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Effect of collecting surface and pathway on the quality of rain water to be harvested

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Abstract

In the case of rainwater harvesting projects, the path way may contribute to the water quality in function of construction materials used. To evaluate the impact of collecting surfaces and pathways on the water quality of the rainwater harvested, physico-chemical and bacteriological analyses were performed along the pathway the rainwater takes from the roof to the infiltration pit. Five rain events have been followed for two different roofs of the national school for civil engineering in the region of Paris. The results show different contamination pathways for heavy metals and aromatic compounds (measure as SUVA) between the glass roof and a sandwich tile roof. The latter is far more pollutant, giving levels of 24 ppb for total lead, 1264 ppb for total zinc and SUVA of 3.8 L*mg-C⁻¹*m. The analysis of Escherichia showed a slight contamination, increasing from 10² to 10³ cfu *100 ml⁻¹, but no difference between the two surfaces. In the case of the studied building it's recommended to harvest water only from the glass roof and remain so within the norms for unrestricted reuse.

Keywords

Rainwater harvesting, water re-use, water quality, roofing materials, buildings

Introduction

The rainwater harvesting is in France still in its beginning. Despite the lobby of majors of the water distribution, the rainwater harvesting market in France is growing and the last two years important steps were made by new decrees, to regulate rainwater harvesting and water reuse. Though the legal issue might be the main clue for harvesting in public buildings, numerous authors indicate the management of quality as major issue. The quality of harvested water is on one hand dependent on atmospheric pollution and on other hand on the collecting surface. The collecting roof surface might be a simple plate structure or modern sandwich structure with composite materials. Even if the contact time is rather short the roofing material and the collecting system may have an important impact on the quality of water at the collecting end point.

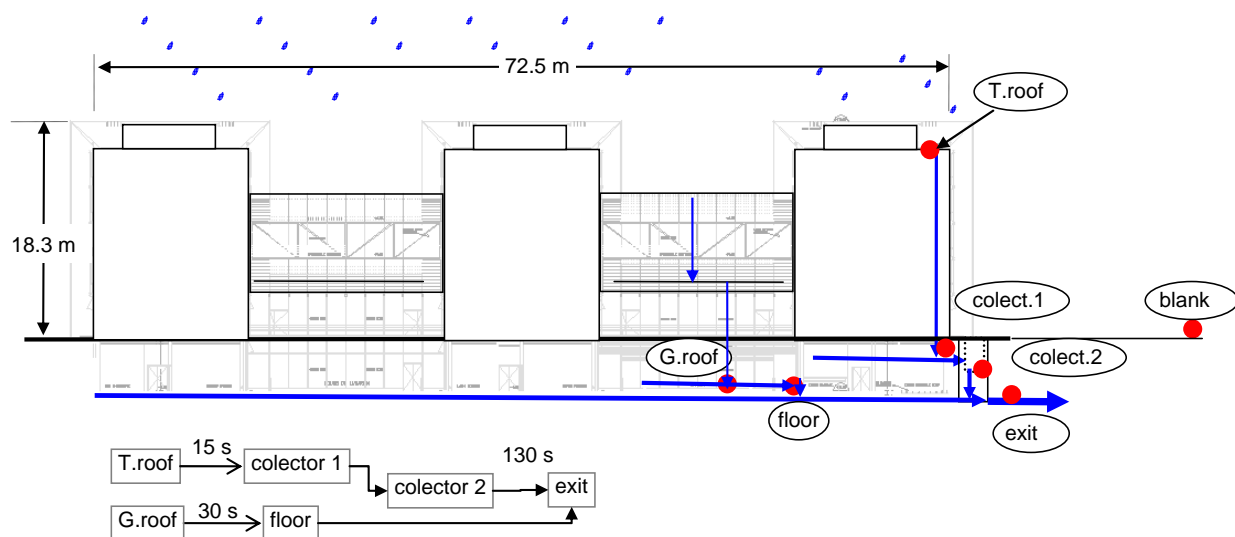
In complex buildings like public buildings, offices or industrial buildings, where rainwater harvesting is to be performed, a good reason might exist to evaluate the collecting surface and disconnect polluting surfaces to preserve a good water quality at the end point. In this

perspective the main objective of our study was to evaluate the contribution of different surfaces and pathways of a complex building to the end pollutant load.

Methodology

We have chosen to study the building of the French national school for civil engineering, constructed about 10 years ago. The building is situated in the metropolitan region of Paris at Champs-sur-Marne, 25 kilometers from the center of Paris. The building is composed of six concrete blocks of four floors, connected by a curved glass entrance hall. The total constructed surface is about 8000 m², whereby the maximum high is 18 meters above the ground level. The building has two main cover types: glass structures of the entrance hall and a sandwich tile structure of the six blocks. The first might be called inorganic: glass, steel and aluminum. The second is more organic, as under the concrete tiles we can find, PVC support system for tiles, isolating foam, coatings, sticking and filling materials.

Figure 1: sampling points of the ENPC building and the hydraulic flow



The average rainfall in Paris is 730 mm/year distributed over the whole year with a minimum in July and a maximum in April. We have chosen to monitor the water quality during five rain events from March to May 2009 at the different outlets as indicated in figure 1.

Most of rainwater harvesting systems discards the first 0.5 mm of the rain, corresponding to the flush of the roof surfaces. As the global objective was the evaluation of pollutant contribution of different collecting surfaces in the case of rainwater harvesting, a manual collection of composed samples was decided. 5 liters acid cleaned PE containers were placed by 3 operators at different outlets few minutes after the beginning of a rain event, the time needed to fill the recipients. The samples correspond globally to a composed sample of each rain event, excluding the first 5 minutes of outflow.

Due to the manually methodology and laboratory availability, only rain events occurring on working days, from 8 AM to 3 PM were considered, with only one weekly sampling campaign. The characteristics of the rain events sampled are resumed in table 1 below:

Table 1: Rain events collected. The events can be described as small morning rains, in most cases collected within one day after the previous rain event.

Rain event	Tue 07/04/09 8:30 AM	Wed 29/04/09 12:51 AM	Thu 14/05/09 9:53 AM	Tue 26/05/09 11:36 AM
Total high	5?	0.8	1.6	0.6
Duration (min)	10?	6	5	34
Mean rain intensity (mm /min)	-	0.133	0.32	0.018
<i>Duration of anterior dry period (h)</i>	<i>240</i>	<i>0.75</i>	<i>6.5</i>	<i>11</i>
<i>High of last rain before sampling</i>	<i>0.6 mm</i>	<i>0.8 mm</i>	<i>8 mm</i>	<i>7.2 mm</i>

As the pathway may contribute to the water quality at the outflow, due to construction materials used, samples were collected along two different pathways the rain water follows from roof to exit. The number of sampling points of each pathway was determined by presence of inspection access. The water issued from tile roof was sampled at three distinct points and the water issued from the glass roof at two points (figure 1). The starting- and endpoints were the same for both. The starting point or blank, was collected at 100 meter behind the building, as wet deposition on 4 m² of an acid cleaned polyethylene film, placed at 50 cm above a grass field. The end point was the main collector exit. The precipitation was automatically registered at 30 seconds interval, by a rain gauge placed at the top of the central building.

The parameters measured were, aside from basic indicators like conductivity, pH and turbidity, also more qualitative parameters like carbon (dissolved, particulate and absorbance at 254 nm), total heavy metal content and pathogens as *Escherichia.coli*. The parameters were measured according to French national norms (AFNOR, 2003) and Standard water methods (APHA, AWWA 2009) according to table 2 below:

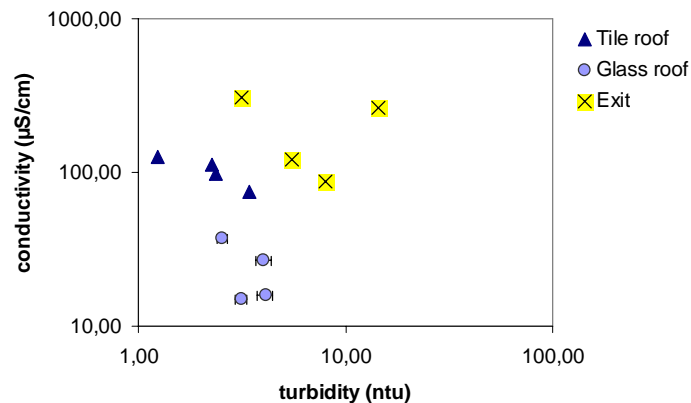
Table 2: Methods applied for the physico-chemical analysis

parameter	norm	apparatus	sample preservation
pH	NF T 90 - 008	WTW Multi Parameter 340i (pH/ORP probe)	<24h
Conductivity	NF EN 27888	WTW Multi Parameter 340i (conductivity probe)	<24h
Turbidity	NF EN ISO 7027	HACH 2100P Turbidity meter	<24h
S.S.	NF EN 872	Whatmann GF/F	<24h, 4°C
BOD5	NF EN 1899-1	YSI 52 Dissolved oxygen meter	<24h, 4°C
COD	NF T 90-101	HACH micro method, PERKIN Elmer UV /VIS spectro Lambda 11	H2SO4
TOC / DOC	NF EN 1484	L Analytical 1010-O Total organic carbon analyzer	GF-F / H3PO4
Indices SUVA	NF T01-035	PERKIN Elmer UV /VIS spectro Lambda 11	<24h
Total Coliformes + E. Coli	NF T 90-413	incubation after pre-concentration on filter (Chromocult ®)	<24h, 4°C
Heavy metals	NF EN ISO 15586	VARIAN ICP-AAS	HNO3 ultra

Result and discussion

The results show a variation of almost all parameters as function of the pathway the rainwater takes. If we take as example turbidity (Figure 2), we can see that the glass roof is generating just slightly more solids than the tile roof. But the tile roof is contributing far more to the total dissolved solid content, as the concrete is being dissolved by the slightly acid rain (pH 6.5).

Figure 2: Basic characterization of the three extreme points samples: Glass roof, Tiles Roof and main exutory



As can be seen in the scheme of figure 1, two main pathways of the rainwater were sampled. Figure 3 below, shows two major factors of concern for rainwater harvesting: pathogens and heavy metals. We note that the blank is not exempt of pathogens and that 10 to 20 fold enrichment with pathogens take place toward the exutory along both pathways. There is no difference between the two surfaces; both of them contribute to the end contamination. We can see an initial enrichment to a level of 10^3 /100 ml. The pathogens contamination is most probably due to the presence of birds on the roofs during the sampling campaign.

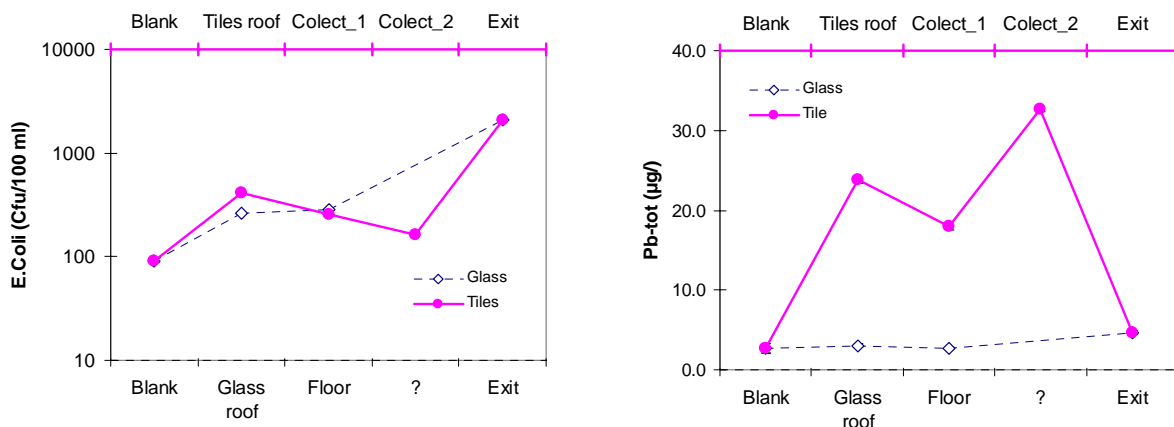


Figure 3: Evolution of Escherichia Coli (left) and total lead (right) from the roof to main exit.

The effect of the pathway on the heavy metal content depends on the type of metal. The example of lead gives enrichment for the tile roof, probably due to presence of lead enclosures and lead containing coatings on the roof. For zinc (table 3) the impact is a bit different : mean level of contamination at the issue of the glass roof ($543 \pm 153 \mu\text{g/l}$) and a high level of contamination at the issue of the tile roof ($1264 \pm 579 \mu\text{g/l}$) followed by other

contamination in the pathway and ending with an in between level of $666 \pm 100 \mu\text{g/l}$). The contamination can be explained by zinked iron barriers on the tile roof and the presence of some zinked iron tubes in its further pathway.

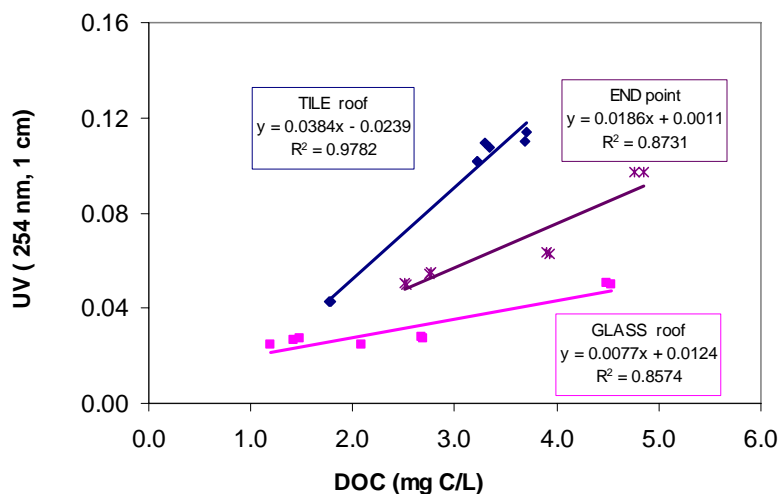


Figure 4: Relation between dissolved organic carbon and UV absorbance at 254 nm, for the runoff of the glass roof (SUVA = $0.77 \text{ L} \cdot \text{mg}^{-1} \cdot \text{C}^{-1} \cdot \text{m}$) and the tile roof (SUVA = $3.8 \text{ L} \cdot \text{mg}^{-1} \cdot \text{C}^{-1} \cdot \text{m}$)

Another interesting difference between the two surfaces is the specific UV absorbance (SUVA) calculated as quotient of ultraviolet light absorbance (254 nm) and DOC content. In figure 4, the relation between UVA and DOC is given for the three extremes. We can remark that the tile roof, or rather the organic constituents of it, contributes to the aromaticity of the run-off, an impact not revealed for the glass roof. The characteristics at the end point are therefore a mean of both characteristics.

Conclusions

The values found in our study correspond to levels found in other semi-urban regions (Zobrist et al. 2000; Villarreal et al 2003). The results show a significant enrichment with dissolved solids along the pathway, the rainwater is taking from roof to exutory. This is however less true for particulate matter being almost constant after a first contact with the collecting surface. We can see enrichment with some heavy metals like lead or zinc due to their application in the construction. In the case of lead and the tile roof they exceed the European norms of crude water for drinking water preparation. The tile roof showed also more important contamination by polycyclic organic compounds measured as SUVA. More specific analysis is needed to determine the exact type of these compounds. Though the roofs or collecting surfaces were not accessible to public, they were contaminated by pathogens. All surfaces studied showed a level of 10^2 to 10^3 E.Coli /100 ml.

From above results we can conclude that for rain water harvesting purposes, it is preferable to use glass surfaces, and avoid composite surfaces with heavy metals components, but also those containing isolating plastic compounds.

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Table 3: Arithmetic mean values for the rain events sampled. For SUVA the mean obtained by regression (figure 4 should be preferred)

		Blank	Tiles roof	Colect_1	Colect_2	Glass roof	Floor	Exit
S.S	mean (mg/l)	3,75	2,28	2,21	2,81	4,54	6,69	8,27
	std.	0,71	0,28	0,77	1,53	1,33	2,68	4,81
Cond.	mean (µg/l)	20,50	102,75	87,00	38,25	23,75	27,00	194,75
	std.	4,95	21,55	33,94	18,87	10,37	10,46	107,43
pH	mean (-)	6,62	6,57	6,75	6,55	6,61	6,42	7,07
	std.	0,47	0,21	0,31	0,19	0,32	0,28	0,39
POC	mean (mg/l)	0,78	0,92	0,43	0,83	0,74	1,44	1,49
	std.	0,33	0,66	0,05	0,61	0,35	0,52	0,69
POC / S.S.	mean (%)	21%	25,9%	20,3%	27,0%	18,5%	21,8%	19,0%
	std.		8%	5%	7%	10%	2%	2%
TOC	mean (mg/l)	3,28	3,93	3,13	3,57	3,53	4,38	4,99
	std.	0,17	1,32	0,68	0,80	0,92	0,79	1,48
SUVA	mean (-)	1,14	2,96	2,85	1,39	1,20	1,18	1,90
	std.	0,56	0,39	0,43	0,23	0,18	0,13	0,19
E.coli	mean (cfu/100 ml)	90	411	256	162	265	284	2107
	std.	10	779	282	175	426	499	2544
Pb (tot)	mean (µg/l)	2,7	23,8	18,0	32,7	3,1	2,7	4,7
	std.	--	7,8	--	29,8	2,0	1,7	1,1
Zn (tot)	mean (µg/l)	37	1264	850	1237	543	1479	666
	std.	--	579	--	822	153	1535	100