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Quality of the Diluted Landfill Leachate in Water Supply Used in the Performance of Drippers

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The landfill percolate (LP) has appreciable amounts of nutrients that can be used in the production of biomass for energy purposes and serves as parameters to study the performance of irrigation systems. The objective of this work is to analyze the drip performance indicators applying diluted landfill percolate, well as the main obstruction factors and the percolate quality. The experiment was assembled up in split-plot scheme with kind drippers (G1 - non-pressure compensated; G2 - pressure compensated; G3 - pressure compensated; and G4 - pressure compensated) in the plot and operating times (0, 20, 40, 60, 80, 100, 120, 140 and 160 h) in subplots, with four replications. The flow rates tested in the main and secondary plots in this work were: main plots - types of drippers (G1 - 1,6 L h^{-1}; G2 - 2,0 L h^{-1}, G3 - 4,0 L h^{-1} e G4 - 8,0 L h^{-1}) and in the subplots the

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operating times (0, 20, 40, 60, 80, 100, 120, 140 e 160 h), with four replications. The suspended solid and dissolved solids attributes present a severe risk of dripper obstruction for the diluted landfill percolate.

Keywords: Clogging; percolate; emitters; obstruction.

1. INTRODUCTION

The Brazilian semiarid region is facing acute shortage of water due to prevailing socio economic conditions, lack of drinking water and sanitary services. The use of waste water is a better alternative for improving quality of rural and urban population by harvesting the nutrients from it [1,2].

In Brazil, from the rapid urban growth of cities, the need to properly take care of the management and management of urban solid waste requires the implementation of efficient technologies for the treatment and, or disposal of urban solid waste, due to the serious problems caused to the environment. The specialized literature mentions cites as incineration methods for the treatment of solid urban waste, pyrolysis and the composting, and as a final disposal method, the landfill [3].

The destination of solid waste in landfill, although, it is the appropriate most form from the environmental and social final disposal of the solid urban waste, this method generates some other major negative environmental impacts on the environment, where the main aggravating factor is the high production of the percolate produced in the landfill cells and the need for another type of treatment technology, only for this liquid waste [4].

An alternative method for disposal of landfill percolate is to use it as a source of nutrients and water for the soil under controlled conditions, applying it in the form of irrigation for biomass-producing crops, using together, agronomically, adequate management to solve the quality problems of the soil-plant system [5,6].

The landfill percolate, when treated and disposed of in a planned and controlled manner, can be used in several other activities, such as being raw material for civil construction, manufacture of recycled products and in the controlled fertigation of grasses and forest crops. The percolate has variable temporal and spatial composition and depends on the physical characteristics of the waste disposal site. The percolate is generated during the entire life cycle of the landfill for long periods, and must be monitored and sent for treatment for a long period after the landfill closes. In which, the minimum period required for effective management of environmental liabilities is 30 years [7].

Clogging emitters reduces flow and, consequently, decreases the uniformity of application of fresh water or effluents from localized irrigation systems [8]. Second [9], the number and location of partially clogged drippers were the factors that most affected the uniformity of water application in drip irrigation systems. These authors obtained Christiansen's uniformity coefficient values of 96, 95, 87, 82 and 69% for application units equipped with drippers with partial clogging of 0, 5, 10, 20 and 30%, respectively. According Capra et al. [10] studied the hydraulic performance of drip irrigation systems equipped with four types of drippers, non-self-compensating, with nominal flow of 3.8 a 4.0 L h^{-1} and supplied with treated domestic sewage for 60 h. These authors showed that the values of the uniformity distribution coefficient in the irrigation systems ranged from 0 to 77%.

The combination of physical, chemical and biological agents is the main cause of obstruction of drippers used in the application of wastewater [11]. In the work presented by Taylor et al. [11], checked that 90% of the drippers had clogged with biofilm, formed by decomposing organic matter, bacteria and exoskeleton of *Daphnia sp*, due to the application of treated domestic sewage. Second [12] found the formation of biofilm, resulting from bacterial mucilages and suspended solids, in drippers supplied with secondary domestic sewage. [13], stated that the biofilm was accumulated mainly at the entrance to the labyrinth of non-self-compensating drippers and in the silicone membrane of self-compensating drippers.

Given the exposed, the objective was to analyze the performance indicators of drippers applying diluted landfill percolate (DLP), well as the main obstruction factors and the percolate quality, in the county of Mossoro-RN.

2. MATERIALS AND METHODS

This work was carried in from August/21 to October/10 from 2017, at the Experimental Unit for Water Reuse (UERA), of the Federal Rural University of the Semi - Arid (UFERSA), in county Mossoro-RN, Brazil.

The climate of the region, according to the Köppen-Geiger classification, is BSwh 'type (hot and dry), with very irregular rainfall, with an annual average of 673.9 mm; average temperature of 27.4°C; average relative humidity of 68.9%; average daily sunshine of 7.83 hours and annual of 2771.27 hours of sunlight during a historical period of 30 years; and average wind speed of 0.84 m s-1 [14].

The supply water used in this work came of the Water and Sewage Company from Rio Grande of Norte (CAERN), and, before carrying out the studies, stored in a 10 m^3 waterproofed reservoir, it was stored in a 10 m^3 impermeable reservoir, shaded by cashew trees, to prevent water heating.

The experiment was carried out in a split plot scheme, using dripper models as main parcels (G1, G2, G3 and G4) and, in the subplots or main secondaries, the evaluation periods (0, 20, 40, 60, 80, 100, 120, 140 and 160 hours), with four repetitions (each lateral line represented one repetition), according to the methodology proposed by [15].

For the conduction of the experimental tests, was built of masonry platform, in the dimensions of 2.0 m above 8.0 m, having a slope of 1% and a side channel with a slope of 2% for the effluent recirculation (Fig. 1).

Based on this Figure, for carrying out the experimental tests, a bench consisting of a 0.5 m3 reservoir for storing the landfill percolate, a 10 m^3 reservoir for storing water from the supply network, a 5.0 m^3 reservoir for storing the mixture of PL and AA and a platform built in masonry and concrete, with dimensions of 2.0 m wide by 8.0 m long, having a side channel for waterproofing the effluent recirculated.

In the derivation line were installed 16 connectors with sealing rubber, where four lateral lines were inserted by type of dripper (each lateral line represented a repetition). In each side line, nine drippers were marked to assess the hydraulic performance, totaling 144 drippers evaluated in the four drip units, every 20 h until the 160 h operation time was completed. The lateral lines, 8 m long, were installed level over the platform floor. Table 1, shows the main technical information of the drippers used in the experimental tests.

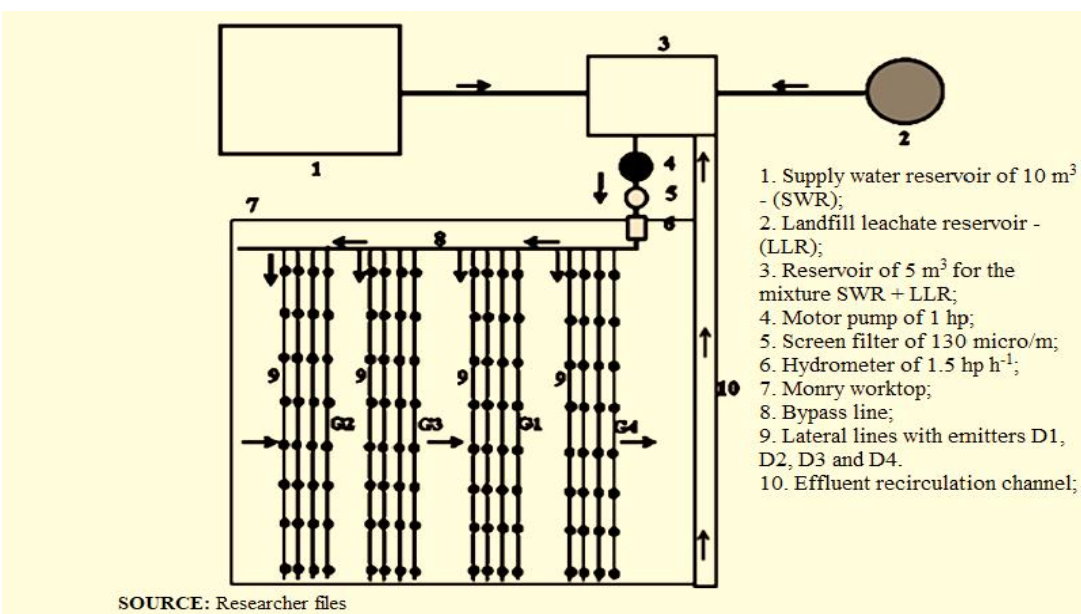

Fig. 1. Schematic of the experimental bench, highlighting all its components for storage, conduction and recirculation of the diluted landfill percolate (DLP)

Inside the platform, four drip units were assembled, consisting of a 1.0 hp pump set, a 1.5 m^3 h^{-1} water meter, a screen filter with 130 µm openings, one with a bypass line with a diameter nominal 32 mm of PVC and PN 40 and 16 lateral polyethylene lines, with nominal diameter of 16 mm, equipped with four types of drippers, as shown in Fig. 2.

The four types of drippers used in the experimental tests were chosen because they are the most commercialized in Mossoro-RN and region, for the reality of the state of Rio Grande do Norte-RN, Brazil. In this sense, this work has as main focus the adequate use of irrigation of several agricultural crops and with the type of emitter suitable to the realities of the Brazilian semiarid, mainly, recreational parks, gardens and forages. In Table 1, shows the technical characterization of the four types of drippers used in the experimental test.

In the derivation line, the 16 connectors with sealing rubber were inserted, with four connectors for each type of dripper. In these connectors, the lateral lines, 8 m long, were installed level on the platform floor. Nine equidistant drippers were marked along each lateral line to assess obstruction levels.

The percolated landfill (LP) was transported from a superficial reservoir, located in the landfill of Mossoro-RN, through a plastic container with a storage capacity of 1.0 m^3. Meanwhile, the supply water (SW) came from the Rio Grande do Norte Water and Sewage Company (WSC), which was stored in concrete reservoir with until 10 m^3.

In each lateral line of the irrigation units, nine drippers were fixed, spaced every 0.80 m and 0.30 m between the lateral lines, totaling 144 drippers in the entire system, for the assessment of hydraulic performance. Every 20 h of operation of the drip units, the flow of the 144 drippers fixed by a lateral line was measured. To measure the flow of the drippers, 200 ml plastic collectors and a 100 ml beaker were used. The volume of effluent applied by the drippers was quantified for three minutes, as recommended by NBR ISO 926 [16].

Table 1. Drippers (D) used in the experimental tests, highlighting the manufacturer (M), the self-compensation device (SD), the nominal flow (F), the flow coefficient (k), the exponent of the flow that characterizes the flow regime (x), the filtration area (FA), the labyrinth length (LL), the manufacturing variation coefficient (MVC), recommended pressure range (RPR) and the spacing between the emitters (SE)

D	F	SD*	F * ($L\ h^{-1}$)	k*	x*	FA (mm^2)	LL (mm)	MVC_m* (%)	RPR* (kPa)	SE* (m)
G1	Plastro Hydrodrip Super	No	1.65	0.53	0.48	4.0**	37**	± 5	60 - 150	0.30
G2	Netafim PCJ-CNJ	Yes	2.00	2.00	0.00	2.0*	35*	± 7	50 - 400	0.80
G3	Netafim PCJ-CNJ	Yes	4.00	4.00	0.00	2.0*	35*	± 7	50 - 400	0.80
G4	Netafim PCJ-CNJ	Yes	8.00	8.00	0.00	2.0*	35*	± 7	50 - 400	0.80

*Note: * and ** information obtained from the manufacturers' catalogs and information measured with the aid of a digital parking meter with an accuracy of 0.01 mm, respectively. CNJ - anti-drainage system.*

*Note: Researcher of Archives * and ** information obtained from the manufacturers catalogs and information measured with the aid of a digital caliper with a precision of 0.01 mm, respectively. PCJ - this maintains a uniform flow even under different inlet pressures, ensuring an exact distribution of water and nutrients, in addition, the emitter has wide sections of water passage and constant action of the self-cleaning mechanism, which increases its resistance to clogging. CNJ - anti-drainage system*

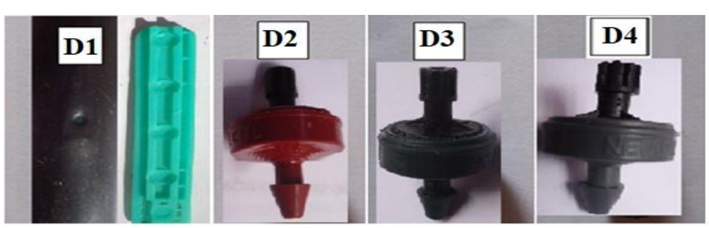

Fig. 2. Image of the four types of drippers (D1, D2, D3 and D4) used in the experimental tests of the hydraulic performance of the drippers using percolation of landfill diluted in water supply

Source: Researcher of file (2017)

The flow calculation (FC) was obtained using Equation 1.

$$FC = \frac{V}{1000\,x\,t} \,.\, 60 \qquad (1)$$

In what:

FC – Dripper flow, L h^{-1};
V – Volume of effluent collected, mL;
t – effluent collection time, min

The service pressure was maintained daily at 140 kPa using an analog glycerine manometer, graduated from 0 to 400 kPa, with an accuracy class of ± 1% of full scale.

During the experimental period, several determinations of the physical-chemical and microbiological characteristics of the percolate of the diluted sanitary landfill and of the water supply, inherent to the risk of dripping obstruction, were carried out. For this, the samples were collected every 20 h, after the filtration system, being subsequently stored insterile containers, at a temperature of 4ºC in an isothermal box with ice, until the moment of the analysis in FURSA laboratories.

In the Laboratory of Soil, Water and Plant Analysis (LASAP) and in the Laboratory of Environmental Sanitation (LSA) of the Department of Environmental and Technological Sciences at the UFERSA, the values of hydrogen potential (Hp) quantified with bench parameters; and of electrical conductivity (Ec) expressed in dS m^{-1}, with the bench-top conductivity meter; the concentrations of total iron (Fe^{2+}), Zinc (Zn^{2+}) and total manganese (Mn^{2+}) in mg L^{-1}, by the atomic absorption spectrophotometry; the concentrations of calcium (Ca^{2+}) and magnesium (Mg^{2+}) in mmolc L^{-1}, using the titrometric method. The concentrations of suspended solids (SS) and total solids (ST), in mg L^{-1}, were obtained by the gravimetric method, while the concentrations of dissolved solids (SD), in mg L^{-1}, were obtained by the difference in solids total and suspended solids.

While, at the Animal Products Inspection Laboratory (LIPOA), also, at UFERSA, the population levels of total coliforms (CT) were detected and quantified, using the multiple tube technique. Total coliforms were used as bacteria that causers of clogging in drippers, by the fact from incorporate the genera *Escherichia, Citrobacter, Klebsiella* and Enterobacter [17], which according to Nakayama et al. [18] lead to the formation of mucilage inside the emitters, and consequently, clogging problems.

It should be noted that the entire procedure for collecting, storing and analyzing the samples followed the technical recommendations of the Standard Methods for the Examination of Water and Wastewater [19].

After of elapsed at 160 hours of operation of the drip units, the cut and opening was carried out in four lateral lines, one of each type of dripper; selecting the last dripper evaluated for each line to take samples of the material that caused the obstruction, and, in parallel, their photographic record was performed, using a Sony digital camera, with 2.0 megapixel resolution.

The drippers with biofilm were stored in sterile 60 mL flasks and sent to the UFERSA Histology and Embryology Laboratory, where the biological agents causing bio-encrustation were identified and characterized, with the help of an Olympus DP72 camera, with a resolution of 12.8 megapixels, coupled to an Olympus BX51 optical microscope. Samples of the biofilm were distributed on optical microscopy slides, being analyzed under the optical microscope with a 100x objective.

For the purpose to minimize the levels of clogging in the four types of drippers, the service pressure of the drip units was maintained at 140 kPa by means of a manometer, following the recommendations of [20] for the operation of a drip unit operating with landfill percolate. The service pressure was measured daily with a glycerin manometer graduated from 0 to 400 kPa, with an accuracy of 10 kPa. In the analysis of the relationship between the hydraulic performance variables and the physical-chemical and microbiological characteristics of the diluted landfill percolate (DLP) in drinking water, Pearson's correlation test at 5% probability was used.

The data were subjected to analysis of variance (ANOVA), using the F test at 5% probability. For the qualitative factor type of drippers, the averages were compared, using the Tukey test, at 5% probability. For the operating time quantitative factor, the simple and multiple regression models were chosen based on the significance of the regression coefficients, applying the “t” test at a level of up to 10%, in the determination coefficient (≥60%) in the process under study [21].

3. RESULTS AND DISCUSSION

In Table 2 shows the values of the physical-chemical and microbiological characteristics of the diluted landfill percolate over the 160 h of operation of the drip units. In this table, we notice variations in the values of the attributes, throughout the experimental period, due to the weekly replacement of the landfill percolate. The evaporation losses probably caused increases in the values of the pH, EC, SS, DS, Zn^{2+}, Fe^{2+}, Ca^{2+} and Mg^{2+} attributes together with the operating time of the drip units.

The superiority of sodium over other cations results in its adsorption to the exchange complex with negative effects on the dispersion of clays and loss of physical quality to the dynamics of water and nutrients [22].

The average pH value is within the range of 7.0 to 7.5 proposed by Nakayama et al. [18] that classifies the risk of dripper obstruction as moderate, due to the precipitation of chemical elements. In different experimental conditions, [23] presented in his study a pH range from 5.68 to 7.70 for percolate of urban solid waste, indicating greater variation in pH data in relation to the present study.

Analyzing Ordinance No 154/2002 [24], the average value of electrical conductivity was below the limit of 3.0 dS m^{-1} proposed for agricultural wastewater use. Using the criterion proposed by Moreira et al. [25], the average value of electrical conductivity is within the limit range of 1.0 to 4.5 dS m^{-1}, indicating a moderate risk for dripping obstruction. This result differs from the range of 12.3 to 19.4 dS m^{-1} found by [5] in studies with percolate of solid urban waste, in experimental conditions different from those found in the present study.

The suspended and dissolved solids had contents above 100 mg L^{-1} and 2.000 mg L^{-1}, respectively, indicating a severe risk of dripper obstruction, according to the criteria proposed by [18]. In the work conducted by [20] with landfill percolate, in experimental conditions different from those found in the present work, ranges from 10 to 7000 mg L^{-1} and from 390 to 38000 mg L^{-1} are presented for the suspended solid and dissolved solids characteristics, respectively, for the percolate of landfills in the acid phase. According to Moreira et al. [25], high levels of dissolved solids indicate the appearance of liquid from the decomposition of solid waste.

The average content of total iron is in the range of 0.2 to 1.5 mg L^{-1}, with a risk of obstruction of drippers classified as moderate, due to the formation of precipitates. In addition, the bacteria that oxidize iron (*iron-bacteria*) contribute to the clogging of drippers caused by chemical and biological agents. However, the second factor is the most relevant, because these bacteria produce large amounts of gelatinous mucilage [18]. This result was well below the range of 83.4 to 981.3 mg L^{-1} found by [23] in percolate of urban solid waste, however under experimental conditions different from those presented in this study.

The average concentrations of zinc in the PL were 0.03 mg L^{-1}. In relation to PL, the mean zinc value was below the 5.0 mg L^{-1} limit established for the discharge of effluents into receiving water bodies [26]. These results differ from those found by [27], where the average zinc levels for PL and AA were 1.13 and 0.05 mg L^{-1}, respectively. According to Coelho [28] reported that zinc levels below 2.00 mg L^{-1} do not represent toxicity to plants in soils with a pH above 6.0 and with a fine texture. According to Nascimento et al. [29], the mobility of Zn, can be strongly influenced by the non-specific adsorption reactions, by the formation of external sphere complexes, of less stability, which plays an important role in the retention of this metal in the studied soil.

For total manganese, the average concentration was below the value of 0.1 mg L^{-1} which classifies the risk of dripper obstruction as low [18]. In addition, the average concentration of manganese was below the range of 0.428 to 0.676 mg L^{-1} obtained in the study presented by [30] with landfill leachate, in experimental conditions different from those presented in this study.

The average values of calcium and magnesium were lower than the limit values of 12.5 mmolc L^{-1} and 2.0 mmolc L^{-1}, indicating a low risk of dripper obstruction, according to the criteria established by [31]. In the work developed by Souza et al. [3], the percolate of solid waste showed ranges from 3.91 to 63.24 mmolc L^{-1} and from 5.72 to 785.16 mmolc L^{-1}, for the characteristics calcium and magnesium, respectively, however under experimental conditions different from those found in the present work.

Table 2. Values of the physical-chemical and microbiological attributes of the diluted landfill percolate, obtained every 20 h until completed 160 hours of the operating time

Attributes	Operating time (h)									Mean/standard deviation
	0	20	40	60	80	100	120	140	160	
pH	6.90	7.13	7.24	7.40	7.33	7.37	7.86	7.88	7.92	7.45±0.36
CE (dS m^{-1})	2.54	1.91	2.10	1.91	3.19	2.93	3.30	3.56	3.76	2.80±0.71
SS (mg L^{-1})	38	43	68	120	108	234	380	447	502	216±183
DS (mg L^{-1})	288	360	868	1325	2373	3310	4135	5467	6125	2695±2193
Fe (mg L^{-1})	0.55	0.68	0.70	0.78	0.85	0.95	1.02	1.02	1.12	0.85±0.19
Zn (mg L^{-1})	0.02	0.014	0.05	0.08	0.012	0.09	0.015	0.02	0.02	0.031±0.02
Mn (mg L^{-1})	0.03	0.05	0.03	0.03	0.03	0.02	0.03	0.02	0.03	0.03± 0.01
Ca^{2+} ($mmol_c$ L^{-1})	0.74	0.75	0.90	1.06	1.26	1.35	1.40	1.42	1.52	1.16± 0.30
Mg^{2+} ($mmol_c$ L^{-1})	1.32	1.39	1.46	1.61	2.23	2.49	2.18	2.34	2.44	1.94± 0.48
TC (MLN 100 mL^{-1})	23	3	3	9	43	3	93	3	3	20.33± 30

Note: EC - electrical conductivity; SS - suspended solids; DS - dissolved solids; Fe – total iron; Mn – total manganese; Ca^{2+} - calcium; Mg^{2+} - magnesium; CT –total coliforms; e MLN – most likely number

The average population level of bacteria was lower than the limit of 5.000 MLN per 100 mL proposed by Ordinance No. 154/2002 [22] for irrigation of agricultural crops not consumed raw. Regarding the risk of obstruction caused by the bacterial population, it was classified as low, as proposed by [18]. These results differ from those found by [32] for percolating solid residues in residences and health services, where the population levels of total coliforms were 1.9x109 and 4.9x108 MLN 100 mL^{-1}, respectively, under different experimental conditions than those obtained in the present study.

Based on the aforementioned Table, even though it does not offer risks for irrigation of agricultural crops not consumed raw, the variation of TC from 3 to 93 MLN 100 mL^{-1} of the AA was mainly due to the decomposition of leaves and fruits near the supply tank. Some studies have shown that bacteria in the total coliform group caused problems of obstruction with microbial mucilage in pipes and drip irrigation systems [18,33]. According to [18], bacteria of the genera *Pseudomonas, Enterobacter, Clostridium, Flavobacterium*, *Vibro*, *Brevibacterium, Micrococcus* and *Bacillus* produce mucilages capable of providing dripper obstruction.

According to Brito et al. [17] the group of bacteria called total coliforms are represented by gram-negative bacilli, with the majority of bacteria belonging to the genera *Escherichia, Citrobacter, Klebsiella* and *Enterobacter*. However, the genera of bacteria *Pseudomonas, Enterobacter, Clostridium, Flavobacterium, Vibro, Brevibacterium, Micrococcus* and *Bacillus* cause problems with drip clogging and many of these are within the total coliform group [18]; thus justifying the adoption of this characteristic as an indicator of biological clogging in the present study.

4. CONCLUSION

The suspended solid and dissolved solids attributes presents a severe risk of dripper obstruction for the diluted landfill percolate.

The physical-chemical attributes that most interfered in the obstruction process using diluted landfill percolate in irrigation systems with self-compensating emitters were suspended solids, dissolved solids, pH, electrical conductivity and total iron.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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