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Developmnent of *Mucuna sloanei* and *Brachystegia eurycoma* Seeds as Sorbent: Effect of Some Physical Properties on Their Swelling Behaviour

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Authors' contributions

This work was carried out in collaboration between all authors. Author SAO designed the study and write the first draft of the manuscript. Authors OAG and IIN participated in the management of laboratory analyses and procedures. Author AMK performed the statistical analysis and author AA did literature research. All authors read and approved the final manuscript.

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ABSTRACT

Mucuna sloanei seeds (MSS) and *Brachystegia eurycoma* seeds (BES) were immobilized by mixing 50 cm^3 of viscous layer of MSS/ BES and 50 cm^3 of 4% stock solution of sodium alginate, the mixtures were transferred into a beaker containing 60 cm^3 of 0.12 M calcium chloride solution allowed to stand for 2 h. The precipitates were filtered and dried for 72 h, giving rise to immobilized *Bucuna sloanei* seed (IMSS) and *Brachystegia eurycoma* seed (IBES). The swelling behavior of IMSS and IBES showed that the water uptake increases with increase in concentration, and pH, and decreased with increase in ionic strength and temperature in both IMSS and IBES. The contact time increases from 30 mins to 4 h and decrease gradually to 8 h for IBES and percentage water of IMSS increases as the contact time increases. Their swelling capacities were recorded as 350% for IMSS and 332% for IBES.

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1. INTRODUCTION

Water is a source of energy, life and basic need for mankind; however, millions of people worldwide are suffering from the shortage of clean drinking and fresh water. Fresh water quality and availability remain one of the most critical environmental and sustainability issues of the twenty first century [1]. Water serves in many aspect of life. Water and its management will continue to be a major issue with definite and profound impact on our lives and that of the planet earth [2]. Water is the most important natural resources without which life would have been meaningless. The issue of environment and water is elementary to all types of lives. The availability of safe and dependable source of water is an essential requirement for sustainable development and encouraging good standard of living. No one can survive in desert; it is not habitable because of lack of water. Yet, water is the major carrier of heavy metals [3].

Rapid pace of population expansion, industrialization, and unplanned urbanization have largely contributed to the severe water pollution and surrounding soils. Discharge of toxic industrial wastes and untreated sanitary, dumping of industrial effluent, and runoff from agricultural fields can be the main sources of freshwater pollution. It is well known that 70 to 80% of all illnesses in developing countries are related to water contamination, particularly susceptible children and women [4]. Contamination of aqueous environments by heavy metals is a worldwide environmental problem due to their toxic effects and accumulation through the food chain [4]. The major pollutants are heavy metals in ground, marine, industrial, and even untreated wastewaters [5]. The presence of heavy metal ions in drinking water will be hazardous to consumers. Zn, Cd, Hg, Pb, Cr, Cu, and can damage liver, nerves and block functional groups of vital enzymes and bones [5]. Metal ions in water can occur naturally from anthropogenic sources and from leaching of ore deposits, which mainly include solid waste disposal and industrial effluents. The levels of heavy metal ions in water system have substantially increased over time with rapid development of industrial activities [6]. These heavy metal ions are non degradable and cannot be detoxified biologically [5]. The contamination of water by toxic heavy metals is a worldwide problem [7]. This fear has been heightened in recent times due to advancement in technology coupled with increasing industrial activities, both contributing to the release of heavy metal ions into the environment [8].

One of the ways to address this problem of water shortage is to treat the polluted water through removal of the contaminants. To date, the removal of metal ions from water has been previously achieved by various methods such as ion exchange, precipitation, oxidation, reduction, and membrane filtration [9]. These methods are already being used to clean up the environment from these kinds of contaminants, but most of them are very costly and far away from their optimum performance. The chemical technologies generate large volumetric sludge and increase the costs [7].

Consequently, there is a growing requirement for efficient, novel, and cost-effective techniques for the remediation of metal ions bearing wastewaters before their discharge into the environment. Over the last two decades, biosorbent is one approach which has shown considerable potential for metal removal from aqueous media; that is, the use of raw or natural materials and wastes from agricultural and industrial activities to adsorb metals from aqueous solutions [10]. Biosorption of heavy metals from aqueous solution is a relatively new technology for the treatment of industrial waste water [11]. The main advantage of using biosorption technology is due to its cost effectiveness, affordability, availability and environmental friendliness [12]. These materials could be an alternative to the expensive wastewater treatment process [10]. However, the use of raw sorbents in adsorption has its problems since most plants contain a green pigment known as chlorophyll (sparingly soluble in water), and some organic matter may be leached out, consequently affecting the taste and colour of the treated waters [13], hence the need for immobilization of these samples.

Mucuna sloanei and *Brachystegia eurycoma* seeds are used as a thickener in soups and other traditional baked food products because of high viscosity, binding and swelling propensity [3]. These properties are some of the characteristics of a good sorbent [3]. Assessment of the phytochemical contents of *Brachystegia eurycoma* and *Mucuna sloanei* seeds shows that its contains flavonoids [14]. Flavonoids are a group of polyphenolic compounds that are found in fruits and vegetables, these metabolites posses some functional groups and their presence in the seeds indicates that they could have potential to exhibit a suitable binding sorbent hydrophilicity and swelling capacity [11, 15]. However, nothing has yet been reported on the industrial use of *Mucuna sloanei* and *Brachystegia eurycoma* seeds which are available all round the year and wasting away in the wild. In this study*, Mucuna sloanei* and *Brachystegia eurycoma* seeds were immobilized with the aim of studying its swelling behaviors so as to ascertaining their industrial potential.

2. MATERIALS AND METHODS

2.1 Collection of Materials

The materials used were sodium alginate, sodium chloride, sodium hydroxide, calcium chloride, and hydrochloric acid. These chemicals were obtained from IBDH, British Drug House. *Mucuna sloanei* and *Brachystegia eurycoma* seeds were obtained at Afikpo North Eke Market, Ebonyi State, Nigeria. The materials were used as obtained.

2.2 Sample Preparation

The *Mucuna sloanei* and *Brachystegia eurycoma seeds* were dried, roasted, soaked in warm water and the shells removed manually, they were further dried in an oven at 60℃. for 48 h [14]. They were milled with blender into powdery form and sieved with 100 µm mesh to obtain a fine powder and then stored in a clean polyethylene bag ready for immobilization process [16].

2.3 Preparation of *Mucuna sloanei* and *Brachystegia eurycoma* Seeds Solution

4.00 g *Mucuna sloanei* and *Brachystegia eurycoma* powder were weighed each and dissolved in a 100 cm^3 distilled water and labels mixture A^1 and A^{11} respectively [16].

2.4 Immobilization of *Mucuna sloanei (MS)* and *Brachystegia eurycoma (BE)*

50 cm^3 of viscous layer of dissolved MSS seed was thoroughly mixed with 50 cm^3 of 4% stock solution sodium alginate and stirred vigorously for even mixing in a 250 cm^3 beaker. The mixture was transferred into another beaker containing 60 cm^3 of 0.12 M calcium chloride solution and the reaction allowed to stand for 2 h for complete precipitation. The solid form was allowed to dry at room temperature for 72 h. The dry solid was wash in distilled water and store in a clean polyethylene bag (B^1) for further usage [16]. The above process was repeated for BES and the sample labelled B^{11}.

The above process was repeated at different ratios of sodium alginate and MSS (100:0 90:10, 80:20, 70:30, 60:40 and 50:50). The precipitates were dried and kept separately for further use [16]. For BES, the above processes for MSS were repeated but substituting BES in place of MSS.

2.5 Determination of Water Uptake

The water uptake of immobilized *Mucuna sloanei* seeds were determined using modified tea bag method as reported by [11], this involve the immersion of 0.2 g of immobilized solid blend in 50 cm^3 distilled water inside a polyethylene bag. The gross combination was pre-weighed and sealed for 24 h at temperature of 30℃ to attain equilibrium. At the end of equilibrium period, excess solution was carefully sucked out using a micro-syringe. The percentage water uptake was calculated using the formula below.

$$Water\ uptake\ (\%) = \frac{w_s - w_g}{w_g}\ X\ 100$$

Where Wg and Ws represents weight of the dry and wet IMSS respectively [11]. The above procedure was also used to determine water uptake capacity of (IBES).

2.6 Determination of the Effect of Temperature on Water Uptake

This was determined by immersing 0.2 g of the immobilized samples in distilled water for 4h using the modified tea bag method. The samples were kept at 30℃ for 4 h with the use of regulated water bath. The water uptake was determined by procedure as reported earlier. The procedure was repeated at various temperatures ranging from 40℃ to 80℃ in each case, the average of three determinations was taken [11].

2.7 Determination of the Effect of Ionic Strength

This was determined by immersing 0.2 g of the immobilized samples in excess solution of sodium chloride of various concentration ranges (0.1 – 1.0 g w/w). Using the modified tea bag method, then the percentage water uptake was calculated at the end of the equilibration period of 24 h [11].

2.8 Determination of the Effect of Time on Water Uptake

The effect of time on water uptake was studied. Different sets of sample containing 0.2 g of the immobilized seeds was immersed in distilled water. The percentage water uptake of each of sample was determined at different time interval from 30 mins to 24 h [11].

2.9 Determination of Effect of pH on the Water Uptake

The water uptake of the immobilized sample at different pH values (i.e. ranging 2 - 12) were investigated at 30℃ using the modified tea bag method. Standard solution of 1.0 M HCL and 1.0 M NaOH solution were used to adjust the test solution to the required pH as the case may be. The process was repeated with different pH value, and the result was recorded [11].

3. RESULTS AND DISCUSSION

3.1 Immobilization of *Mucuna sloanei* Seeds and *Brachystegia eurycoma* Seeds

The immobilization of *Mucuna sloanei* seeds *(MSS) and Brachystegia eurycoma* seeds*(BES)* was achieved by entrapping or caging it within the polymeric matrix of calcium alginate. It has been established that sodium alginate (SA) consists of L. guluronic acid (G) and D mannuronic acid (M) units. The contacting of Ca^{2+} ions with guluronic acid blocks forms an ionically cross-linked structure in aqueous environment. The cross-linking of the polymer is due to binding of divalent cations (Ca^{2+}) to the – COO^- group of L – guluronic acid block [17].

Divalent cations Ca^{2+} act as a cross-linker and cause an ionic binding between G – blocks in polymer chains and forms three dimensional network [18]. This network immobilized *Mucuna sloanei and Brachystegia eurycoma seeds* to produce a biosorbent.

3.2 Water Uptake Capacity of IMSS and IBES

Water uptake capacity obtained for both IMSS and IBES was recorded as 350% and 332% respectively. This result shows that the cellulose molecule of the immobilized samples has a polar group which attracts water molecule through hydrogen bonding, attachment of water molecules to cellulose molecules leads to moisture build-up within the cell walls [19].

3.3 Effect of Concentration on Water Uptake

Fig. 2; shows the effect of the concentration of IMSS and IBES on water uptake. It was observed that the water uptake by IMSS and IBES increases with increase in the concentration of the IMSS and IBES. The development is explained by an increase in hydrophilicity of the IMSS and IBES with increase in the amount of the sorbent [11]. Higher percentage of biomass implies a higher percentage of cellulose molecules in the biomass which in turns leads to higher water uptake and swelling characteristics [20]. It is attributed to the concept that water migrate from the more concentrate medium to less concentrate one [21].

3.4 Effect of Temperature on Water Uptake

The effect of temperature on water uptake by immobilized IMSS and IBES is shown in Fig. 3. It can be observed that the water uptake decreases sharply from 30℃ to 60℃, this result may be attributed to the intrinsic molecular structure of the polymer reacting to form another compound of the immobilized samples. Molecules of immobilized samples decreased in water uptake as the temperature increases and this is due to the more compacted form of membrane which causes the pore to be narrower and the suction sites be hidden or inaccessible to the water molecules [11]. Also due to the dissolution of the low molecular weight polymer and non cross-linked polymer with increasing temperature [3]. The effect of temperature on water uptake also depends on the heat of sorption. Usually for physical sorption heat of sorption is negative; sorption reaction is exothermic and preferred at lower temperature. For chemisorptions the overall heat of sorption is combination of heat of various reactions taking place at sorption sites [9].

3.5 Effect of Ionic Strength on Water Uptake

Fig. 4; shows the effect of ionic strength on water uptake. It is evident that the water uptake decrease as the ionic strength increases. This result is attributed to the decrease in the expansion of the polymer network, which was caused by repulsive forces of the counter ions on the polymeric chain shielded by the ionic charge. Therefore, the difference of the osmotic pressure between the polymer network and the external solution decreased with increase in the ionic strength of the saline concentration in both IMSS and IBES [22]. Also the decrease in water uptake may be attributed mainly to the slow movement of moisture through porous materials caused by increasing concentration of sodium chloride and the presence of trapped air bubbles inside the immobilized samples during water uptake [21].

3.6 Effect of Time on Water Uptake

The effect of contact time on water uptake is shown in Fig. 5. It can be seen that the rate of water uptake increased rapidly within the first 30 min and gradually up to 4 h which mark the saturation point of the bio-sorbent. The water uptake then reduced from 4h gradually until equilibration was reached for IBES while in IMSS the percentage water uptake increased with increase in time. This development is as a result of the swelling of the biomass, also the hydrophilic nature and porosity of the polymer structure [23]. The reason for higher water absorption can also be explained by diffusion phenomenon. During diffusion process, fluid migrates and spread itself through cellular wall of plant biomass thereby migrating from more concentrated medium toward the lesser one. The rate of water uptake depends on the difference between the saturated water content and the water content at a given time [21]. Equilibration is attained when immobilized samples start to swell, the stress on the matrix stretches and make more space for the swelling or water uptake, this continues until the stress exerted by the immobilized samples is balanced by the countervailing stress of the matrix which is the point of equilibrium [21].

3.7 Effect of pH on Water Uptake

The effect of pH on water uptake was investigated within the pH range of 2.0 – 12.0. The rate of water uptake changed from 180% to 249% in IMSS and 194% to 252% in IBES showing an incremental difference of 60% and 58% respectively. Also, a gradual incremental difference of 25% in IMSS and 50% in IBES was recorded as water uptake increased from 325 to 350% and 310 to 360% respectively within the pH values of 6.0 – 8.0 as shown in Fig. 6.

The rate of water uptake increases with increasing pH values, which shows that alkaline pH favors higher water uptake by IMSS and IBES biomass. This can be explained by the extent of ionization of the carboxylic group of alginate, which produces greater number of carboxylate ions along the alginate molecules. These fixed anionic charge centers repels one another and produce a rapid relaxation in network chains, thus resulting in rise in the degree of water uptake [24]. Also as sorption proceeds and pH increased, the water content increased thereby increasing the driving force and absorption rate of the immobilized samples [21].

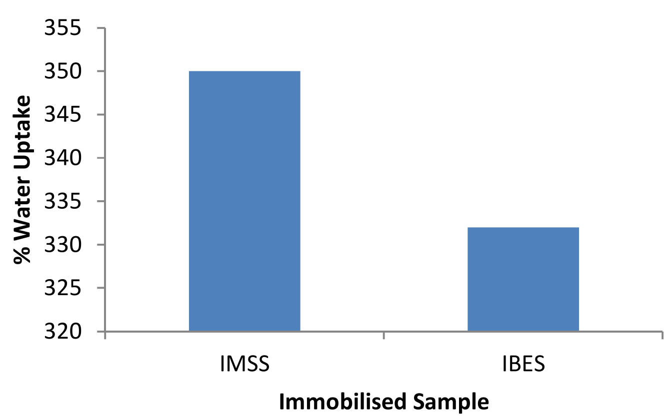

Fig. 1. Percentage water uptake of IMSS and IBES

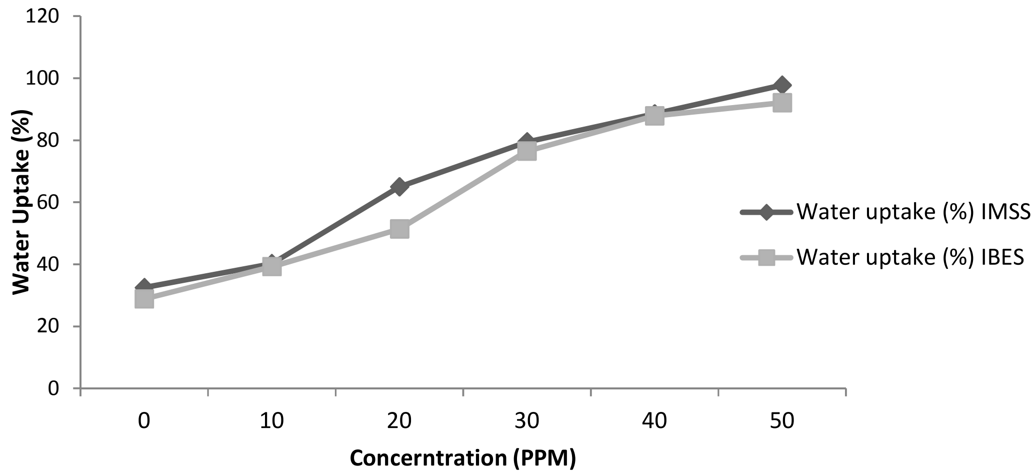

Fig. 2. Effect of concentration on water uptake of IMSS and IBES

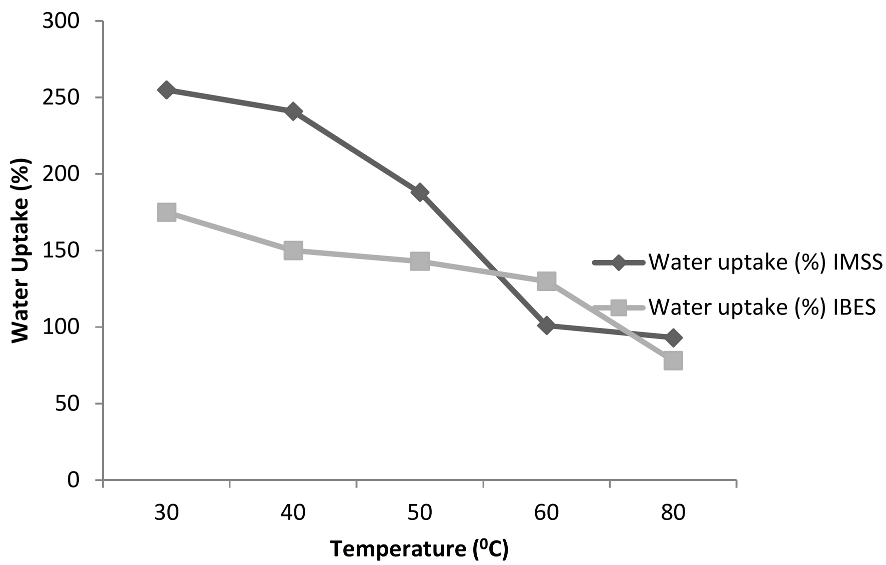

Fig. 3. Effect of temperature on water uptake of IMSS and IBES

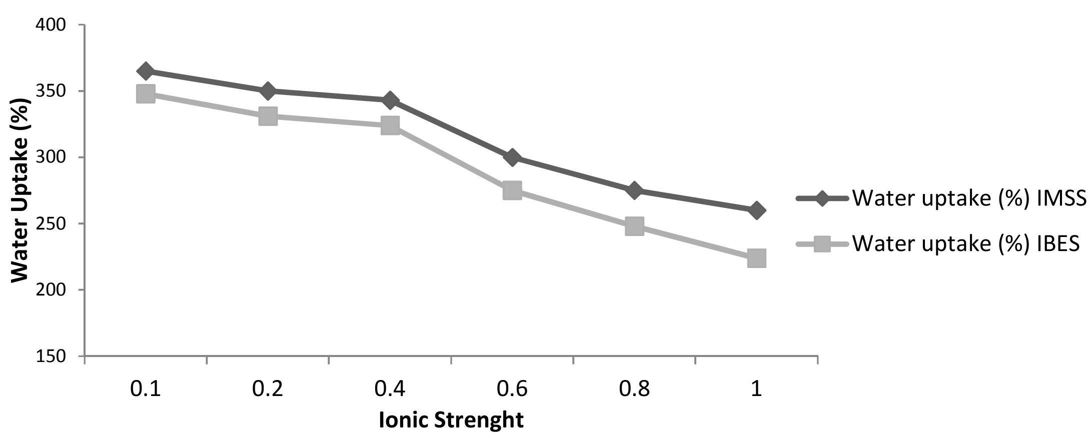

Fig. 4. Effect of ionic strength on water uptake of IMSS and IBES

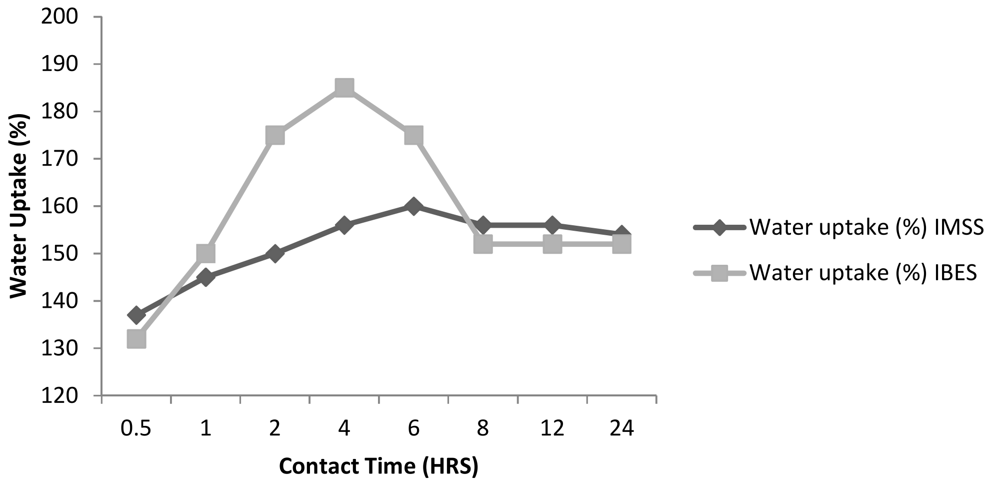

Fig. 5. Effect of contact time on water uptake of IMSS and IBES

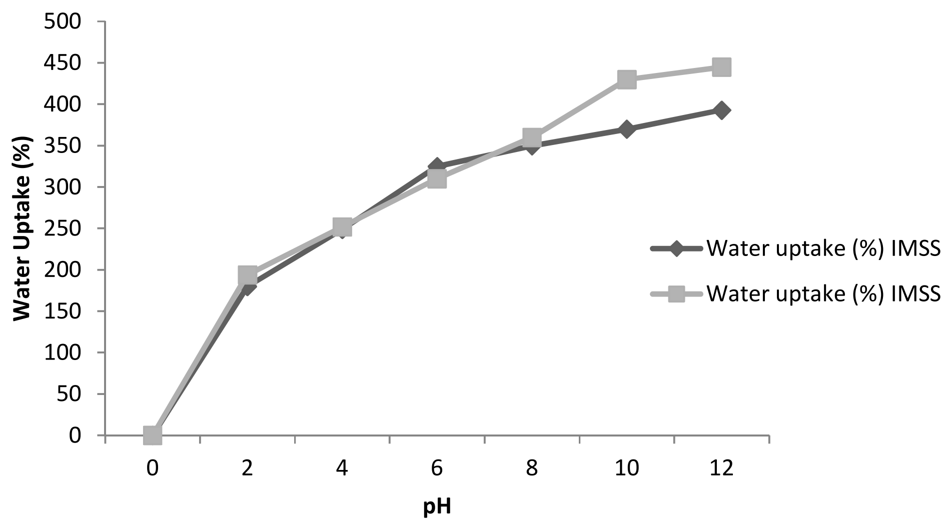

Fig. 6. Effect of pH on water uptake of IMSS and IBES

4. CONCLUSION

In this research work, the immobilization of *Mucuna sloanei seeds (MSS) and Brachystegia eurycoma seeds (BES)* were achieved by caging it within a polymeric matrix with sodium alginate. The result of swelling behavior recorded was satisfactory. The water uptake by the bio-sorbent decreased as the ionic strength and temperature increased, but increased with increase in pH values and concentration in both IMSS and IBES. The contact time increased from 30 min to 4h and decrease gradually to 8 h for IBES and percentage water of IMSS increased as the contact time is increased. From the study, it was deduced that IMSS and IBES can be sorbent for water remediation in industries.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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