

PHYSICOCHEMICAL QUALITY OF WASTEWATER PURIFIED BY INFILTRATION-PERCOLATION: CASE OF THE PLANT OF BEN SERGAO (SOUTH-WESTERN MOROCCO) AFTER TEN YEARS OF RUNNING

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ABSTRACT

Samples of raw, decanted, and purified waters were taken off during five months (in 2004-2005) from a wastewater treatment plant using infiltration-percolation and eleven physicochemical parameters were analyzed to determine the performances of this purification system under an arid climate. Compared to raw and decanted waters, the values of chemical and biochemical oxygen demands, NH_4^+ , total phosphorus and PO_4^{2-} in the purified water were significantly decreased. In contrast, the contents of nitrites and nitrates in the purified water were 56 and 177 times greater (a mean of 0.11 g/L for N-NO_2 and 5.5 g/L for N-NO_3). Using a principal component analysis, chemical and biochemical oxygen demands, NH_4^+ , total phosphorus and PO_4^{2-} were correlated with the raw water, while the purified water was correlated with nitrites, nitrates and electric conductivity. The huge increase of nitrites and nitrates noted in the purified water would be due to a malfunction of the system, probably in reason of an organic material overload which accumulated in sand filters during water alimentation of basins. Owing the nitrite and nitrate concentrations in the purified water, its reuse in agriculture poses a real problem for soil and vegetation so that an additional treatment is necessary for

eliminating these both salts from the purified water.

Keywords: infiltration-percolation; physicochemical parameters; purification; wastewater

INTRODUCTION

The city of Agadir (south-western Morocco) knows a very important and diversified economic activity focused on agriculture, food industry, fishing and tourism. The development of these different activities requires huge quantities of waters which consequently, generates important volumes of wastewater. These last are often poured out into water courses without any prior treatment causing pollution of aquatic environment, particularly sea water (El Hatimi *et al.*, 2002; Mimouni, 2004). Moreover, the region of Agadir suffers from a very accentuated water deficit from several years and one possibility for short-circuiting this problem is the reuse of purified wastewater. Indeed, since 1980, awareness of the Wilaya (province) of Agadir, for the importance of water in the region, led to the purification of its wastewater by constructing several treatment plants since 1989. Thus 50,000 m³/day are purified by the infiltration-percolation technique and are available to be reused, in agriculture, in the form of non-conventional water (Brissaud *et al.*, 1999).

As high loads of chemical and biological pollutants were found in wastewater (Howard *et al.*, 2004), the reuse of these untreated waters constituted a real danger for human health and environment (Howard *et al.*, 2004; El Asslouj *et al.*, 2007; Yu *et al.*, 2008). As for several countries in the world, the reuse of this wastewater after their treatment is conditioned by guidelines and recommendations for the sanitary quality of treated wastewater (World Health Organization, 1989).

Several studies on the microbiological quality of purified wastewater coming from the treatment plant of Ben Sergao (south of Agadir) were reported by our laboratory (Ben Zine, 1990; Anajjar, 1997; Touyer, 1997; Ben Yakhlef, 1998; El Hachemi, 1999;

Mimouni, 2004; Mimouni *et al.*, 2005, Mimouni *et al.*, 2009). However, no study is still performed by our team on the physicochemical parameters of wastewater treated by the Ben Sergao plant. In view of this situation, water samples were collected from three sites from November 2004 to April 2005 and eleven physicochemical parameters were analyzed to answer the following two questions: What is the physicochemical quality of water purified by this plant? can this purified water be directly reused in agriculture without any restriction?

MATERIALS AND METHODS

1. Studied site

The principle of infiltration-percolation applied at the Ben Sergao plant is based on the purifying power of the soil for eliminating pollutants. The plant is sized to treat 750 m³/day of wastewater and is located at 6 km south of the city of Agadir. From the upstream to the downstream zones, it comprises *i*) a metal grate placed at the entry to retain greater than 2.5 cm solid wastes, *ii*) a settling pond of 1,500 m³ which allowed a pre-treatment of wastewaters by anaerobic digestion during 24 hours, *iii*) a pond of 330 m³ allowing to prepare three water volumes of 250 m³ each to evacuate them in the single time and alternately in the five following ponds, and *iv*) five infiltration-percolation ponds of 1,500 m³ each disposed in parallel. These last ponds are surrounded by 0.5-m high dikes constituted by sand fixed by plantations of *Carpobrotus* sp. (Fig. 1).

2. Water sampling

Monthly samples concerning the three types of wastewater (raw, decanted, and purified waters) were collected in the morning (at 9 a.m.) from October 5, 2004 up to April 18, 2005 (excepted in December 2004 and January 2005). Samples of raw water were taken at the entrance of the station (at the level of the channel which drives raw

water towards the decantation basin). Collection of decanted water was performed at the exit of the decantation basin, while samples of purified water were taken at the level of the spillway located in the downstream part of the treatment plant. For DOB_5 wastewater samples were collected in polyethylene bottles without air bell, for the microbiological analysis and the other physical chemical analysis wastewater samples were collected in the glasses bottles. All samples were transported to the laboratory using a cool box (4° - 6° C).

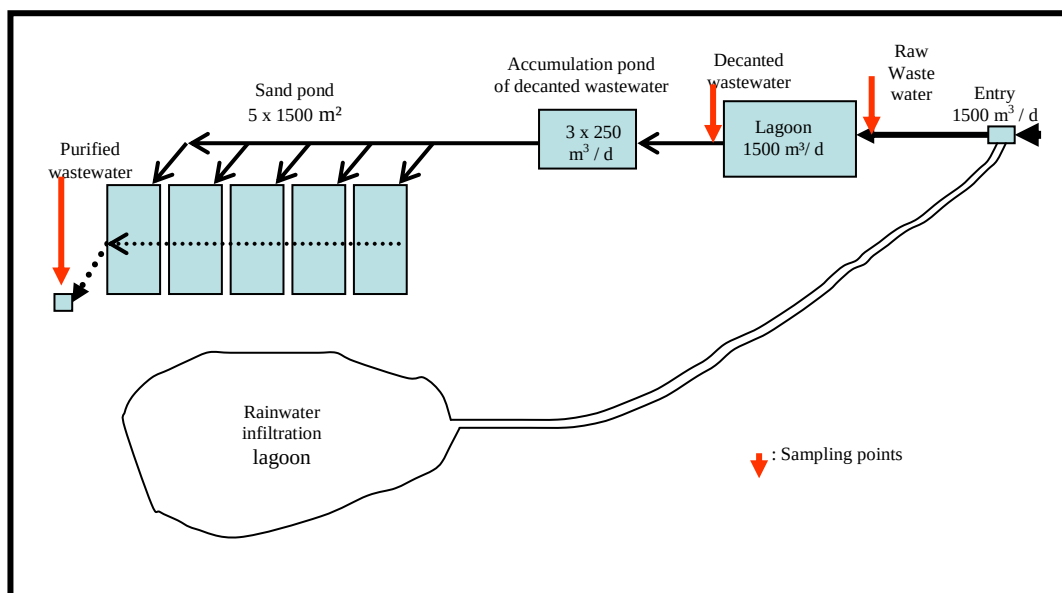


Figure 1: Principle of running of the wastewater treatment plant of Ben Sergao

3. Methods of analysis

Water pH and electric conductivity were directly determined in the treatment plant using a WTW525 pH meter/conductimeter. The values of the other parameters were measured in the laboratory in compliance with the following AFNOR norms of 1985: chemical oxygen demand (T90-101), biochemical oxygen demand (T90-103), suspended matters (T90-105), total phosphorus (T90-023), orthophosphates (T90-023), nitrates (T90-012), nitrites (T90-013), ammonia nitrogen (T90-015) and chlorides (T90-

014).

4. Statistics

Individual values noted for each parameter were subjected to one-way analysis of variance. When a significant difference was found, its abatement rate between raw and purified waters or its magnification was calculated. A principal component analysis was also performed to show similarities and differences between the three types of waters. This test was also used to search possible correlations between the different physicochemical parameters analyzed. The treatment of this analysis was made using the Statistica V6.0 software.

RESULTS

1. Physicochemical parameters.

In the raw, decanted and purified waters, the pH ranged from 7.12 to 7.62, from 7.28 to 7.60, and from 7.55 to 7.90, respectively (data not shown). No significant difference between these pH values was noted, whatever the mode of comparison.

In spite of high values (from 1,680 to 3,190 $\mu\text{S}/\text{cm}$) noted for electric conductivity (Fig. 2a), the differences between the three types of waters were insignificant. The suspended matters (Fig. 2b) also did not significantly differ from each other. The chemical oxygen demands (Fig. 1c) and biochemical oxygen demands (Fig. 2d) were clearly lower (COD: $F=5.29$, $P<0.05$; BOD: $F=6.44$, $P<0.05$) in the purified water than in the decanted water, while no significant difference between the decanted and raw waters was noted. In contrast, the concentrations of nitrates (Fig. 2e) and nitrites (Fig. 2f) in the purified water were significantly higher (NO_3 : $F=15.72$, $P<0.01$; NO_2 : $F=7.32$, $P<0.05$) than those found in the other two types of water.

Figure 3 shows the monthly variations of the last four parameters. The concentrations of ammonia nitrogen (Fig. 3a), total phosphorus (Fig. 3b) and

orthophosphates (Fig. 3c) were significantly lower (NH_4^+ : $F=7.36$, $P<0.05$; P : $F=8.56$, $P<0.05$; PO_4^{2-} : $F=20.16$, $P<0.01$) in the purified water than in the decanted water while

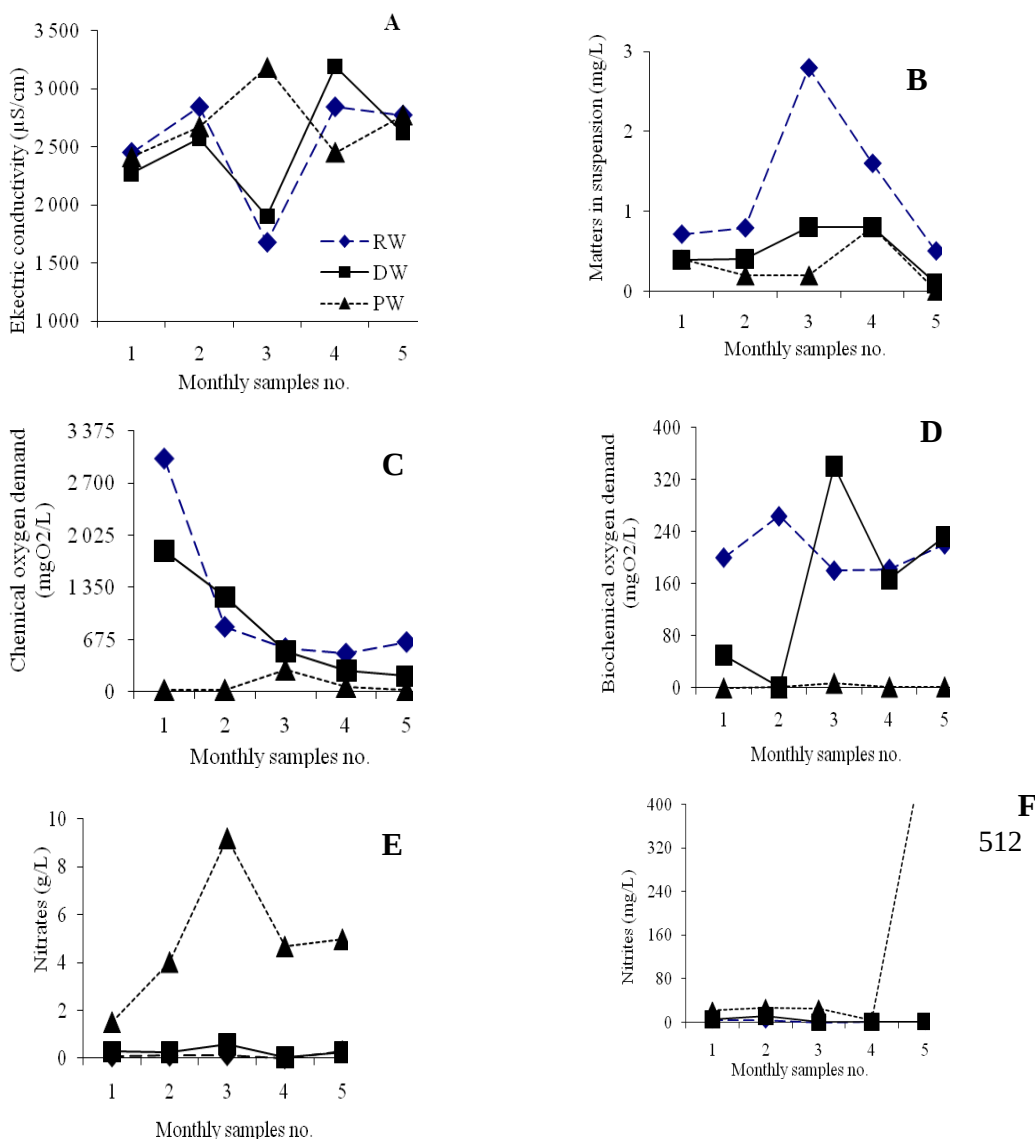


Figure 1. Mean monthly values of electric conductivity (1a), matters in suspension (1b), chemical oxygen demand (1c), biochemical oxygen demand (1d), nitrates (1e) and nitrites (1f) in the raw (RW), decanted (DW) and purified (PW) waters. The S.D.s are not given in these graphs.

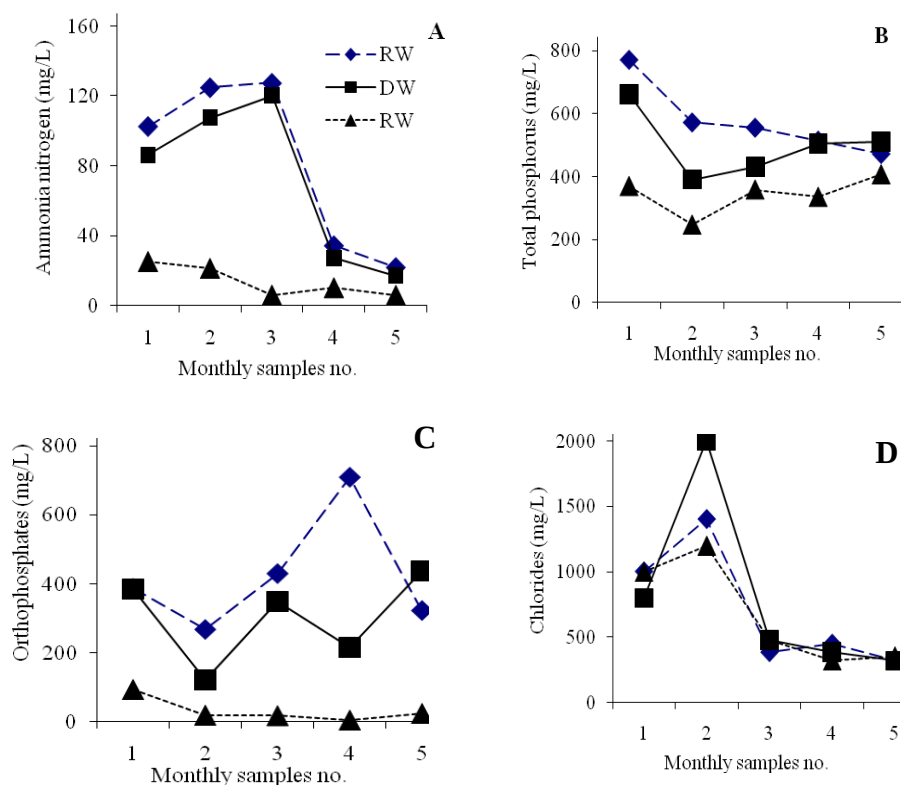


Figure 3. Mean monthly values of ammonia nitrogen (2a), total phosphorus (2b), orthophosphates (2c) and chlorides (2d) in the raw (RW), decanted (DW) and purified (PW) waters. The standard deviations (S.D.s) are not given in these graphs.

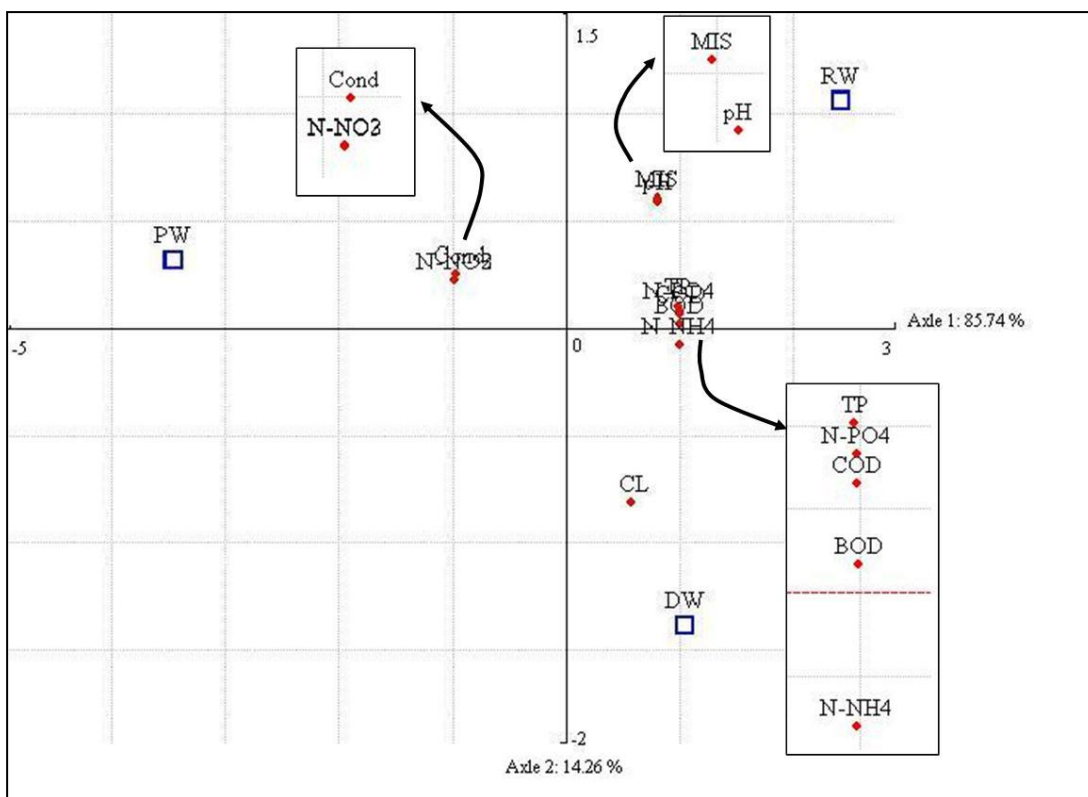


Figure 4. Principal component analysis concerning the three types of water from the Ben Sergao plant. The different points are projected onto the plan of factorial axes 1 a

the differences between the raw and decanted waters were insignificant. Lastly, the concentrations of chlorides (Fig. 3d) found in the three types of waters did not significantly differ from each other.

The mean values of these parameters and their standard deviations (S.D.s) are given in Table 1. In the case of chemical oxygen demand, the abatement rate between the raw and the purified waters was 92.8%, whereas it was 99.9% for biochemical oxygen demand. Similar findings were also noted for ammonia nitrogen (with an abatement rate of 83.5%), total phosphorus (41%) and orthophosphates (92.6%). In contrast, the contents of nitrites and nitrates in purified waters were 56 and 177 times greater in the purified water.

Table 1. Mean values (S.D.) for several physicochemical parameters concerning waters treated in the plant of Ben Sergao.

Parameters	Type of water		
	Raw water	Decanted water	Purified water
pH (USI)	7.6 (0.20)	7.4 (0.13)	7.3 (0.22)
Conductivity ($\mu\text{S}/\text{cm}$)	2,516 (494.3)	2,510 (476.3)	2,696 (309.3)
MIS (mg/L)	1.2 (0.9)	0.5 (0.3)	0.3 (0.3)
COD (mgO_2/L)	1110.5 (1078.1)	808.0 (698.2)	80.0 (113.1)
BOD (mgO_2/L)	209.5 (34.5)	158.0 (137.1)	2.2 (2.8)
N- NO_3 (mg/L)	31.2 (33.1)	37.0 (16.3)	5546.0 (3106.4)
N- NO_2 (mg/L)	2.1 (2.2)	2.4 (2.5)	118.1 (220.5)
N- NH_4^+ (mg/L)	82.1 (50.5)	71.6 (46.9)	13.6 (8.9)
TP (mg/L)	576.2 (115.0)	500.0 (103.5)	343.1 (59.8)
P- PO_4^{2-} (mg/L)	422.5 (171.8)	301.4 (129.7)	31.2 (35.0)
Chlorides (mg/L)	710.4 (470.9)	796.8 (697.4)	670.4 (402.9)

Number of samples for each type of water: 5.

2. Principal component analysis

All physicochemical parameters (Fig. 4) are located in a system of axles in which of which the first two, A_1 and A_2 , represent 100% of complete inertia. The axle A_1 (predominant factorial axle) represents 85.74% of total variance. In its positive part, it is characterized by BOD, COD, total phosphorus, PO_4^{2-} and NH_4^+ , thus corresponding to raw wastewater. In its negative part, it is characterized by nitrite and nitrate contents as well as by values of electric conductivity, as they are correlated with the purified water. In the negative part of the axle A_2 (14.26% of total variance), the concentrations of chlorides are correlated with the decanted water.

DISCUSSION

The values obtained for most physicochemical parameters in the present study agreed with the data reported by other authors for the technique of wastewater treatment using infiltration-percolation. As shown in Table 1, the slight decrease of water pH from the upstream towards the downstream part of the plant may be explained by the buffer power of this treatment. Even if the pH values were comparable to those which characterized superficial waters (Moroccan Ministerial Decree, 2002), the comparison of electric conductivity in the purified water with the limit values given in the Moroccan norm for the quality of superficial waters (Moroccan Ministerial Decree, 2002) demonstrated that the purified water coming from the Ben Sergao plant must be placed in the category 4, i.e. those of bad quality. The values of BOD and COD agreed in the three types of waters agreed with the results reported by Auset *et al.* (2002) and Mouhir *et al.* (2007) for other wastewater treatments plants using infiltration-percolation. The significant decrease of the total phosphorus and orthophosphates in the purified water demonstrated the purifying power of the infiltration-percolation technique. However, this diminution was insufficient for both phosphorous parameters because it would be necessary to attain values located in an interval from 0.6 to 1 mg/L to have water with

the same content of phosphates as that existing in Moroccan watercourses. In spite of the concentration of chlorides in the purified water of Ben Sergao that received exclusively urban wastewater was not significantly decreased and this finding might be explained by the some seasonal informal activities consuming high concentrations of salt, i.e: pickling process of olives, tanneries, etc. (Piperidou *et al.* 2000; Panizza *et al.* 2004, Lefebvre *et al.* 2006).

The most interesting results concerned nitrites and nitrates whose concentrations were strongly increased in the purified water, whereas that of NH_4^+ was significantly decreased. As nitrites and nitrates are two oxidized forms of nitrogen, the intermediate values of nitrites noted in the present study may be explained by the place of these salts in the nitrogen cycle between ammonia and nitrates. However, the huge increase of nitrites and nitrates in the purified water requires other explanations because these highest concentrations were disproportional (more than 177 times for nitrates and only 56 times for nitrites). The more valid hypothesis is to relate these findings to a malfunction of this treatment system, probably in reason of an organic material overload which accumulated in sand filters during water alimentation of basins. An argument supporting its approach was the report by Wanko *et al.* (2005). According to these authors, in a wastewater treatment system using infiltration-percolation, an accumulation of organic matters occurred during water alimentation in sand basins and caused the development of the biomass. Under normal conditions, this biomass dropped during the absence of water in basins, thus ensuring their good functioning. However, another assumption based on an exogenous addition of nitrogen from trees and herbaceous vegetation bordering these basins cannot be excluded. Plantations of reeds, willow trees and bamboos around the basins of purified water have already been recommended by several authors (Al-Omari and Fayyad, 2003; Mouhir *et al.*, 2007) in treatment plants because these species were capable to absorb important quantities of nitrates and phosphorus via their roots. If this last above-mentioned hypothesis is

considered valid, a carefully designed management of the planted vegetation around basins must be set up in order to cut and remove the reeds and branches of trees at appropriate time periods.

At the present time, the purification technique of wastewater by infiltration-percolation at Ben Sergao allows to clearly ameliorate the physicochemical quality of the purified water. Nevertheless, the reuse of this last water in agriculture would pose a real problem for soil and vegetation owing to its high concentrations of nitrates, total phosphorus and chlorides. A denitrification of the purified water and a decrease in their phosphorus and chloride contents is necessary before any reuse.

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