Cost-Effective Conditioning and Dewatering

A groundwater treatment facility saves big by conditioning with polymer instead of iron and lime

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Treating and disposing of residuals account for a significant portion of operating costs at treatment plants. Among the processes that add to these costs, conditioning and dewatering of residuals are two of the most expensive. This cost grows larger if inorganic conditioners are used instead of polymers, because they require higher dosages and the increased cake mass that results increases disposal costs. Accordingly, options for enhancing conditioning and dewaterability are desirable.

At a water treatment plant in Henderson, Nev., options to improve dewatering were investigated, including pretreatment with enzymes before inorganic conditioning and before polymer conditioning, as well as polymer conditioning alone. Operated by Veolia Water North America Operating Services (Houston), the facility biologically treats groundwater contaminated with perchlorate. Residuals were conditioned with lime and ferric chloride before dewatering via standard plate-and-frame press. Laboratory testing found that enzyme pretreatment together with either iron and lime or polymer conditioner can enhance the dewaterability of residuals.

However, polymer conditioning alone appears to condition the sludge properly before dewatering, even when employed at a much lower dose than is used normally. Results of full-scale testing showed that the increase in cake dewatering associated with enzyme pretreatment does not offset the cost of enzyme addition. Accordingly, polymer alone was tested at full scale. After results from full-scale tests confirmed the laboratory findings, the plant converted to polymer conditioning with satisfactory results.

Evaluating the Treatment Process

Outfitted with eight fluidized bed reactors, the facility is designed to treat approximately 1000 gal/min (3800 L/min) of groundwater with perchlorate levels as high as 400 mg/L. Residuals

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are separated through dissolved-air flotation, thickened in a gravity thickener, and then pumped to a conditioning tank before dewatering. Residuals are dewatered by two standard plate-and-frame presses. Operating at a feed pressure of 100 psi (690 kPa), each press has a capacity of 80 ft^3 (2.3 m^3), plates that measure 47 in. by 47 in. (1200 mm by 1200 mm), and 1.25-in.-thick (32-mm-thick) cake chambers.

During the initial design stages for the dewatering process, polymer vendors were unable to demonstrate sufficient flocculation to achieve mechanical dewatering. Therefore, designers opted to condition thickened residuals with inorganic conditioners having a concentration of 400 g/L of ferric chloride at a rate of 210 gal/d (0.8 m^3/d) followed by lime added at a rate of 1330 lb/d (603 kg/d). Chemical costs associated with this practice were high, and the inorganic conditioners reduced the capacity of the presses while increasing costs associated with hauling and disposing of dewatered cake.

Implementing the Laboratory Test

Laboratory conditioning and dewatering tests were conducted on residual samples obtained from the plant before conditioning. Four doses — 10, 25, 50, and 75 mg/L — of a commercial enzyme were evaluated. Available in dry form, the enzyme contains protease, lipidase, anaerobic bacteria, *Aspergillus oryzae*, and a mixture of other hydrolytic enzymes. Residual samples were incubated with the different enzyme doses for 16 hours at 95°F (35°C) before chemical conditioning. An untreated sample used as a control also was incubated at the same temperature and for the same time. A bench-scale pressure filter device was used to simulate dewatering via the full-scale plate-and-frame presses. The capillary suction time (CST) value for the different samples was measured to indicate whether samples had been conditioned properly. A value of 20 seconds or less indicated good conditioning. The optimum conditioning dose was determined by observing the minimum CST values.

The same dosages of ferric chloride and lime employed by the plant were used to condition the residual samples following enzyme treatment. Initially, ferric chloride was added to the residuals and mixed at 200 rpm for 2 minutes. Lime then was added and mixed for another 2 minutes at 200 rpm.

Polymer conditioning used high molecular weight and cationic polymer. Different doses of polymer at 0.45% concentration were used to condition the residual samples that had been treated by enzymes. Initial jar testing indicated that a short mixing time is needed to flocculate these type of residuals properly.

To assess dewaterability, the bench-scale filter press tested a 1200 mL sample of conditioned residuals using an initial pressure of 30 psi (207 kPa) for 5 minutes, followed by 50 psi (345 kPa) for another 5 minutes, before finally increasing pressure to 80 psi (552 kPa) for another 5 minutes. Each sample's filtrate volume was recorded along with time of filtration. After pressure had been applied for 15 minutes, the whole sample's cake

Figure 1. Iron and Lime Conditioning Results Using Different Enzyme Dosages and Dewatering via Lab Filter Press

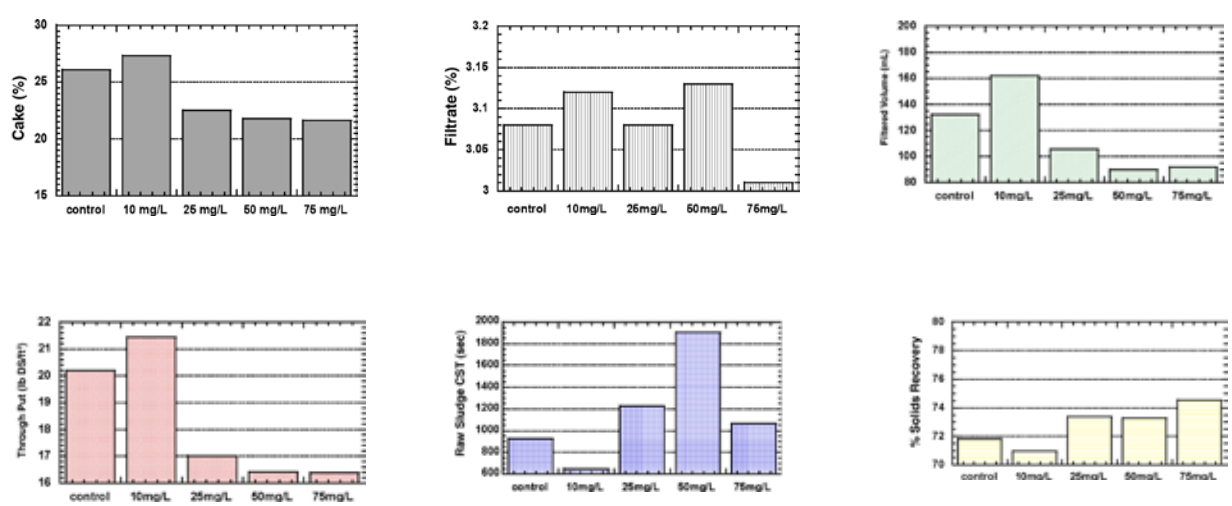

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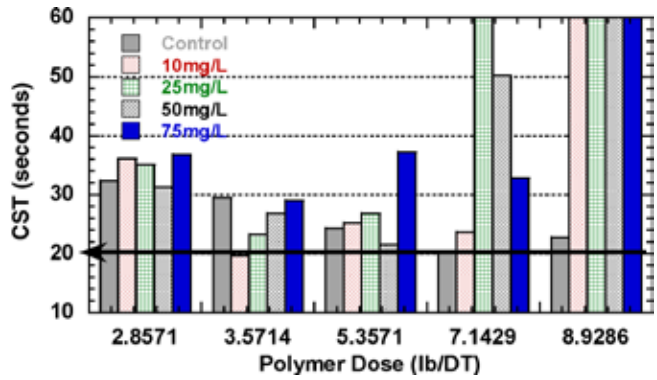
Figure 2. Capillary Suction Time (CST) Versus Polymer Dose for Samples Treated With Enzymes



solids concentration was measured, as was the concentration of total solids in the filtrate.

Assessing the Bench-Scale Results

Except for the results pertaining to filtrate total solids, pretreating residuals with an enzyme dose of 10 mg/L enhanced conditioning — as shown by CST results — and dewaterability results (see Figure 1, p. 65). Moreover, this enzyme dose increased cake solids, filtered volume, solids throughput, and solids cake recovery. However, increasing the enzyme dose beyond 10 mg/L impaired the conditioning and dewaterability of the residuals. Higher enzyme dosages produced darker filtrate and reduced the solids recovery. Thus, 10 mg/L of enzyme seems to be the optimum dose for pretreating residuals before conditioning with iron and lime and enhancing dewaterability. The results also show that enzyme pretreatment alone is not sufficient to condition residuals properly, as evident from the high CST value of 646.9 seconds for residuals treated with enzymes but without chemical conditioning. The solids recovery depicted in Figure 1 is calculated as total solids. The low values result from the high soluble solids that were not captured during pressure filtration. The residual sample was found to have a soluble chemical oxygen demand of 6833±511 mg/L.

Figure 2 (above) presents results of polymer conditioning following pretreatment of residuals with different enzyme dosages. Surprisingly, with no enzyme treatment, a low optimum dosage of polymer — approximately 7 lb per dry ton (3.5 kg per dry tonne) of solids — was able to condition the residuals properly to an average CST of 20.3 seconds, indicating the potential for good dewatering. When the polymer dose was halved to 3.5 lb per dry ton (1.8 kg per dry tonne) of solids, the enzyme dose of 10 mg/L was able to lower the CST to 19.6 seconds. Higher enzyme dosages produced minimum CST with polymer dosages of 3.5 to 5.5 lb per dry ton (1.8 to 2.8 kg per dry tonne) of solids. However, the minimum CST was slightly higher than 20 seconds, indicating a potentially acceptable dewatering rate.

Another experiment was conducted to predict the dewaterability of conditioned residuals with different polymer doses using the bench-scale filter press. Another objective of the experiment was to examine the effectiveness of a lower dose of enzyme — in this case, 5 mg/L — in enhancing dewaterability. Based on minimum CST values, a polymer dose of 5.3 lb per dry ton (2.6 kg per dry tonne) of solids may represent the optimum with no enzyme pretreatment (see Figure 3, below). The enzyme pretreatment dose of 10 mg/L produced the lowest CST value of approximately 20 seconds at a low polymer dose of 3.8 lb per dry ton (1.9 kg per dry tonne) of solids. The enzyme dose of 5 mg/L did not seem to enhance conditioning, as evident from slightly higher CST values when compared to control samples. Beyond a polymer dose of 3.8

Figure 3. Capillary Suction Time (CST) Versus Polymer Dose With Pretreatment Enzyme Dosages of 5 and 10 mg/L

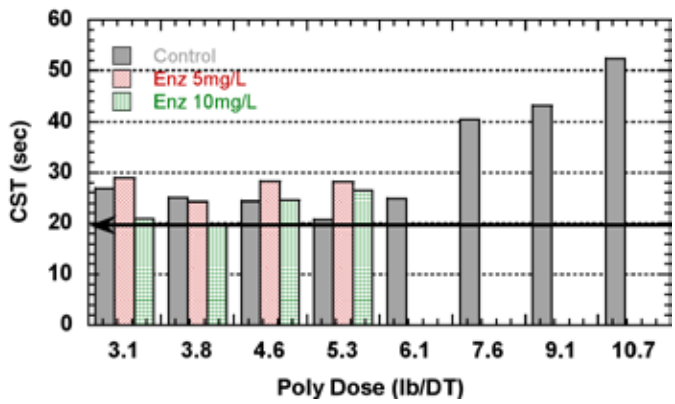


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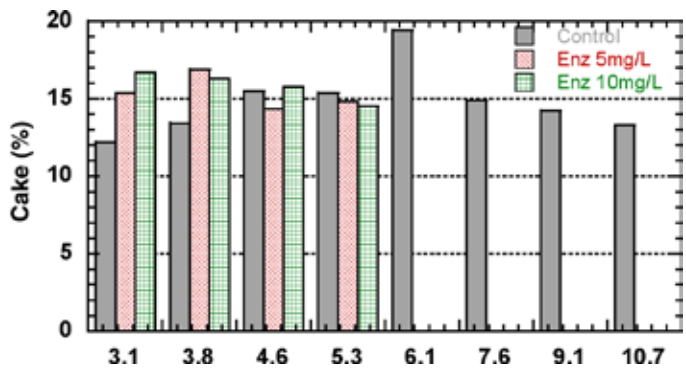
Figure 4. Dewaterability Results Versus Polymer Dose With Different Enzyme Dosages



lb per dry ton (1.9 kg per dry tonne) of solids, enzyme pretreatment seems to affect dewatering adversely. Accordingly, polymer conditioning and dewaterability assessment were not conducted on samples treated with enzymes and with polymer doses higher than 5.3 lb per dry ton (2.6 kg per dry tonne) of solids.

Enzyme pretreatment seems to enhance cake solids at lower polymer doses (see Figure 4, above). By contrast, enzyme pretreatment enhances dewaterability less and less as polymer dose increases. Beyond a certain polymer dose — 4.6 lb per dry ton (2.3 kg per dry tonne) of solids, in this case — an adverse effect on dewaterability can be observed.

Laboratory results revealed five conditioning alternatives able to produce dewaterable residuals (see Table 1, below). The alternatives were analyzed in terms of their cost-effectiveness to determine which should be studied on a full-scale basis. This analysis included the cost of chemicals — polymer, enzymes, ferric chloride, and lime — used for conditioning and the cost per wet ton produced to haul and dispose of residuals. The percentage of recovered solids was used to estimate the amount of disposed solids.

Option E, which employed only a polymer dose of about 6 lb per dry ton (3 kg per dry tonne) of solids, was the most cost-effective conditioning alternative. In terms of net cost per year, Option A was the most expensive and E was the least expensive. Although Options A and B resulted in cake solids with higher percentages that should have translated to lower hauling and disposal costs, these savings were offset by the concomitant high chemical costs and the higher mass of residuals requiring disposal as a result of the use of inorganic chemicals for conditioning.

Implementing the Full-Scale Test

According to the analysis of the cost-effectiveness of several conditioning options, polymer conditioning alone with a target dose of 5 to 6 lb per dry ton (2.5 to 3 kg per dry tonne) of solids represents the most cost-effective option for conditioning residuals. However, full-scale trials were needed to verify the predicted laboratory results from the bench-scale pressure filtration test with full-scale plate and frame dewatering. For the trial, it was determined that the test would be considered successful if it produced cake containing more than 18% total solids without sacrificing experienced solids recovery, and required 3 to 4 hours pressing time. It is worth noting that the plant did not measure filtrate solids and calculate solids recovery when conditioning with iron and lime.

A polymer solution of 0.5% was prepared in a 50-gal (0.19-m^3) tank. The polymer was mixed with water using a flash mixer for 30 minutes. The polymer solution then was pumped to the conditioning tank for further mixing with the residuals. After the addition of about 2.5 lb of polymer per dry ton (1.2 kg per dry tonne) of solids, the conditioned residuals were found to

Table 1. Five Conditioning Alternatives Assessed for Their Cost-Effectiveness

	Option A	Option B	Option C	Option D	Option E
Polymer dose, lb per dry ton of solids (kg per dry tonne)	0.0 (0.0)	0.0 (0.0)	3.1 (1.5)	3.8 (1.9)	6.1 (3.1)
Ferric chloride dose, g/L	12.4	12.4	0.0	0.0	0.0
Lime dose, g/L	45.1	45.1	0.0	0.0	0.0
Enzyme dose, mg/L	0.0	10.0	10.0	5.0	0.0
% cake solids	26.1	27.3	16.7	16.9	19.4
% recovery	71.8	71.0	85.9	84.1	80.4

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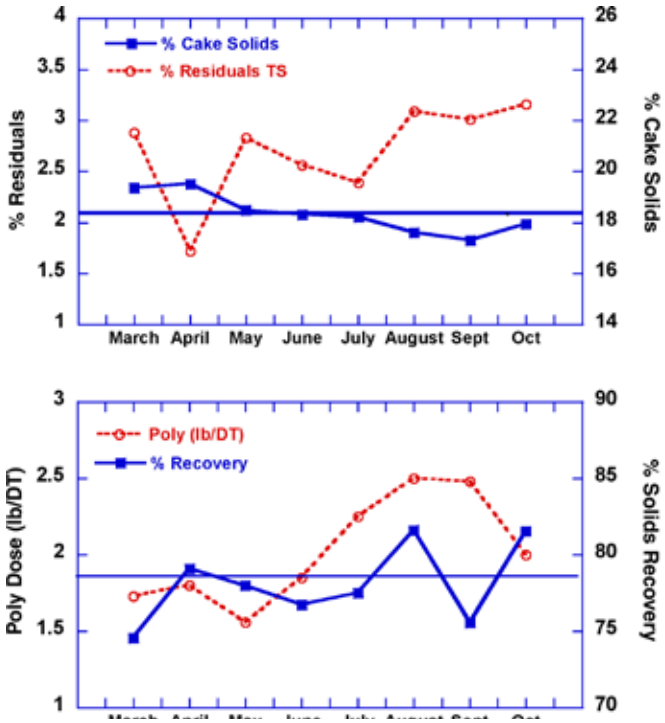
Figure 5. Example of Monthly Average Dewatering Records



have a CST of 18.2 seconds, indicating potentially good dewaterability. Thus, polymer dosing no longer was used, and dewatering proceeded. The results of the initial conditioning and dewatering trials met the success criteria. Low polymer doses produced satisfactory dewatering results with a decent press time — 2.5 to 3.5 hours. However, the dewatered cake produced when using a polymer dose of 2.5 lb per ton (1.2 kg per dry tonne) of dry solids seemed to stick to the press plates and require more effort to remove than cake that had been conditioned with lime and iron, according to plant operators. Although a lower polymer dose resulted in cake that was easier to remove from the press plates, it caused a higher run time and wetter cake. Allowing the cake to stand for 30 minutes following dewatering simplified its removal from the press plates. This waiting time was established as a standard practice following every dewatering cycle.

Assessing the Full-Scale Results

During the first 2 weeks of the test, the residual solids from dewatering fluctuated, resulting in a fairly wide range of results. However, average values from the dewatering fell within the plant's predetermined success criteria (see Table 2, below).

Between March and October 2005, the plant maintained cake solids greater than 18% on a monthly average basis, except during summer months when dewatering performance seems to deteriorate (see Figure 5, above). During the test period, the average cake solids value was 18.34%, average solids recovery was 78.07%, and average polymer dose was approximately 2 lb per dry ton (1 kg per dry tonne) of solids. The solids concentration for dewatering fluctuated.

Table 2. Average Dewatering Results for the First 2 Weeks of Polymer Conditioning

	Polymer dose, lb/ dry ton of solids (kg/dry tonne)	Cake solids, %	Filtrate solids, %	Run time, hour	Raw solids, %	Recovery, %
Average	1.87 (0.94)	19.46	0.71	3.4	2.49	72.29
Standard deviation	0.57 (0.29)	1.92	0.08	0.8	0.74	8.71

Table 3. Savings Associated With Using Polymer To Condition Instead of Iron and Lime

Conditioning scheme	Total operation cost, $/yr	Labor cost, (1) $/yr	Chemical cost, $/yr	Disposal cost, $/yr	Hauling cost, $/yr
Polymer	305,000	182,500	2400	109,800	10,300
Lime–Ferric	708,000	416,100	125,600	152,000	14,300
Contribution from polymer savings		58.0%	30.6%	10.4%	1.0%

(1) Total contact time per conditioning tank for polymer is 10 hours, compared to 22.8 hours for lime ferric conditioning.

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Reaping the Rewards

Although enzyme pretreatment of residuals appeared to enhance dewaterability when the residuals were conditioned with lime–iron and polymer, analysis of the enhancement options revealed that they were not cost-effective in this application. Using polymer to condition solids rather than iron and lime resulted in considerable operating savings, increased the plant's dewatering capacity and solids throughput, and reduced the amount of solids recycled in the plant. Only operating savings are discussed here.

An analysis of the cost-effectiveness of using polymer instead of iron and lime to condition residuals estimated that the switch would save approximately $403,000 per year (see Table 3, p. 68). Major operational savings result from lower labor costs and reduced costs associated with chemicals, disposal, and hauling. The plant has installed a permanent system for feeding polymer.

Several conclusions can be deduced from this study. First, press filtration conducted on a laboratory scale accurately predicted the performance of a full-scale plate-and-frame press. Enzyme pretreatment of residuals generated by the biological treatment of groundwater contaminated with perchlorate enhanced the dewaterability of the residuals when conditioned with iron and lime as well as polymer. However, conditioning solely with polymer proved the most cost-effective alternative for this facility. The study also indicates that a polymer dose lower than what is practiced typically in mechanical dewatering must be evaluated for dewatering using plate-and-frame presses. Finally, polymer conditioning increased the plant's solids capacity compared to conditioning with inorganic chemicals.

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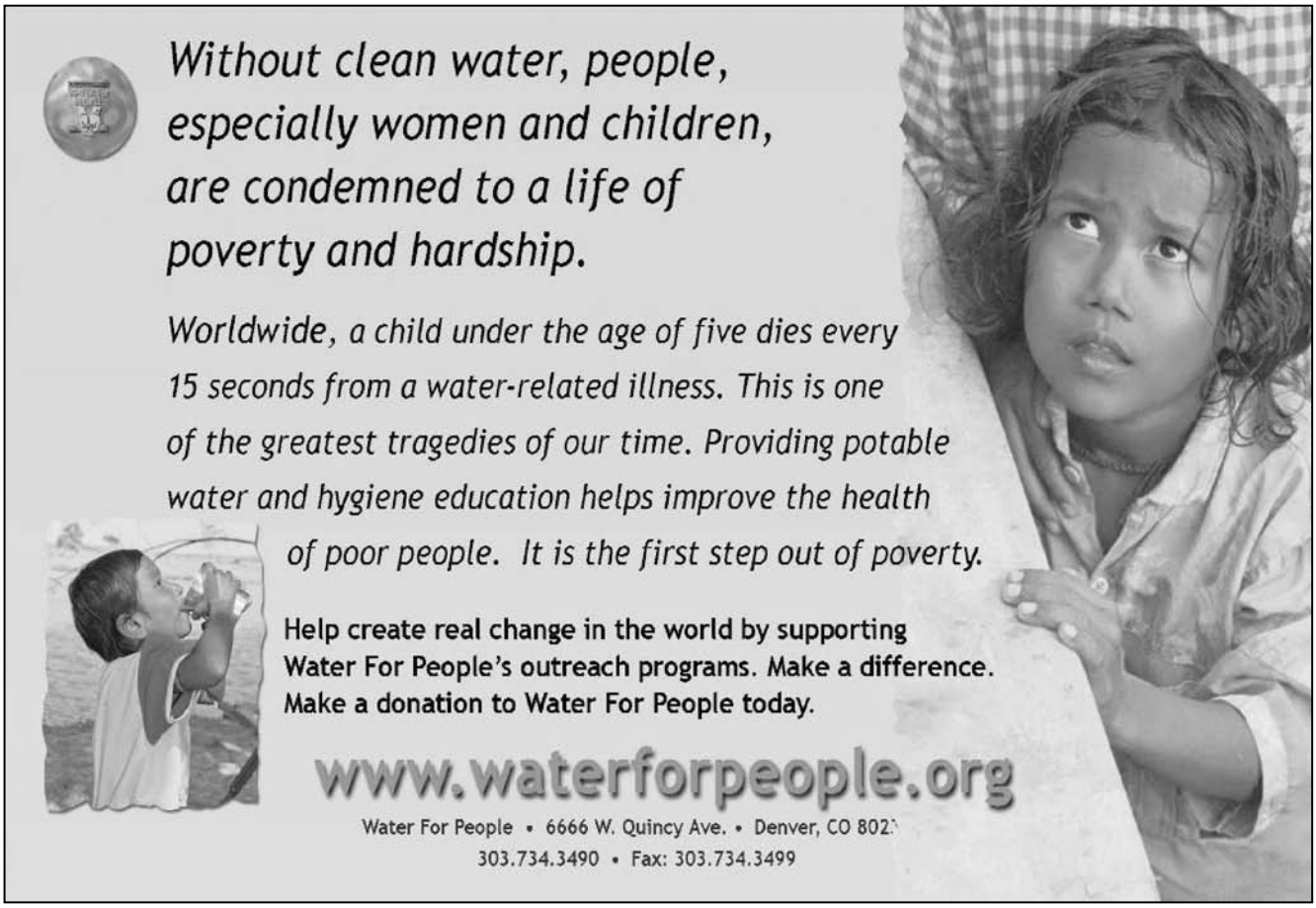

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