⇨ **What is the role of the sediment organic matter in the stormwater basin clogging process ?**

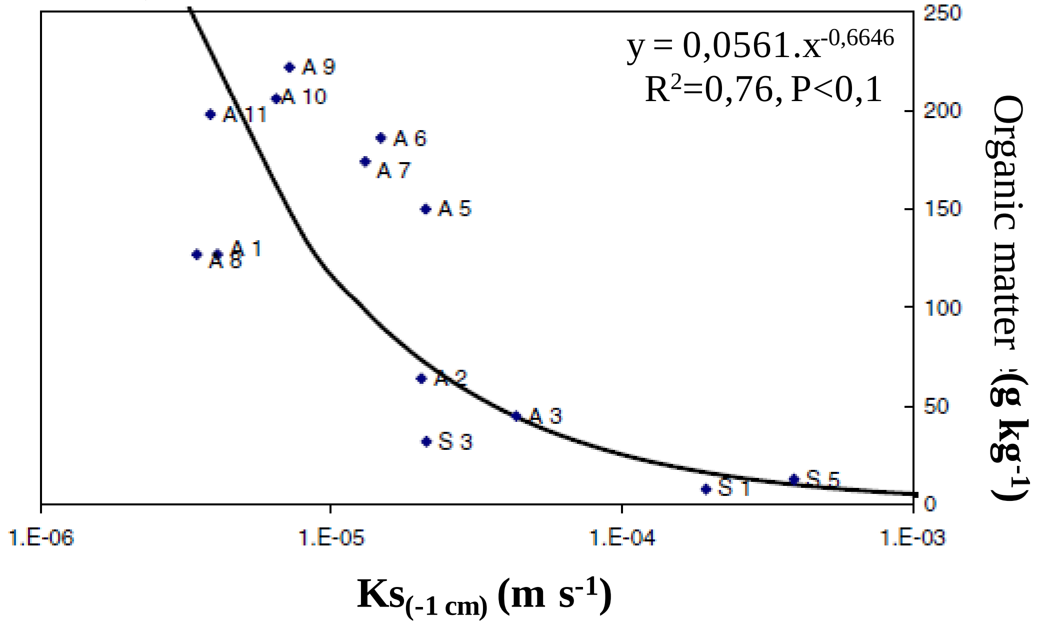
4. Stormwater basin for road water runoff

> 4.2 Infiltration performance and clogging process

> Organic matter influence on water infiltration

Relation between the sediment hydraulic conductivity at saturation (Ks) and its organic matter content

(Cannavo et al., 2010)



⇨ **Inverse correlation: the higher is OM content, the lower is Ks…**

⇨ Contradiction with the natural context:

↳ OM favor soil properties, and particularly water infiltration

⇨ **What is the composition and biodegradation capacity of this OM**

4. Stormwater basin for road water runoff

> 4.2 Infiltration performance and clogging process

> Study case

The stormwater infiltration basin of the Cheviré bridge (Nantes, France)

Ouest France, 2015

4. Stormwater basin for road water runoff

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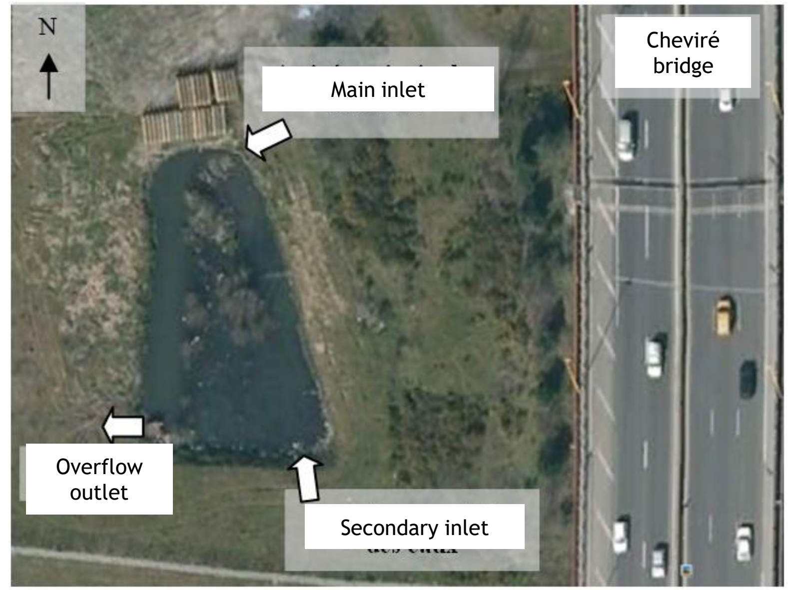
The stormwater infiltration basin of the Cheviré bridge (Nantes, France)



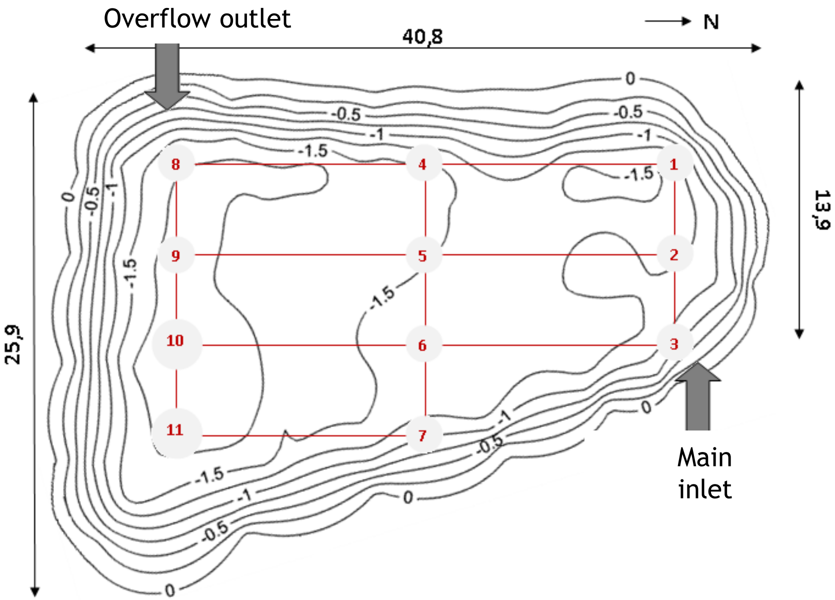
Runoff water origin	Cheviré bridge
Daily trafic	90.000 vehicles/day
Opening	1991
Drainage area	16.000 m^2
Basin area	780 m^2

4. Stormwater basin for road water runoff

> 4.2 Infiltration performance and clogging process

> Study case

Basin topography & sampling points

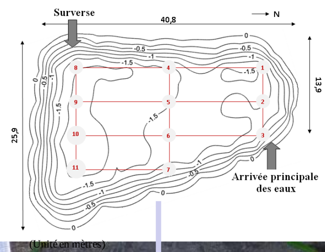


(Units : meter)

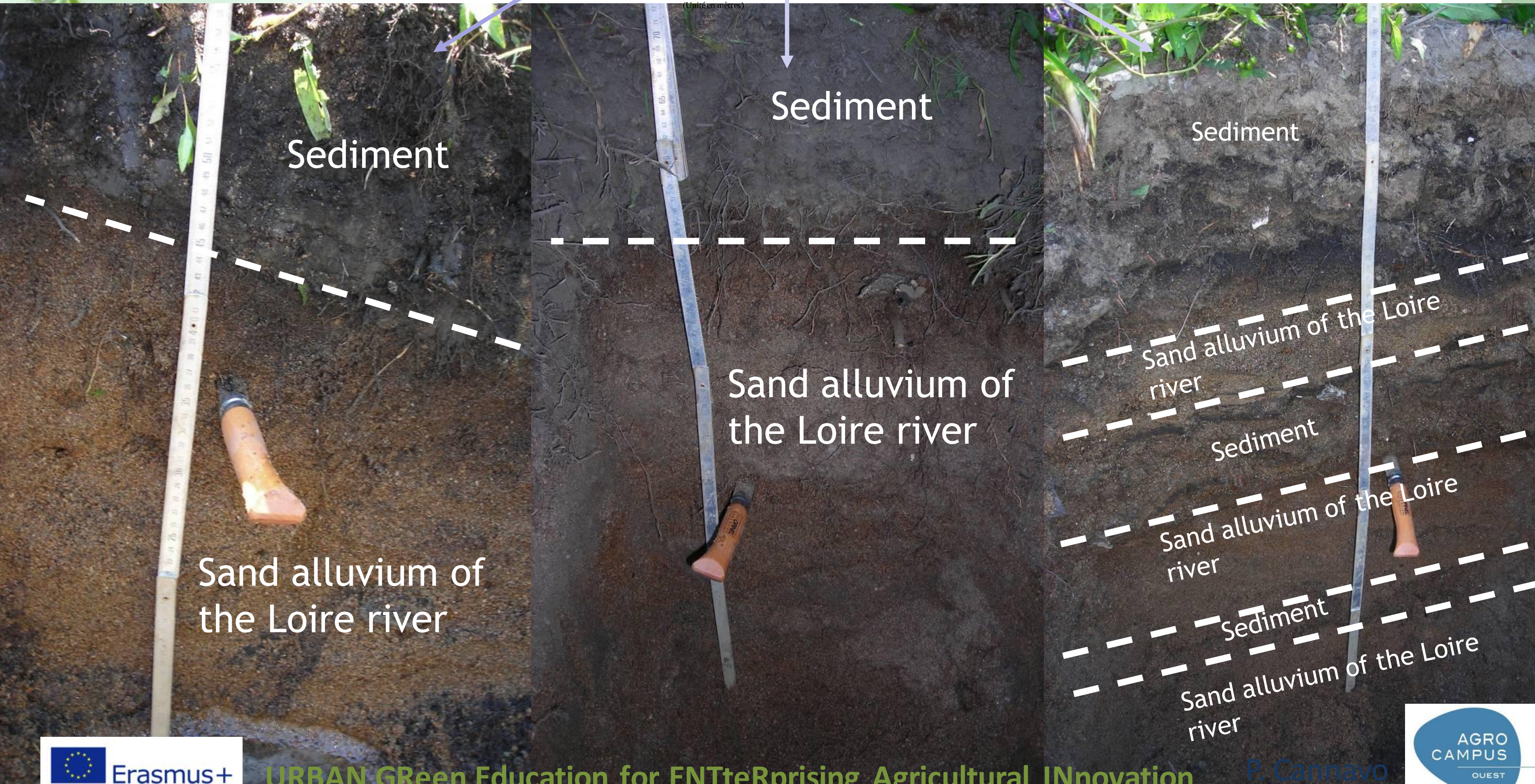
4. Stormwater basin for road water runoff

> 4.2 Infiltration performance and clogging process

> Study case



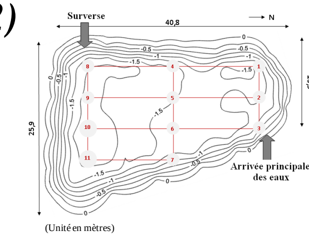
« Mille-feuille » structuration due to intense water + sediment discharge at the inlet



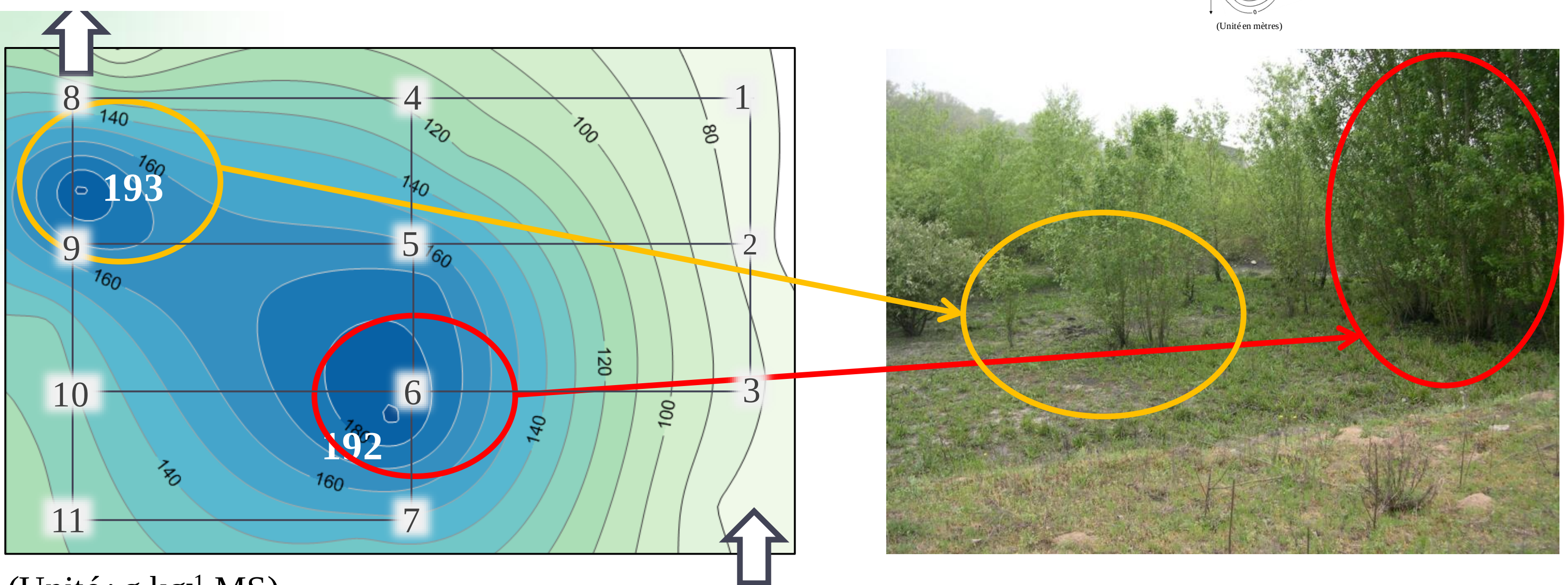
4. Stormwater basin for road water runoff

> 4.2 Infiltration performance and clogging process

> Organic matter spatial distribution *(Coulon, 2012)*



Overflow outlet



(Unité : g kg^{-1} MS)

Main inlet

Mean = 129 g kg^{-1} dw sediment

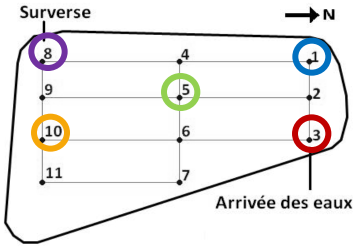
Spatial heterogeneity due to:

- Slope effect from the right to the left
- Dense vegetation in the center of the basin

4. Stormwater basin for road water runoff

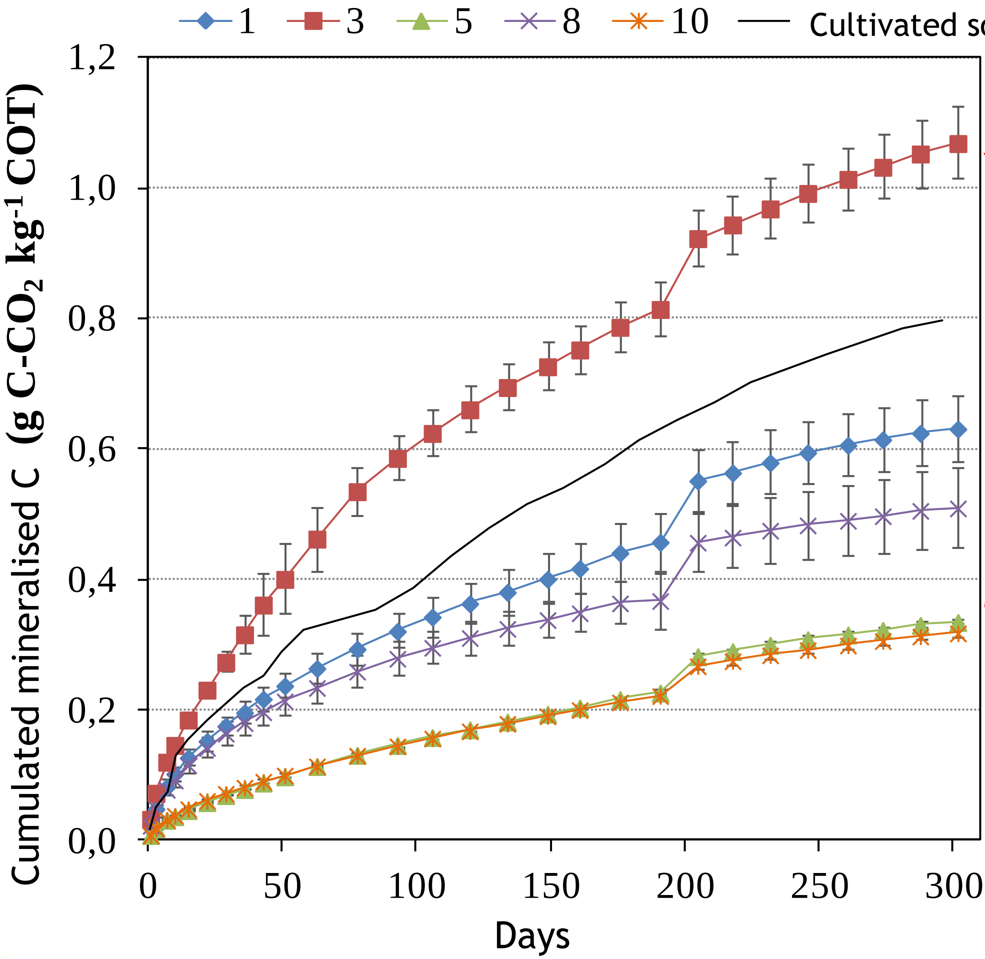
> 4.2 Infiltration performance and clogging process

> Organic carbon potential biodegradability *(Coulon, 2012)*



Sediment C potential mineralization

Incubation at 28 ° C, at 60% of the water-filled capacity



Sampling point	Total organic carbon (TOC) (g/kg)
1	60
3	58
5	104
8	60
10	131
Cultivated soil	7

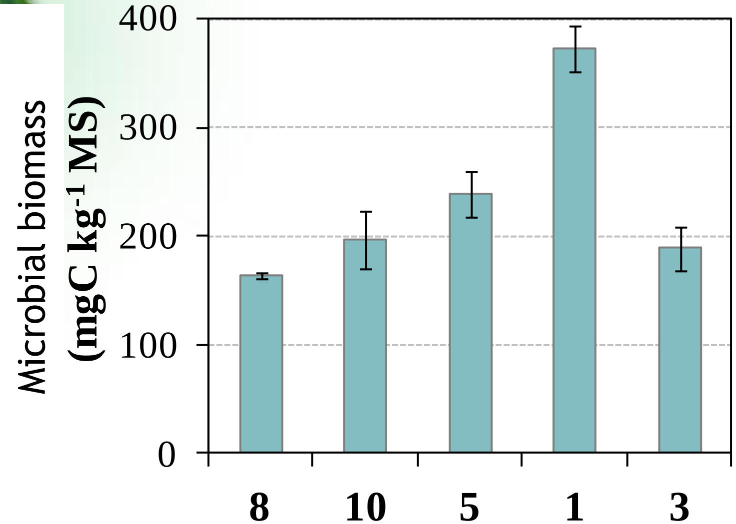
Inverse correlation between C mineralisation and TOC content (R = -0,73, p < 0,5)

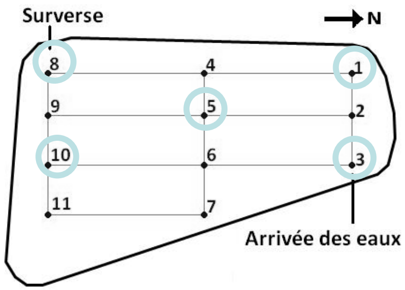
4. Stormwater basin for road water runoff

> 4.2 Infiltration performance and clogging process

> Biologic activity *(Coulon, 2012)*

Sediment microbial biomass





⇨ decrease in biomass from the inlet to the outlet

	C biomass (g/kg of TOC)	Specific respiration (mgCO2-C/g C biomass / day)
Sediment	1,9 à 6,6	4,7 à 18,9
Natural or cultivated soil	30 à 70[i]	31 à 52[ii]

⇨ **Low sediment biologic activity**

[i] von Lützow et al., 2007 ; [ii] Chaussod et al., 1992

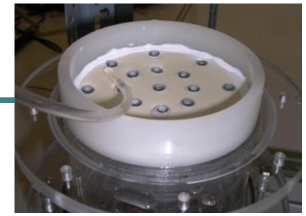
4. Stormwater basin for road water runoff

> 4.2 Infiltration performance and clogging process

> How does the clogging process take place ? => Study in the Lab
(Coulon, 2012)

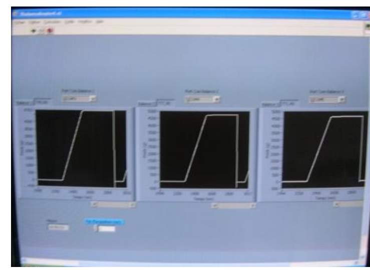
Tank
100L

20 cm of
sand



Water
distribution

Datalogging



Water
outflow
measurement

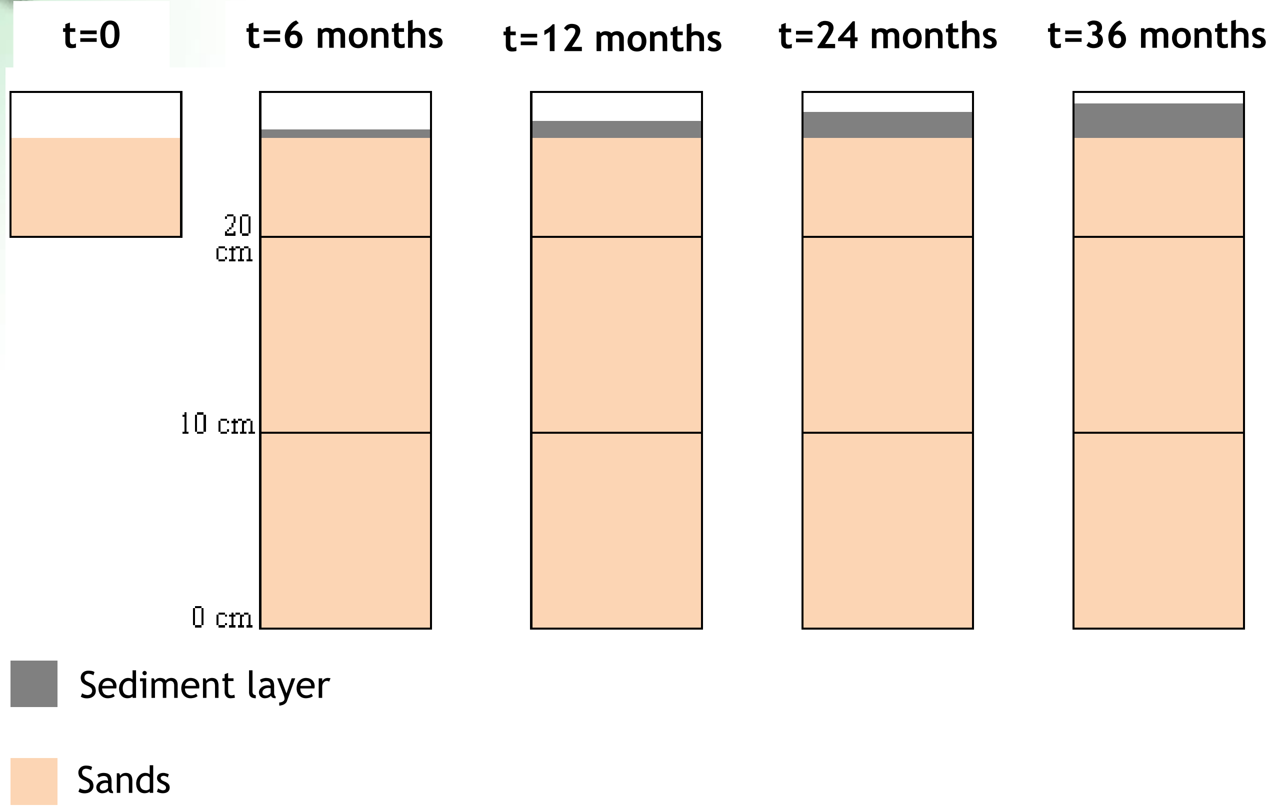
Accelerated functionning of the basin using columns filled in with sand alluvium

Sediment and water supplies deduced from sediment accumulation in the basin during the last 20 years and meteorological data

4. Stormwater basin for road water runoff

> 4.2 Infiltration performance and clogging process

> How does the clogging process take place ? => Study in the Lab
(Coulon, 2012)



⇨ 36 months of functionning simulated within 9 weeks in the Lab

4. Stormwater basin for road water runoff

> 4.2 Infiltration performance and clogging process

> How does the clogging process take place ? => Study in the Lab

(Coulon, 2012)

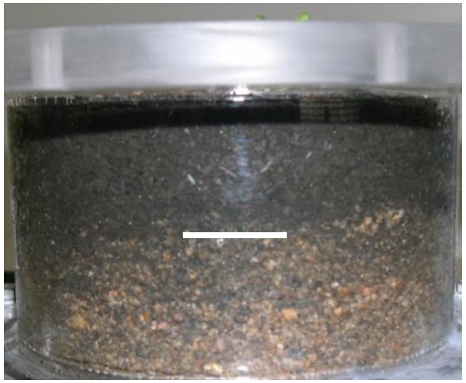
Thickness evolution

t=0

t=6 months

t=12 months

t=24 months

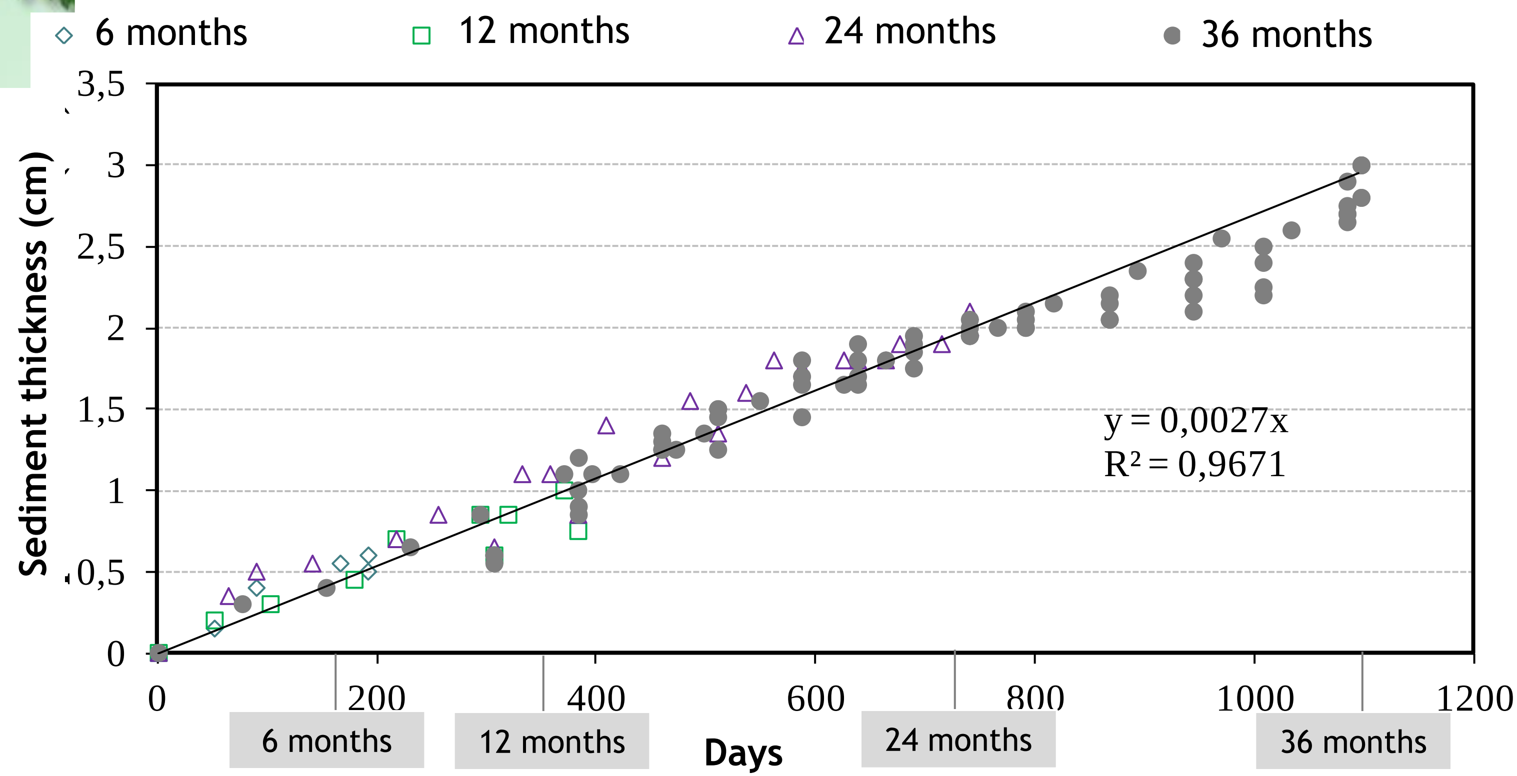


t=36 months

4. Stormwater basin for road water runoff

> 4.2 Infiltration performance and clogging process

> How does the clogging process take place ? => Study in the Lab
(Coulon, 2012)



⇨ **Accumulation rate = 1 cm / year**

⇨ Consistent with Cheviré basin observations

4. Stormwater basin for road water runoff

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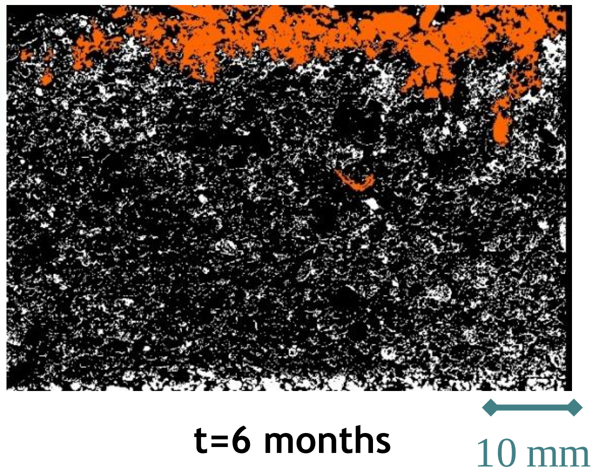
> How does the clogging process take place ? => Study in the Lab

(Coulon, 2012)

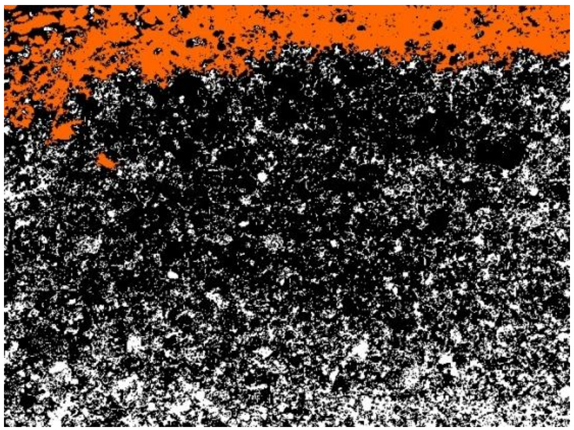
Microscopic image analysis: sediment layer formation

Legend:

- *Sediment*
- *Voids*
- *Mineral matrix*

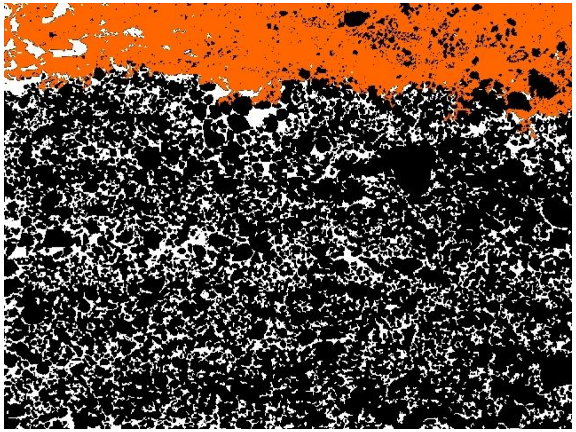


t=6 months

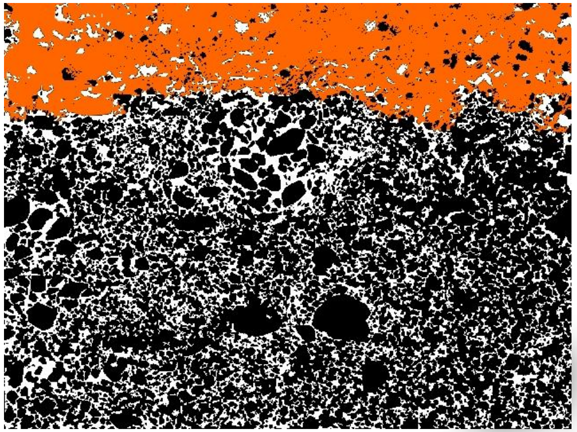


t=12 months

Resolution : 1 pxl = 100µm



t=24 months

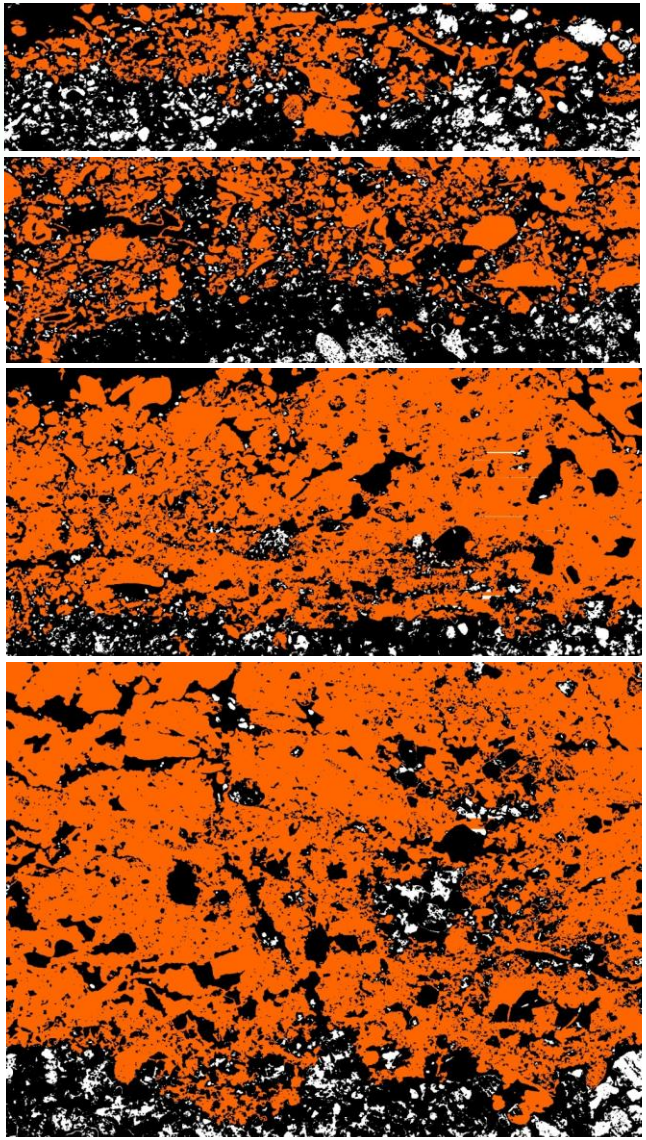


t=36 months

4. Stormwater basin for road water runoff

> 4.2 Infiltration performance and clogging process

Microscopic image analysis: sediment layer porosity and clogging progression



t=6 months

Well individualided particles – Clear visible voids

t=12 months

Numerous small particle well individualised – Voids decrease

t=24 months

Coarse particles apparition (agglomeration)- Few voids

t=36 months

Agglomerated particles
Voids disappearance

Legend:

- *Sediment*
- *Voids*
- *Mineral matrix*

Resolution : 1 pxl = 25 µm

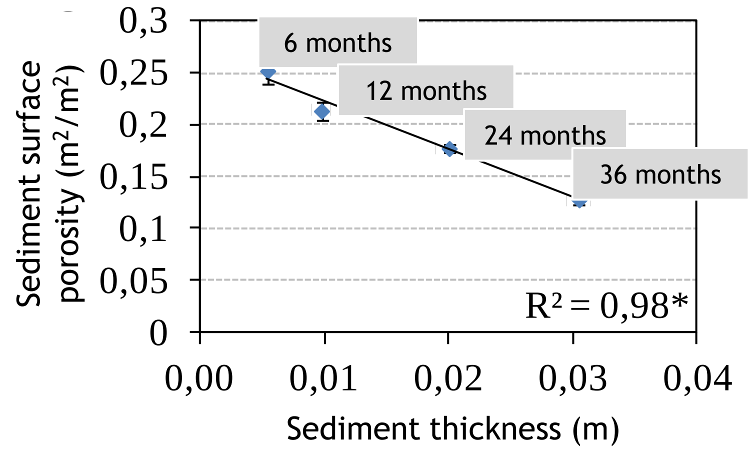
10 mm

4. Stormwater basin for road water runoff

> 4.2 Infiltration performance and clogging process

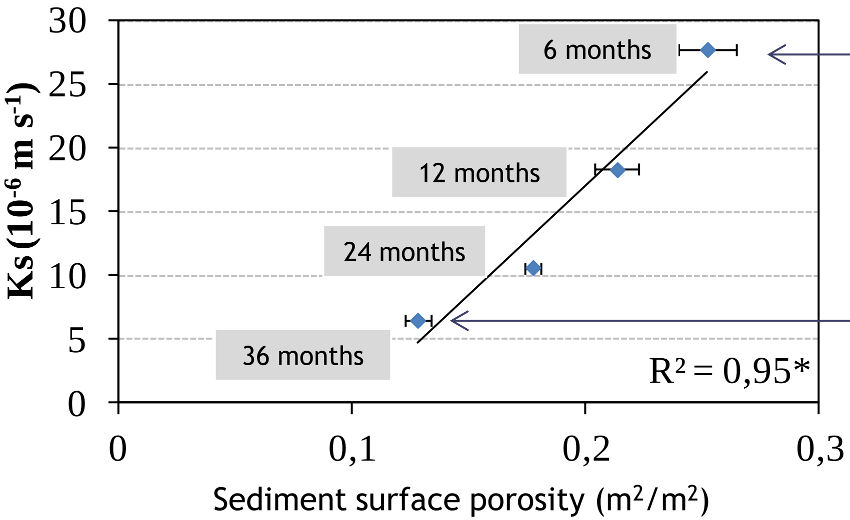
> How does the clogging process take place ? => Study in the Lab

Sediment thickness effect on sediment surface porosity



⇨ **Progressive clogging of the macroporosity**

Sediment surface porosity effect on hydraulic conductivity



28.10^{-6} m s^{-1}

Infiltration capacity divided by 4 during the first 3 years of basin functionning...

7.10^{-6} m s^{-1}

⇨ **Good correlation between hydraulic conductivity and sediment surface porosity**

4. Stormwater basin for road water runoff

> 4.2 Infiltration performance and clogging process

> Stormwater basin maintenance / precautions

(Center for Watershed Protection, 2004)

<u>Vegetation</u>

Trees and brush with extensive woody root systems can destabilize dams, embankments, and side slopes due to the creation of seepage routes

Industrial pollutants can cause alteration in the chemical composition and pH of the discharge water, which, in turn, can affect plant growth even when the source of contamination is intermittent. Nutrients increase plant growth and acidic discharges can decrease vegetation.

Excessive vegetation often provides habitat for rodents and burrowing animals.

Excessive vegetation can affect the flow rates through earthen spillways.

> Stormwater basin maintenance / precautions

(Center for Watershed Protection, 2004)

Sediment dredging and muck removal

Sediment accumulates in stormwater ponds and wetlands by design and eventually requires removal tomaintain efficiency and safety

The maintenance interval for removing accumulated sediment will vary based on the design parameters.

Stormwater ponds and wetlands are frequently presumed to be 80% efficient in trapping total suspended solids.

Sediment dredging almost every 15-20 years
Sediment removed = waste => Incineration

Sediment accumulation in a dry pond

Muck removal and slope dressing by long reach backhoe

4. Stormwater basin for road water runoff

> 4.2 Infiltration performance and clogging process

> Stormwater basin epuration efficiency (Birch et al., 2004)

Weighted average concentrations (WAC) and removal of trace metals (Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn), nutrients (TP, TKN, NOx, TN), total suspended solids (TSS) and faecal coliforms (FC) in stormwater runoff (Events C–I) from inflow and outflow points

Event		WAC (Cd)	WAC (Cr)	WAC (Cu)	WAC (Fe)	WAC (Pb)	WAC (Mn)	WAC (Ni)	WAC (Zn)
C	Inflow	bd	0.0017	0.037	0.15	0.030	0.028	0.0045	0.255
	Outflow	bd	0.0019	0.013	0.47	0.004	0.0192474	0.0060	0.121
	Removal efficiency (%)	–	−11	65	−213	88	32	−33	52
D	Inflow	bd	bd	0.019	0.19	0.030	0.029	0.0017	0.387
	Outflow	bd	bd	0.004	0.34	0.002	0.014	0.0025	0.147
	Removal efficiency (%)	–	–	81	−85	95	52	−45	62
E	Inflow	bd	0.0030	0.013	1.20	0.108	0.027	0.0024	0.194
	Outflow	bd	0.0052	0.007	3.17	0.011	0.073	0.072	0.197
	Removal efficiency (%)	–	−74	49	−165	90	−166	−202	−1
F	Inflow	bd	bd	0.015	0.22	0.21	0.18	0.0015	0.193
	Outflow	bd	0.0011	0.006	0.63	0.002	0.031	0.0047	0.084
	Removal efficiency (%)	–	–	58	−186	91	−78	−213	57
G	Inflow	bd	bd	0.021	0.22	0.029	0.031	0.0026	0.286
	Outflow	bd	bd	0.005	0.16	0.001	0.007	0.0021	0.095
	Removal efficiency (%)	–	–	78	29	98	78	19	67
H	Inflow	bd	0.0012	0.025	0.24	0.029	0.031	0.0029	0.393
	Outflow	bd	0.0017	0.006	0.21	0.001	0.010	0.00362	0.0091
	Removal efficiency (%)	–	−42	76	12	97	69	−9	77
I	Inflow	bd	0.0037	0.025[a]	2.16	0.042	0.072	0.0060	0.142[a]
	Outflow	bd	0.0033	0.023[a]	1.33	0.044[a]	0.044	0.0043	0.159[a]
	Removal efficiency (%)	–	10	8[a]	38	−5[a]	39	27	−12[a]

Event		WAC (TSS)	WAC (P)	WAC (FC)	WAC (TKN)	WAC (NOx)	WAC (TN)
C	Inflow	25	nd	nd	nd	nd	nd
	Outflow	20	nd	nd	nd	nd	nd
	Removal efficiency (%)	20	nd	nd	nd	nd	nd
D	Inflow	16	nd	nd	nd	nd	nd
	Outflow	10	nd	nd	nd	nd	nd
	Removal efficiency (%)	37	nd	nd	nd	nd	nd
E	Inflow	109	0.27	34495	0.54	0.26	0.80
	Outflow	37	0.17	3397	0.29	0.69	0.98
	Removal efficiency (%)	66	37	90	47	−166	−22
F	Inflow	26	0.26	70193	1.68	0.70	2.38
	Outflow	18	0.14	964	0.54	2.29	2.83
	Removal efficiency (%)	34	47	99	68	−229	−19
G	Inflow	17	0.20	54725	1.69	0.76	2.45
	Outflow	2	0.07	922	0.43	1.03	1.47
	Removal efficiency (%)	88	67	98	74	−36	40
H	Inflow	19	0.25	116162	2.16	0.78	2.94
	Outflow	5	0.11	1571	0.64	1.36	1.97
	Removal efficiency (%)	72	55	99	72	−74	33
I	Inflow	80	nd	nd	nd	nd	nd
	Outflow	55	nd	nd	nd	nd	nd
	Removal efficiency (%)	31	nd	nd	nd	nd	nd

Contrasted performances depending on the event and the pollutant…

Conclusion

Urban hydrology vs natural hydrology:

- Water fluxes are different
- Rainwater control is the main concern

Buffering negative hydrological urban effects requires:

- To preserve/increase greening areas
- To take into account the overall soil-plant-atmosfer system
- To control environmental pollution due to human activities

Solutions exist!

Green roofs, greywater reuse, stormwater basins…

…are solutions raising from engineering concepts

Thank you for your attention !