Evolution of radioactivity removal at a Besòs Aquifer Drinking Water Treatment Plant

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***Abstract*—Radioactivity removal at a Drinking Water Treatment Plant (DWTP) is analyzed in the present study. The plant treats groundwater from the Besòs Aquifer (BA) using nanofiltration membranes and reverse osmosis. Inflow and treated waters were sampled to determine Gross Beta, Residual Beta and Gross Alpha activities. Gross Beta results were between 0.30-0.48 Bq/L for inflow waters and 0.02-0.23 Bq/L in treated waters. Residual Beta values were substantially lower because ^{40}K represents the main activity source and only 5 from 26 samples were above the Minimum Detectable Activity (MDA). Gross Alpha analysis provided activities above MDA only in 47% of the samples. The mean values of Gross Alpha results in inflow waters and treated waters were 0.05 and 0.01 Bq/L, respectively. The median removal efficiencies were 87% for beta emitters and 88% for alpha emitters.**

I. Introduction

Water treatment is an industrial process to potabilize raw waters for human consumption. Water can contain detectable radioactive elements, with more or less activity depending on its nature. Spanish regulations (R.D. 140/2003)[1] have established parametrical values for radioactivity in drinking water. Gross Alpha activity is recommended to be lower than 0.1 Bq/L and Residual Beta activity (without considering ^{40}K and ^{3}H activities) lower than 1 Bq/L. The maximum allowed indicative dose is 0.1 mSv/y (without considering ^{40}K, the ^{222}Rn decay chain or ^{3}H). In water treatment processes the technologies applied have different radioactivity removal efficiency as has been shown in previous works on this topic [2] [3] [4]. In the present study the temporal evolution of the specific case of a DWTP located on the Besòs Aquifer (BA) is shown. The studied plant (365 l/s of capacity) is a complementary source for the Barcelona's water supply and present very good properties from the organoleptic point of view due to the membranes treatment [5]. The aim of the present work is to assess the annual evolution of radioactivity concentration in the inflow and treated waters and also the removal efficiency of the DWTP.

II. Materials and Methods

A. Water sources and plant description

The Besòs DWTP is located close to the Besòs River and on the BA, the groundwater reservoir that supplies the plant. Water infiltration from the Besòs River is the main recharging source for the aquifer, although other minor contributions have been suggested [6] [7] [8]. The plant has four treatment lines, one uses nanofiltration, while the other three use reverse osmosis [9].

B. Analytical procedure

Representative samples were collected following the water company's internal protocols to ensure adequate sampling, preservation and storage. The samples were acidified with concentrated HNO_3 (1 mL per liter). Semiannual measurements for alpha and beta activities were carried out during the period 2001-2013.

Gross alpha and beta activities in waters were determined using the methodology detailed in [2]. The water sample was filtered, concentrated by evaporation and deposited on a 20-cm^2 stainless steel planchet. The Gross Beta activity was measured two days after preparation with a low-level proportional counter (Berthold, model LB770-2), calibrated with a ^{90}Sr/^{90}Y source. The Residual Beta activity was quantified by subtracting ^{40}K activity from Gross Beta activity and the potassium content was analyzed by flame photometry. Subsequently, Gross Alpha activity was determined using a ZnS scintillation counter (Canberra, model 2007P) and calibrated with a ^{241}Am source. Conductivity at 20 ºC was determined electrometrically by a robotic titrosampler (Metröhm modules 855 and 856). All these procedures have been accredited by the Spanish Nacional Accreditation Authority (ENAC).

III. Results and Discussion

A. Gross and Residual Beta

Results obtained for Gross Beta activities are presented in Fig. 1 and are shown as an annual mean of the semiannual samplings. In the case of Gross Beta activities there is significant removal of beta emitters. The median removal efficiency for Gross Beta was 87% with a standard deviation of 12%. This significant reduction is related to potassium elimination during the treatment process because most of the gross beta activity is due to ^{40}K. Residual Beta values obtained for inflow waters were always below the MDA (0.027-0.059). In treated waters, Residual Beta results were above the MDA in 5 of the 13 years studied with values between 0.004±0.001-0.010± 0.002 Bq/L.

*Research supported by AGBAR

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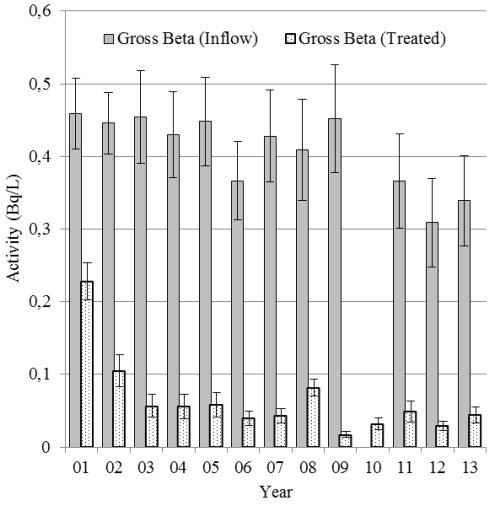

Figure 1. Annual evolution of Gross Beta actvity in inflow and treated waters.

Fig.1 shows that Gross Beta activities have a decreasing trend over recent years related to potassium concentration, as shown in Fig.2. The BA was practically recovered from the marine intrusion in 2004 caused by over-exploitation until the 80's [10]. However, it can be seen that BA is still recovering. The observed potassium decrease between 2001 (15.7±0.3) and 2013 (10.2±0.2) has a similar trend as the conductivity decrease between 2002 (1912) and 2012 (1136) (Fig.2).

B. Gross Alpha

Gross Alpha results are summarized in Table 1. Comparing the mean value of inflow waters with the value for treated waters, removal of alpha emitters is also significant. The reduction calculated for Gross Alpha activities shows a median value of 88% with a standard deviation of 24%. Results for treated waters are always significantly below established parametric values due to the combination of the high removal rate by the treatment process and the initial low alpha emitter concentrations in inflow waters.

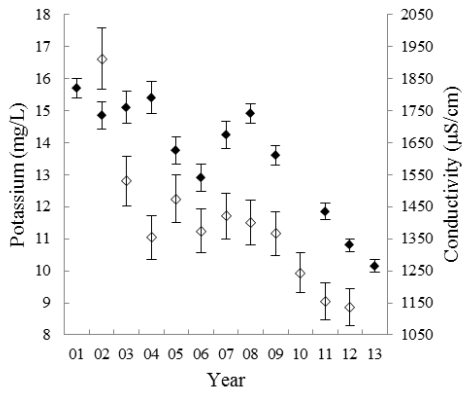

Figure 2. Annual evolution of the potassium concentration (black) and conductivity (white) in the inflow waters.

TABLE I. STATISTICAL ANALYSIS OF THE GROSS ALPHA RESULTS (BQ/L)

	Besòs Aquifer inflow waters	***Treated waters***
x□	0.049 (n=12)	0.009 (n=9)
σ	0.015	0.010
n	21	24
Maximum	0.083±0.041	0.032±0.011
Minimum	0.033±0.017	0.003±0.002

Results in treated waters agree with results for Gross Beta and Gross Alpha activities seen in the Sant Joan Despí DWTP that uses ultrafiltration and reverse osmosis lines and treats mainly surface water from the Llobregat River, unlike the studied plant that is supplied with groundwater [2]. If we consider legislation specifications, the higher concentrations obtained in the studied period are thirty-three times below the parametrical values for Residual Beta and three times lower for Gross Alpha.

IV. CONCLUSIONS

The distributed water by the studied DWTP is well below the parametrical values (R.D. 140/2003).

There is an important radioactivity reduction in the treatment process related to ^{40}K removal for beta emitters.

There is a progressive decrease in potassium and conductivity in the BA in the studied period due to the gradual improvement of the Besòs River and recovery from the marine intrusion.

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