

## Supplementary Materials

# Sequestration and oxidation of Cr(III) by fungal Mn oxides with Mn(II) oxidizing activity

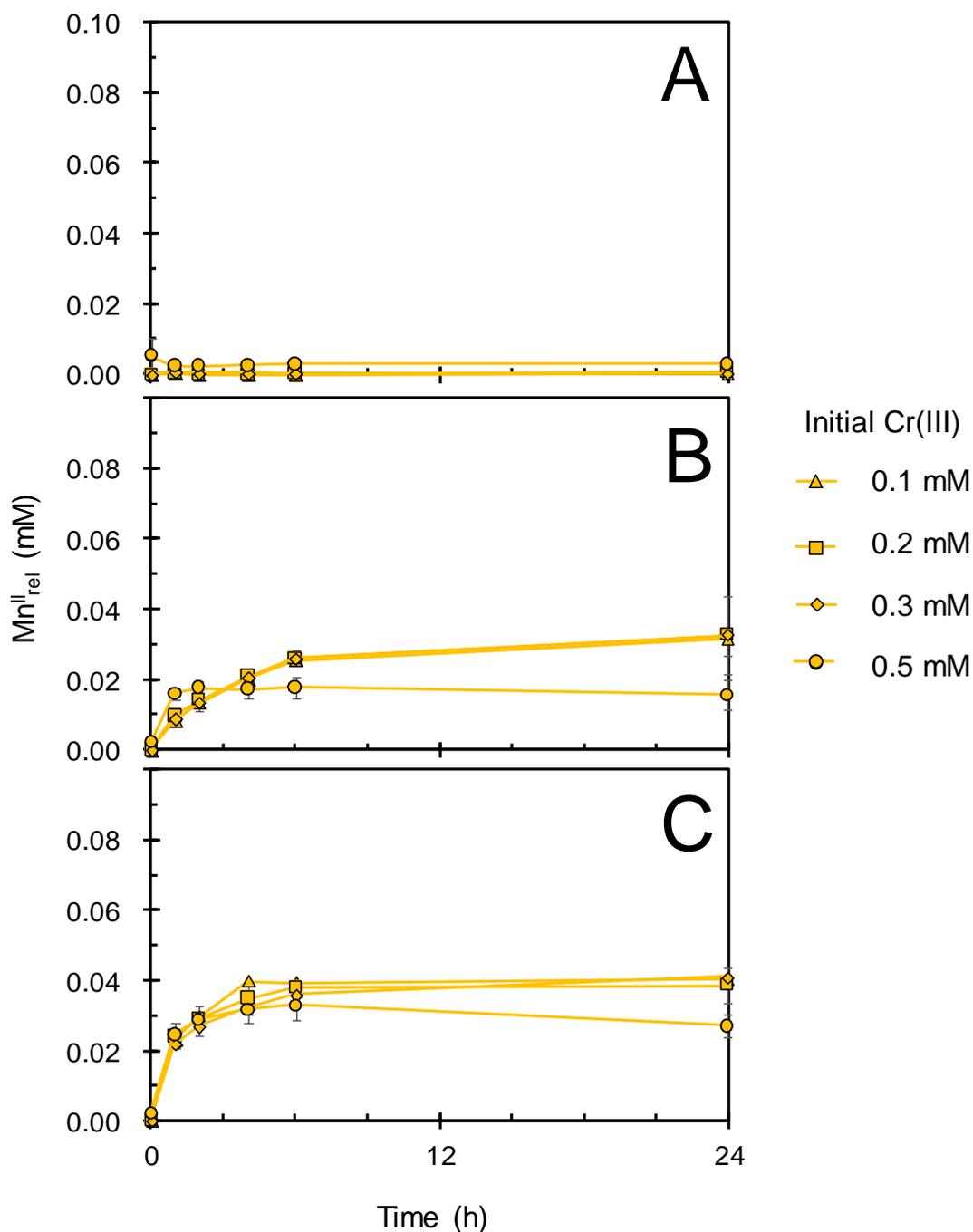
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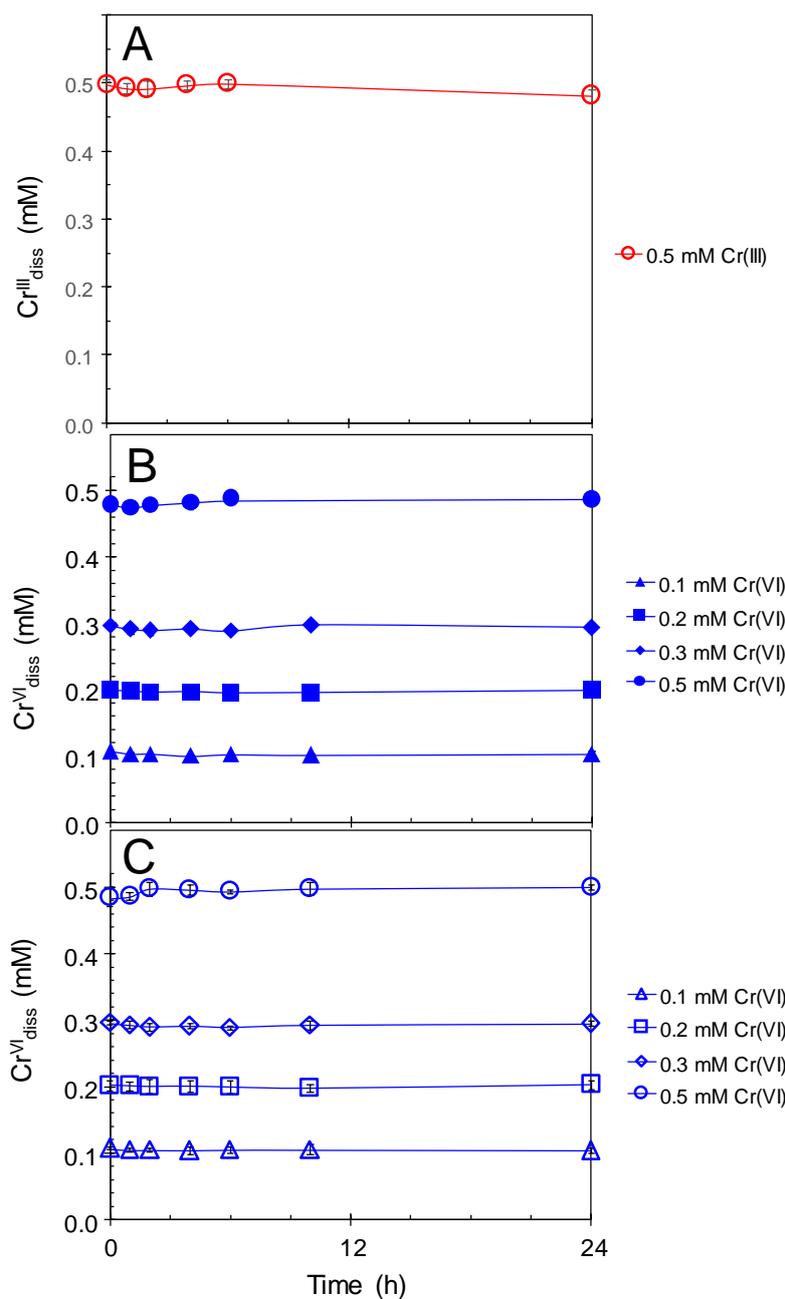
**Abbreviations, Figures S1, S2, and S3, and Tables S1 and S2.**

## Abbreviations used in this study

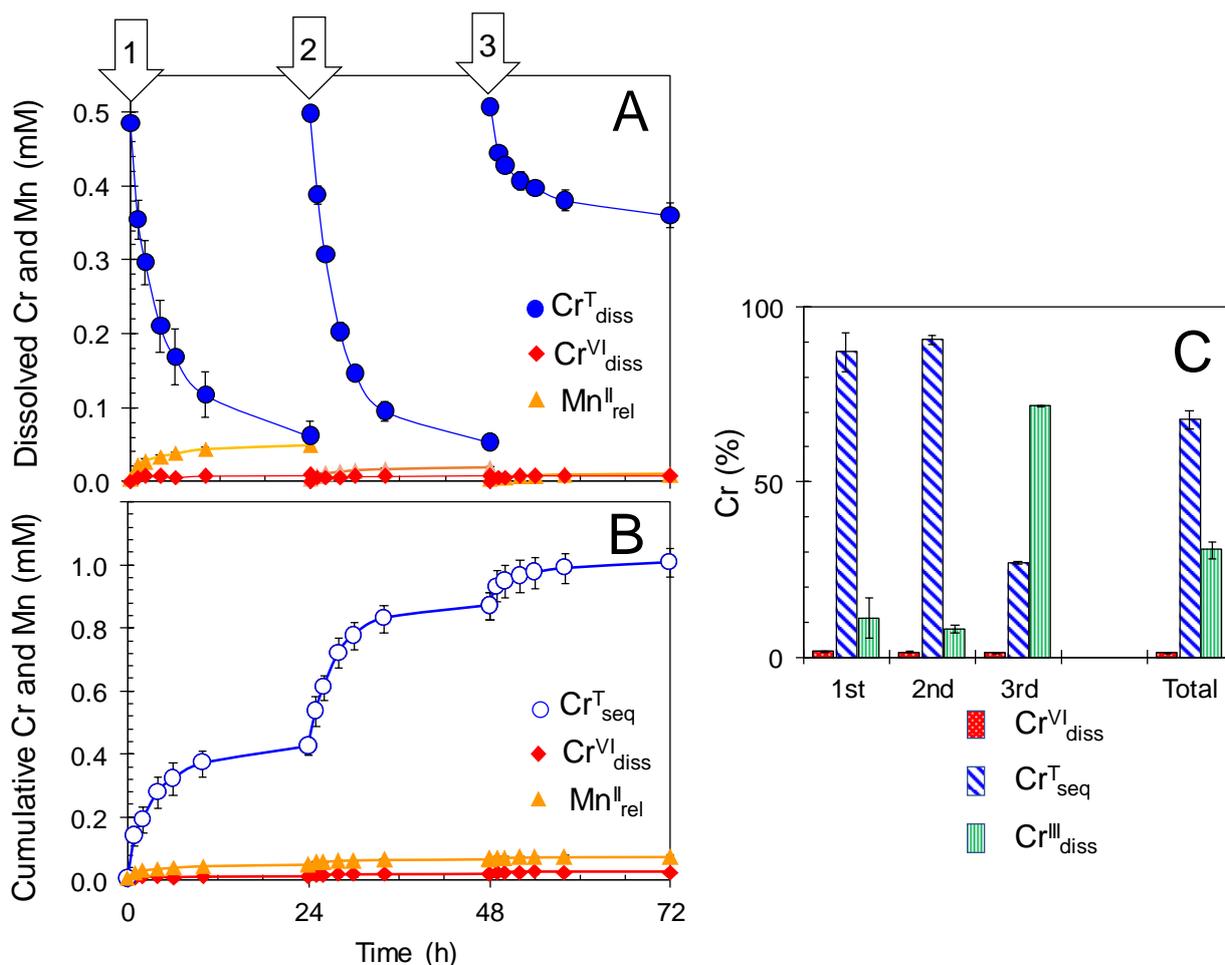
	Definition
$\text{Cr}^{\text{III}}_{\text{Int}}$	Initial concentration of Cr(III) dissolved (measured by ICP-AES).
$\text{Cr}^{\text{T}}_{\text{diss}}$	Total concentration of Cr dissolved (measured by ICP-AES).
$\text{Cr}^{\text{VI}}_{\text{diss}}$	Concentration of Cr(VI) dissolved (measured by th colorimetric method)
$\text{Cr}^{\text{III}}_{\text{diss}}$	Concentration of Cr(III) dissolved (calculated as $\text{Cr}^{\text{T}}_{\text{diss}} - \text{Cr}^{\text{VI}}_{\text{diss}}$ ).
$\text{Cr}^{\text{T}}_{\text{seq}}$	Total concentration of Cr sequestered (calculated as $\text{Cr}^{\text{III}}_{\text{Int}} - \text{Cr}^{\text{T}}_{\text{diss}}$ ).
$\text{Mn}^{\text{II}}_{\text{rel}}$	Concentration of Mn(II) released (measured by ICP-AES).
<b>BMOs</b>	Biogenic manganese oxides
<b>HEPES</b>	4-(2-hydroxyethyl)-1-piperazineethanesulphonic acid
<b>MES</b>	2-morpholinoethanesulfonic acid
<b>ICP-AES</b>	Inductively coupled plasma-atomic emission spectroscopy
<b>XANES</b>	X-ray absorption near-edge structure
<b>XRD</b>	X-ray diffraction



**Figure S1.** Concentrations of Mn(II) released ( $Mn^{II}_{rel}$ ) during single treatments of (A and B) newly formed and (C) heated biogenic manganese oxides (BMOs; 1 mM as Mn) with 0.1–0.5 mM  $Cr(NO_3)_3$  at pH 6.0 (100 mM MES buffer). Experiments were carried out under (A and C) aerobic or (B) anaerobic conditions. Data are shown as mean  $\pm$  standard deviation ( $n = 3$ ).



**Figure S2.** (A) Concentration of dissolved Cr(III) ( $\text{Cr}^{\text{III}}_{\text{diss}}$ ) in 0.5 mM  $\text{Cr}(\text{NO}_3)_3$  in 100 mM MES (pH 6.0). (B) Concentrations of dissolved Cr(VI) ( $\text{Cr}^{\text{VI}}_{\text{diss}}$ ) (0.1–0.5 mM  $\text{K}_2\text{Cr}^{\text{VI}}\text{O}_4$ ) in 100 mM MES (pH 6.0) when contacting with newly formed biogenic manganese oxides (BMOs; 1 mM as Mn). (C) Concentrations of Cr(VI) (0.1–0.5 mM) in 100 mM MES (pH 6.0) when contacting with newly formed fungal hyphae. All experiments were carried out under aerobic conditions. Data are shown as mean  $\pm$  standard deviation ( $n = 3$ ).



**Figure S3.** Repeated treatments of heated biogenic manganese oxides (BMOs; 1 mM as Mn) with 0.5 mM  $\text{Cr}(\text{NO}_3)_3$  under anaerobic conditions at pH 6.0 (100 mM MES buffer). (A) Concentrations of total Cr dissolved ( $\text{Cr}^{\text{T}}_{\text{diss}}$ ), Cr(VI) dissolved ( $\text{Cr}^{\text{VI}}_{\text{diss}}$ ), and Mn(II) released ( $\text{Mn}^{\text{II}}_{\text{rel}}$ ). (B) Cumulative concentrations of total Cr sequestered ( $\text{Cr}^{\text{T}}_{\text{seq}}$ ),  $\text{Cr}^{\text{VI}}_{\text{diss}}$ , and  $\text{Mn}^{\text{II}}_{\text{rel}}$ . (C) Percentages of  $\text{Cr}^{\text{VI}}_{\text{diss}}$ ,  $\text{Cr}^{\text{T}}_{\text{seq}}$  and Cr(III) dissolved ( $\text{Cr}^{\text{III}}_{\text{diss}}$ ) during the repeated treatments. Bathing solutions were renewed every 24 h for 3 days (indicated by arrows). Data are shown as mean  $\pm$  standard deviation ( $n = 3$ ).

**Table S1.** Summary of single treatment experiments for newly formed and heated biogenic manganese oxides (BMOs) in 0.1-0.5 mM Cr(NO<sub>3</sub>)<sub>3</sub>/100 mM MES (pH 6.0).

	Cr <sup>III</sup> <sub>int</sub> / mM	Cr <sup>VI</sup> <sub>diss</sub> / mM (%)	Cr <sup>T</sup> <sub>diss</sub> / mM	Cr <sup>III</sup> <sub>diss</sub> / mM (%)	Cr <sup>T</sup> <sub>seq</sub> / mM (%)	Mn <sup>II</sup> <sub>rel</sub> / mM
<b>Newly formed BMO</b> <b>(1 mM as Mn)</b> <b>Aerobic</b>	0.10 ± 0.00	0.08 ± 0.00 ( 83 ± 2 )	0.08 ± 0.00	0.00 ± 0.00 ( 0 ± 5 )	0.02 ± 0.00 ( 17 ± 3 )	0.00 ± 0.00
	0.20 ± 0.01	0.17 ± 0.00 ( 84 ± 4 )	0.17 ± 0.01	0.00 ± 0.01 ( 0 ± 4 )	0.03 ± 0.02 ( 16 ± 7 )	0.00 ± 0.00
	0.30 ± 0.01	0.24 ± 0.00 ( 79 ± 5 )	0.24 ± 0.01	0.00 ± 0.01 ( -1 ± 2 )	0.07 ± 0.02 ( 22 ± 7 )	0.00 ± 0.00
	0.46 ± 0.01	0.39 ± 0.02 ( 86 ± 2 )	0.39 ± 0.01	0.00 ± 0.02 ( 0 ± 5 )	0.06 ± 0.02 ( 13 ± 3 )	0.00 ± 0.00
<b>Newly formed BMO</b> <b>(1 mM as Mn)</b> <b>Anaerobic</b>	0.11 ± 0.00	0.03 ± 0.00 ( 30 ± 1 )	0.03 ± 0.00	0.00 ± 0.00 ( 1 ± 1 )	0.07 ± 0.00 ( 68 ± 1 )	0.03 ± 0.00
	0.20 ± 0.00	0.03 ± 0.00 ( 16 ± 0 )	0.03 ± 0.00	0.00 ± 0.00 ( 1 ± 1 )	0.17 ± 0.00 ( 83 ± 0 )	0.03 ± 0.00
	0.30 ± 0.00	0.03 ± 0.00 ( 10 ± 0 )	0.03 ± 0.00	0.00 ± 0.00 ( 0 ± 0 )	0.26 ± 0.00 ( 89 ± 1 )	0.03 ± 0.01
	0.47 ± 0.00	0.05 ± 0.01 ( 10 ± 1 )	0.04 ± 0.01	-0.01 ± 0.01 ( -2 ± 2 )	0.43 ± 0.01 ( 91 ± 1 )	0.02 ± 0.00
<b>Heated BMO</b> <b>(1 mM as Mn)</b> <b>Aerobic</b>	0.10 ± 0.00	0.02 ± 0.00 ( 24 ± 1 )	0.02 ± 0.00	0.00 ± 0.00 ( 0 ± 1 )	0.08 ± 0.00 ( 76 ± 0 )	0.04 ± 0.00
	0.19 ± 0.01	0.02 ± 0.00 ( 12 ± 0 )	0.02 ± 0.00	0.00 ± 0.01 ( 0 ± 3 )	0.17 ± 0.00 ( 88 ± 3 )	0.04 ± 0.01
	0.29 ± 0.01	0.02 ± 0.00 ( 6 ± 1 )	0.02 ± 0.00	0.00 ± 0.00 ( 0 ± 2 )	0.27 ± 0.01 ( 94 ± 1 )	0.04 ± 0.00
	0.45 ± 0.00	0.03 ± 0.00 ( 7 ± 0 )	0.03 ± 0.00	-0.01 ± 0.00 ( -1 ± 1 )	0.42 ± 0.00 ( 94 ± 0 )	0.03 ± 0.00

Concentrations of Cr(VI) dissolved (Cr<sup>VI</sup><sub>diss</sub>) and Mn(II) released (Mn<sup>II</sup><sub>rel</sub>) were measured by the colorimetric method.

Total concentration of Cr dissolved (Cr<sup>T</sup><sub>diss</sub>) was measured by ICP-AES.

Concentration of Cr(III) dissolved (Cr<sup>III</sup><sub>diss</sub>) was calculated as Cr<sup>T</sup><sub>diss</sub> - Cr<sup>VI</sup><sub>diss</sub>.

Total concentration of Cr sequestered (Cr<sup>T</sup><sub>seq</sub>) was calculated as Cr<sup>III</sup><sub>int</sub> - Cr<sup>T</sup><sub>diss</sub>.

**Table S2.** Summary of repeated treatment experiments for newly formed and heated biogenic manganese oxides (BMOs) in 0.5 mM Cr(NO<sub>3</sub>)<sub>3</sub>/100 mM MES (pH 6.0).

		<b>Cr<sup>III</sup><sub>int</sub> / mM</b>	<b>Cr<sup>VI</sup><sub>diss</sub> / mM (%)</b>	<b>Cr<sup>T</sup><sub>diss</sub> / mM</b>	<b>Cr<sup>T</sup><sub>seq</sub> / mM (%)</b>	<b>Mn<sup>II</sup><sub>rel</sub> / mM</b>
Newly formed BMO (1 mM as Mn) Aerobic	1st	0.47 ± 0.01	0.41 ± 0.01 ( 86 ± 2 )	0.41 ± 0.01	0.06 ± 0.01 ( 12 ± 2 )	0.00 ± 0.00
	2nd	0.51 ± 0.00	0.46 ± 0.01 ( 90 ± 2 )	0.45 ± 0.00	0.05 ± 0.01 ( 11 ± 1 )	0.00 ± 0.00
	3rd	0.50 ± 0.01	0.10 ± 0.00 ( 19 ± 0 )	0.09 ± 0.00	0.42 ± 0.01 ( 88 ± 1 )	0.00 ± 0.00
	Total	1.48 ± 0.02	0.96 ± 0.01 ( 65 ± 1 )	0.95 ± 0.01	0.53 ± 0.03 ( 36 ± 1 )	0.01 ± 0.00
Newly formed BMO (1 mM as Mn) Anaerobic	1st	0.46 ± 0.00	0.03 ± 0.00 ( 7 ± 0 )	0.04 ± 0.01	0.43 ± 0.01 ( 92 ± 1 )	0.02 ± 0.00
	2nd	0.47 ± 0.01	0.01 ± 0.00 ( 2 ± 0 )	0.01 ± 0.00	0.46 ± 0.01 ( 97 ± 0 )	0.01 ± 0.00
	3rd	0.48 ± 0.01	0.01 ± 0.00 ( 3 ± 0 )	0.18 ± 0.01	0.29 ± 0.02 ( 61 ± 4 )	0.01 ± 0.00
	Total	1.41 ± 0.01	0.06 ± 0.00 ( 4 ± 0 )	0.24 ± 0.01	1.18 ± 0.02 ( 83 ± 1 )	0.05 ± 0.00
Heated BMO (1 mM as Mn) Aerobic	1st	0.48 ± 0.00	0.01 ± 0.00 ( 2 ± 0 )	0.06 ± 0.02	0.42 ± 0.03 ( 87 ± 6 )	0.05 ± 0.00
	2nd	0.50 ± 0.01	0.01 ± 0.00 ( 2 ± 0 )	0.05 ± 0.01	0.45 ± 0.01 ( 91 ± 1 )	0.02 ± 0.00
	3rd	0.51 ± 0.00	0.01 ± 0.00 ( 1 ± 0 )	0.36 ± 0.02	0.14 ± 0.00 ( 27 ± 0 )	0.01 ± 0.00
	Total	1.49 ± 0.01	0.02 ± 0.00 ( 2 ± 0 )	0.48 ± 0.04	1.01 ± 0.04 ( 68 ± 3 )	0.07 ± 0.00

Concentrations of Cr(VI) dissolved (Cr<sup>VI</sup><sub>diss</sub>) and Mn(II) released (Mn<sup>II</sup><sub>rel</sub>) were measured by the colorimetric method.

Total concentration of Cr dissolved (Cr<sup>T</sup><sub>diss</sub>) was measured by ICP-AES.

Concentration of Cr(III) dissolved (Cr<sup>III</sup><sub>diss</sub>) was calculated as Cr<sup>T</sup><sub>diss</sub> - Cr<sup>VI</sup><sub>diss</sub>.

Total concentration of Cr sequestered (Cr<sup>T</sup><sub>seq</sub>) was calculated as Cr<sup>III</sup><sub>int</sub> - Cr<sup>T</sup><sub>diss</sub>.