UNIVERSITY OF ALBERTA

Biodegradation of organic compounds in OSPW with microbial communities indigenous to MFT

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"uplifting the whole people"
— HENRY MARSHALL TORY, FOUNDING PRESIDENT, 1908

Highlights

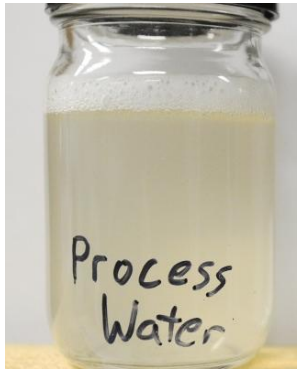
Objective: Evaluate the effectiveness of using indigenous microorganisms in degrading organic compounds in oil sands process-affected water (OSPW)

Experimental Methods: Bench-scale bioreactors

Results and Conclusions:

- With bioreactors, mature fine tailings (MFT) and MFT-extracted biofilms demonstrated the ability of degrading organic compounds in the OSPW. In addition, MFT-extracted biofilms could eliminate interference caused by MFT, allowing easier process monitoring and operation.
- A process of cultivating and recolonizing indigenous microorganisms on carriers to treat tailings water was developed.

Biodegradation and Biological Treatment



Process is cost-effective

Microorganisms are readily available

Aquatic toxicity could be reduced

Experimental Methods

Bench-scale bioreactors treating:

(1) OSPW supplemented with acetic acid

(2) OSPW after advanced oxidation treatment

Indigenous microorganisms with MFT

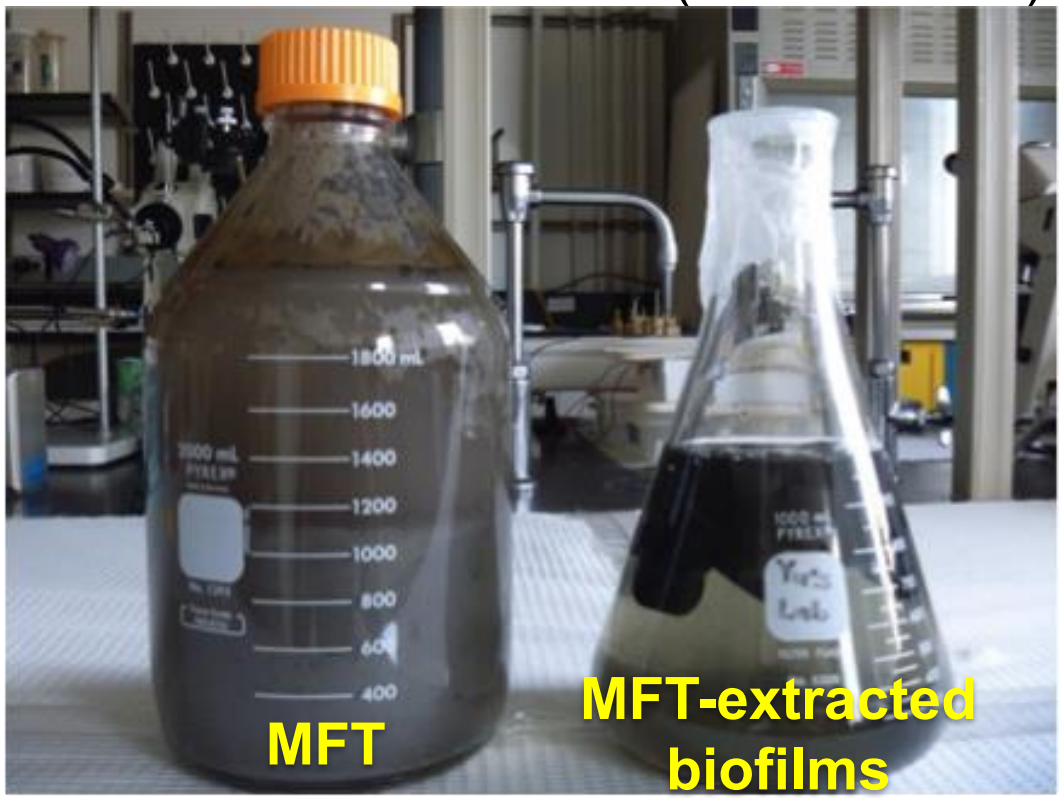
250 to 7000 mL OSPW/L MFT

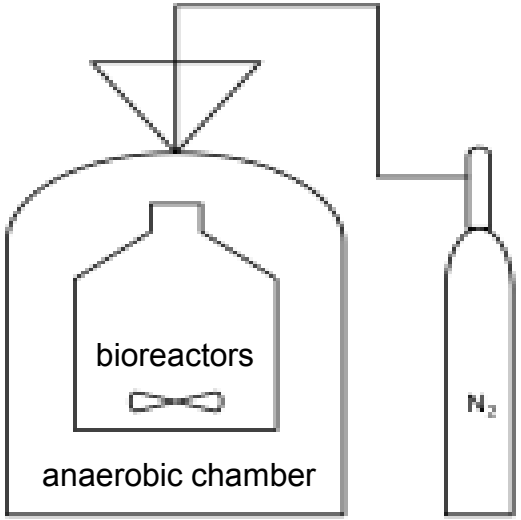
MFT-extracted biofilms on carriers without MFT

8000 to 16000 mL OSPW/m^2 of surface area

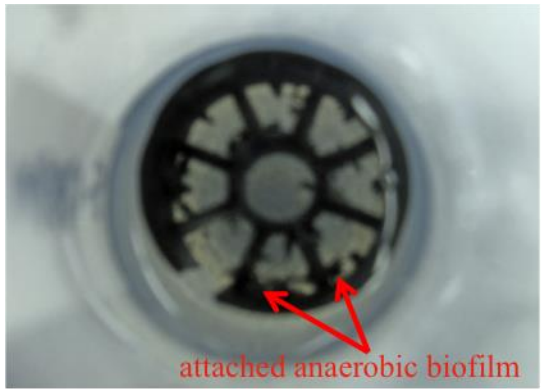
Experimental Methods – Cont.

Bench-scale bioreactors (i.e. bottles ☺)





Surface area: 500 m^2/m^3



Water Quality

Parameter	Units	OSPW	OSPW supplemented with acetic acid	OSPW after advanced oxidation	River (2011)
pH	-	8	**6**	7	6.5 - 9.0
Alkalinity	mg/L as $CaCO_3$	863	-	674	-
Sodium	mg/L	68	-	-	-
Ammonium	mg/L	43	-	-	0.1
Chloride	mg/L	358	358	-	120
Sulfate	mg/L	140	140	390	-
Nitrate	mg/L	ND	ND	ND	13
COD	mg/L	341	**564**	241	-
NAs	mg/L	38	34	1	-

(1) Acetic-acid-supplemented OSPW

Summary of COD removal in bioreactors using indigenous microorganisms with MFT

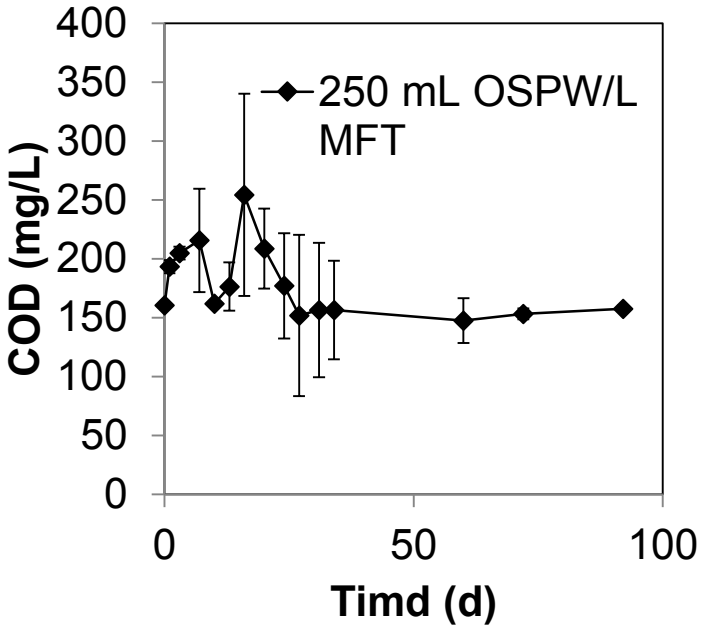
OSPW to MFT ratio (mL OSPW/L MFT)	Initial COD (mg/L)	Residue COD (mg/L)	Removal rate (%)
250	160	157	2
500	299	159	47
1000	564	**185**	67
3000	564	**204**	64
7000	564	**142**	75

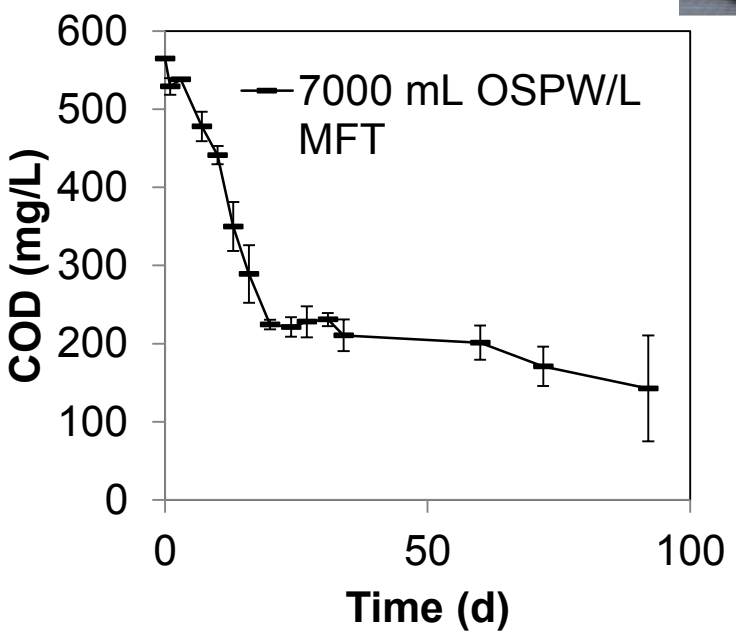
Original OSPW COD=341

(1) Acetic-acid-supplemented OSPW

COD removal in bioreactors

using indigenous microorganisms with MFT

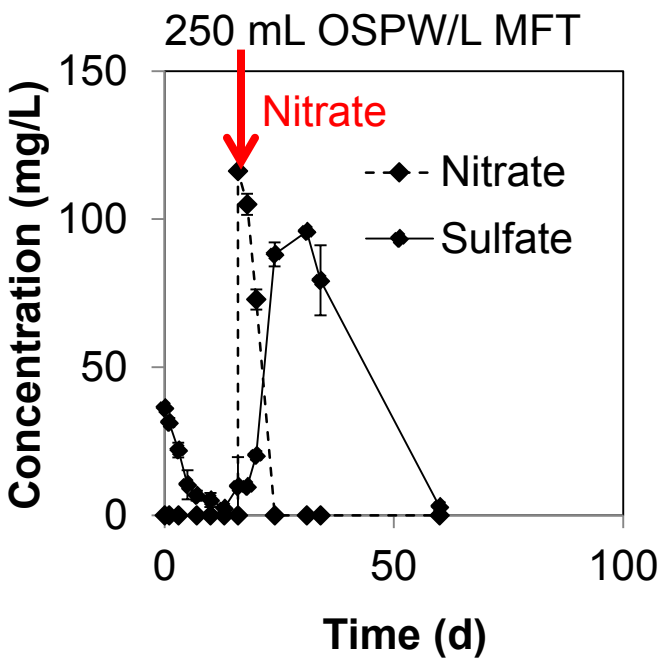


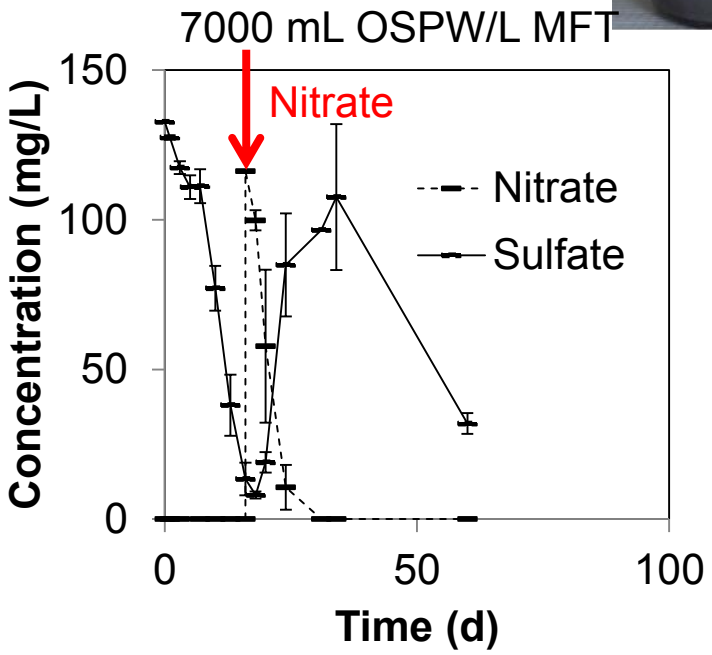


Rapid depletion of readily biodegradable organic compounds when substrate is sufficient

(1) Acetic-acid-supplemented OSPW

Sulfate reducing and denitrification processes





The indigenous microbial community could utilize organic compounds to support different anoxic processes.

(1) Acetic-acid-supplemented OSPW

Summary of NAs removal in bioreactors using indigenous microorganisms with MFT

OSPW to MFT ratio (mL OSPW/L MFT)	Initial NAs (mg/L)	Residue NAs (mg/L)	Removal rate (%)
250	17	23	-37
500	21	23	-12
1000	19	13	16
3000	25	22	13
7000	27	23	16

Moderate NAs removal when substrate is sufficient

(1) Acetic-acid-supplemented OSPW

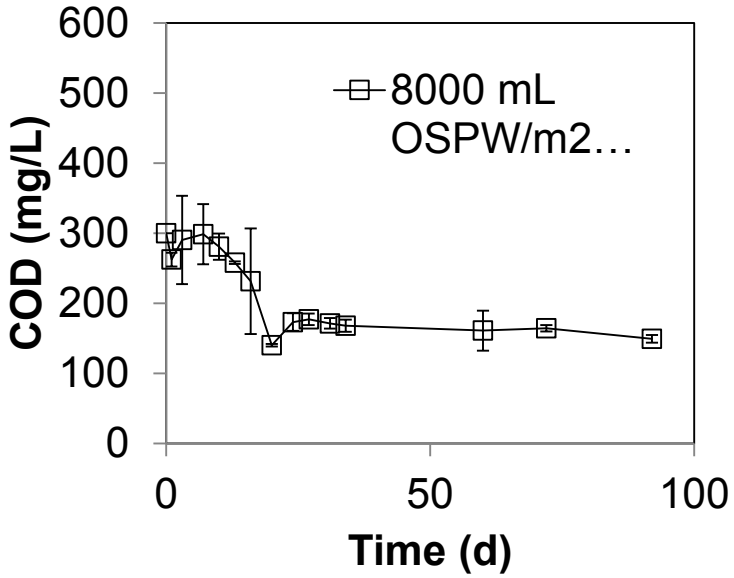
The hypothesis and solution

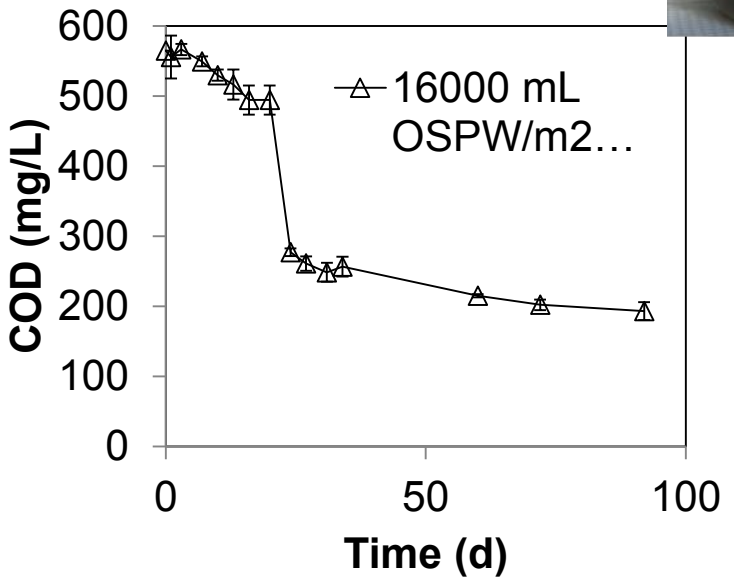
- Hypothesis: Leaching of NAs in residue bitumen carried by MFT.
- As a consortia of multiple microbial species that adhere to a surface, biofilm attached to carriers could eliminate the MFT while preserving the indigenous microbial communities.
- MFT-extracted biofilms was developed and tested for biodegradation.

(1) Acetic-acid-supplemented OSPW

COD removal in bioreactors

using MFT-extracted biofilms on carriers



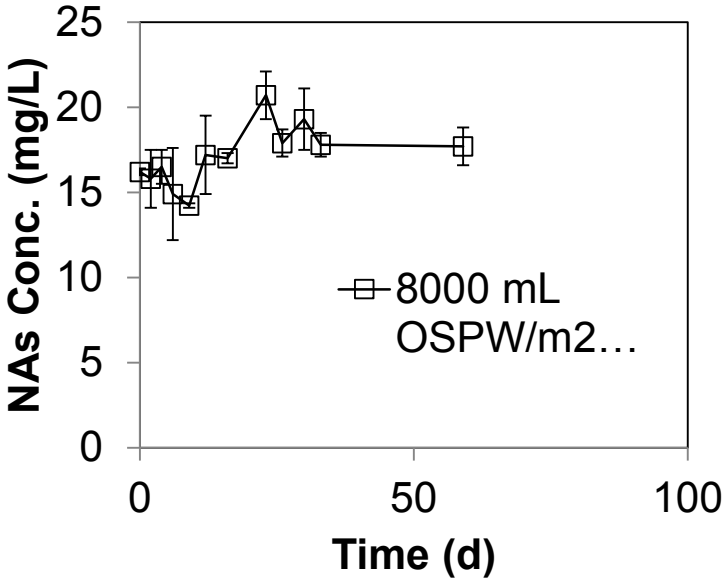


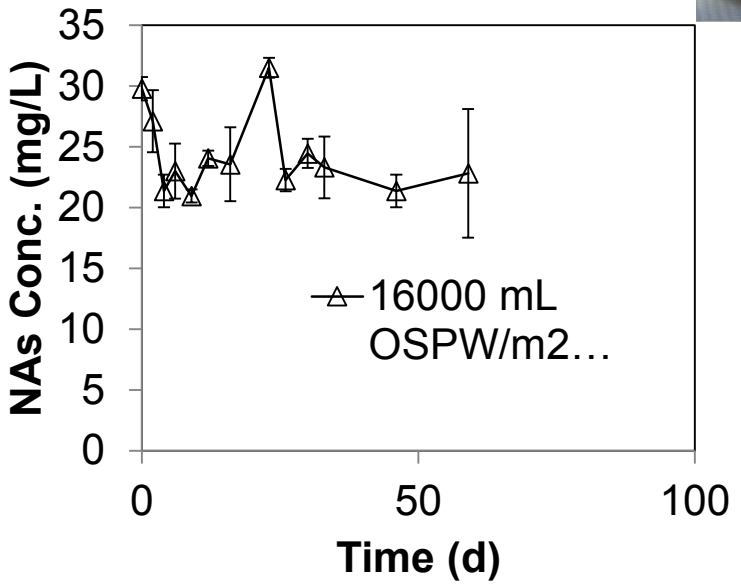
OSPW to surface area ratio (mL OSPW/m^2)	Initial COD (mg/L)	Residue COD (mg/L)	Removal rate (%)
8000	299	149	50
16000	564	193	66

(1) Acetic-acid-supplemented OSPW

NAs removal in bioreactors

using MFT-extracted biofilms on carriers





OSPW to surface area ratio (mL OSPW/m^2)	Initial NAs (mg/L)	Residue NAs (mg/L)	Removal rate (%)
8000	16	17	-9
16000	29	22	23

(1) Acetic-acid-supplemented OSPW

1. MFT harbors active and diverse microbial communities that could utilize organic compounds in OSPW to support different anaerobic biodegradation processes.

2. With the presence of acetic acid, partially removal of OSPW-originated dissolve organic compounds could be achieved indicating potential co-metabolism.

3. Using MFT-extracted biofilms could largely eliminated the interference caused by leaching of organic compounds from the MFT.

Water Quality

Parameter	Units	OSPW	OSPW supplemented with acetic acid	OSPW after advanced oxidation	River (2011)
pH	-	8	6	**7**	6.5 - 9.0
Alkalinity	mg/L as $CaCO_3$	863	-	674	-
Sodium	mg/L	68	-	-	-
Ammonium	mg/L	43	-	-	0.1
Chloride	mg/L	358	358	-	120
Sulfate	mg/L	140	140	**390**	-
Nitrate	mg/L	ND	ND	ND	13
COD	mg/L	341	564	**241**	-
NAs	mg/L	38	34	**1**	-

(2) OSPW after advanced oxidation

Summary of COD removal in bioreactors using indigenous microorganisms with MFT

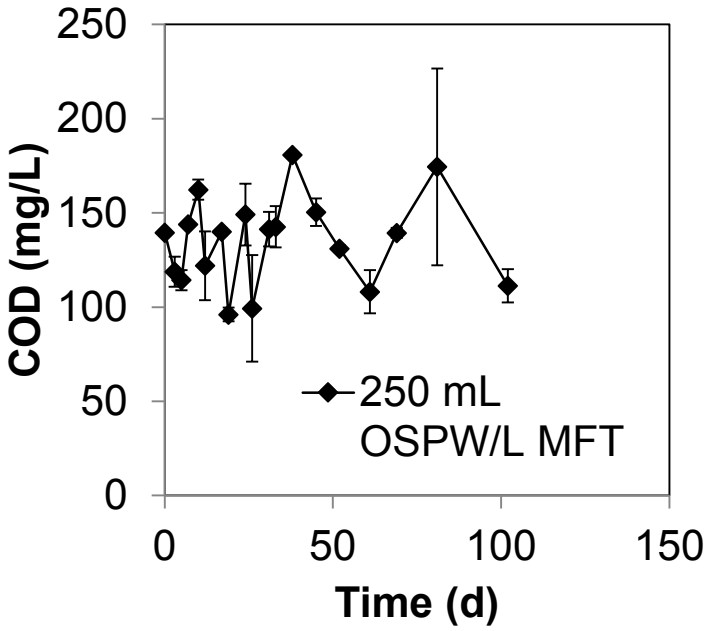
OSPW to MFT ratio (mL OSPW/L MFT)	Initial COD (mg/L)	Residue COD (mg/L)	Removal rate (%)
250	139	111	20
500	161	123	23
1000	244	148	39
3000	248	145	41
7000	266	137	48

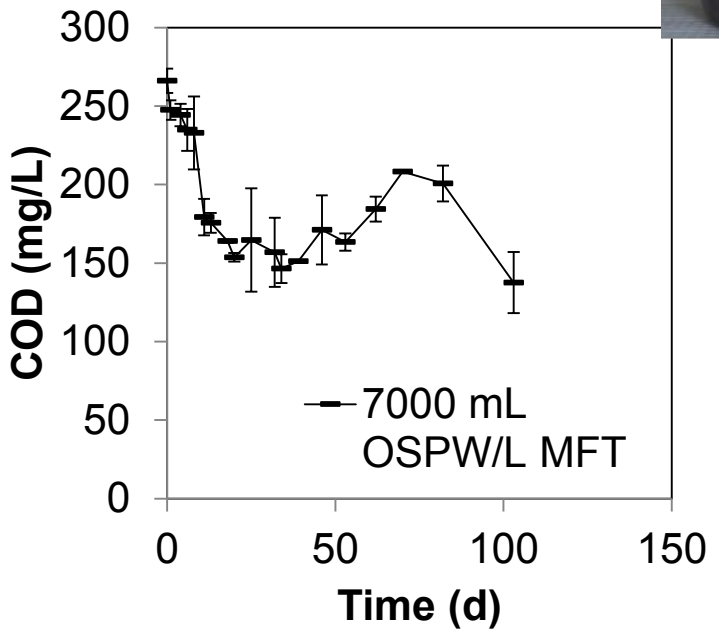
Advanced oxidation treatment promotes the biodegradation of dissolved organic compounds

(2) OSPW after advanced oxidation

COD removal in bioreactors

using indigenous microorganisms with MFT

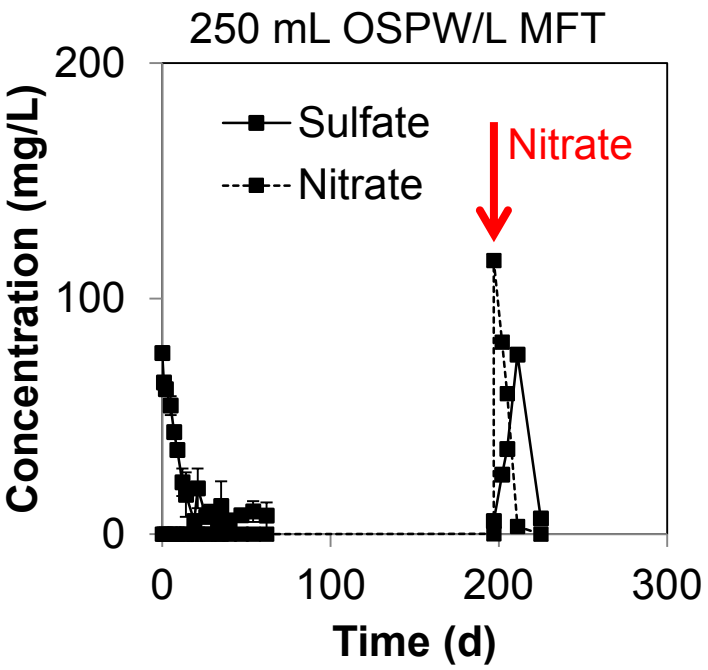


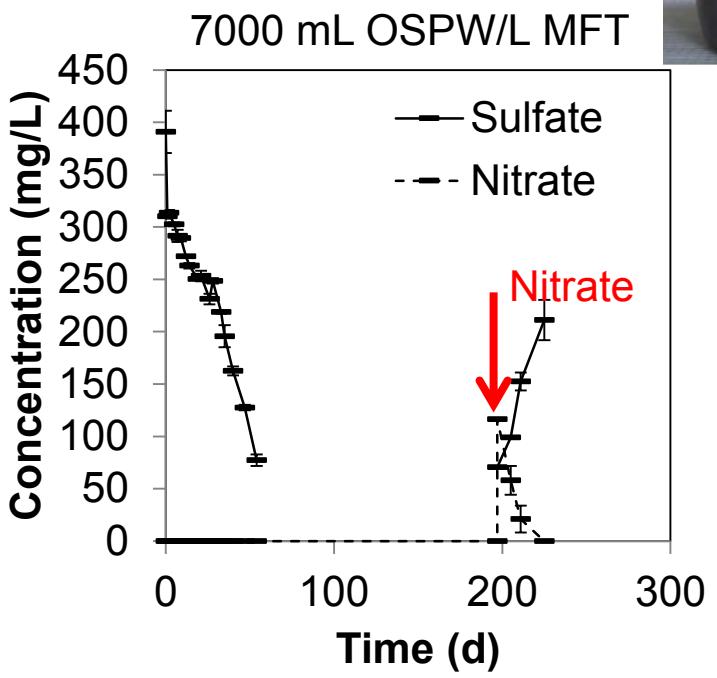


Frequent fluctuation when substrate is not sufficient, indicating unstable effluent quality

(2) OSPW after advanced oxidation

Sulfate reducing and denitrification processes



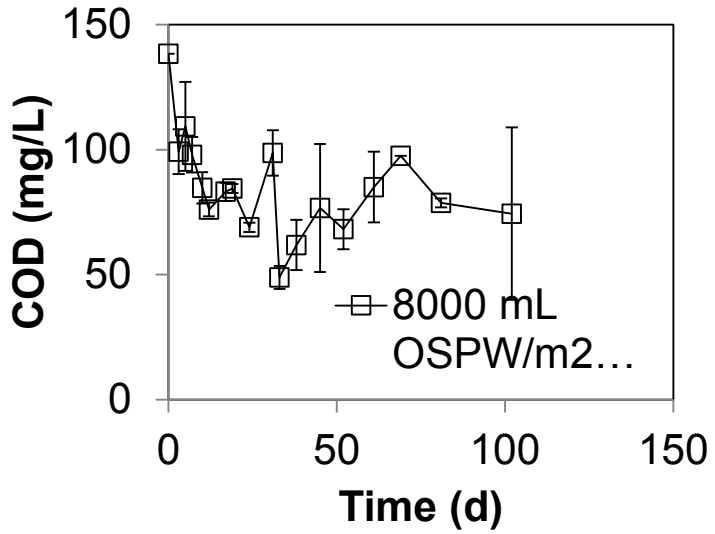


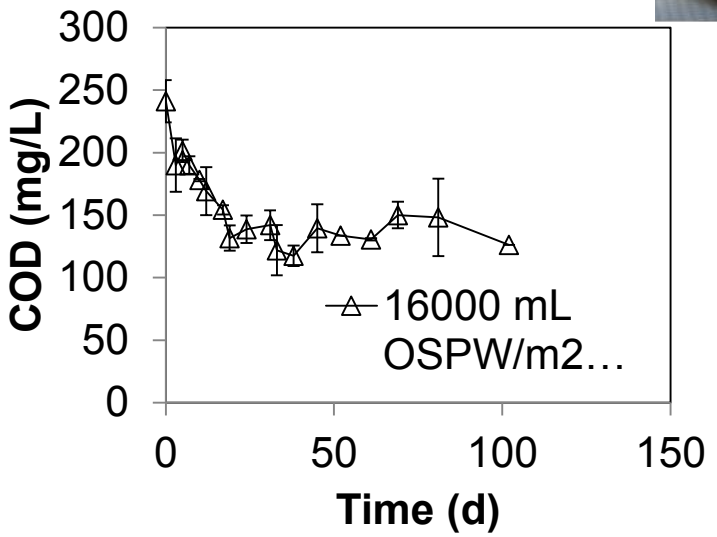
The indigenous microbial community could utilize organic compounds to support different anaerobic processes.

(2) OSPW after advanced oxidation

COD removal in bioreactors

using MFT-extracted biofilms on carriers

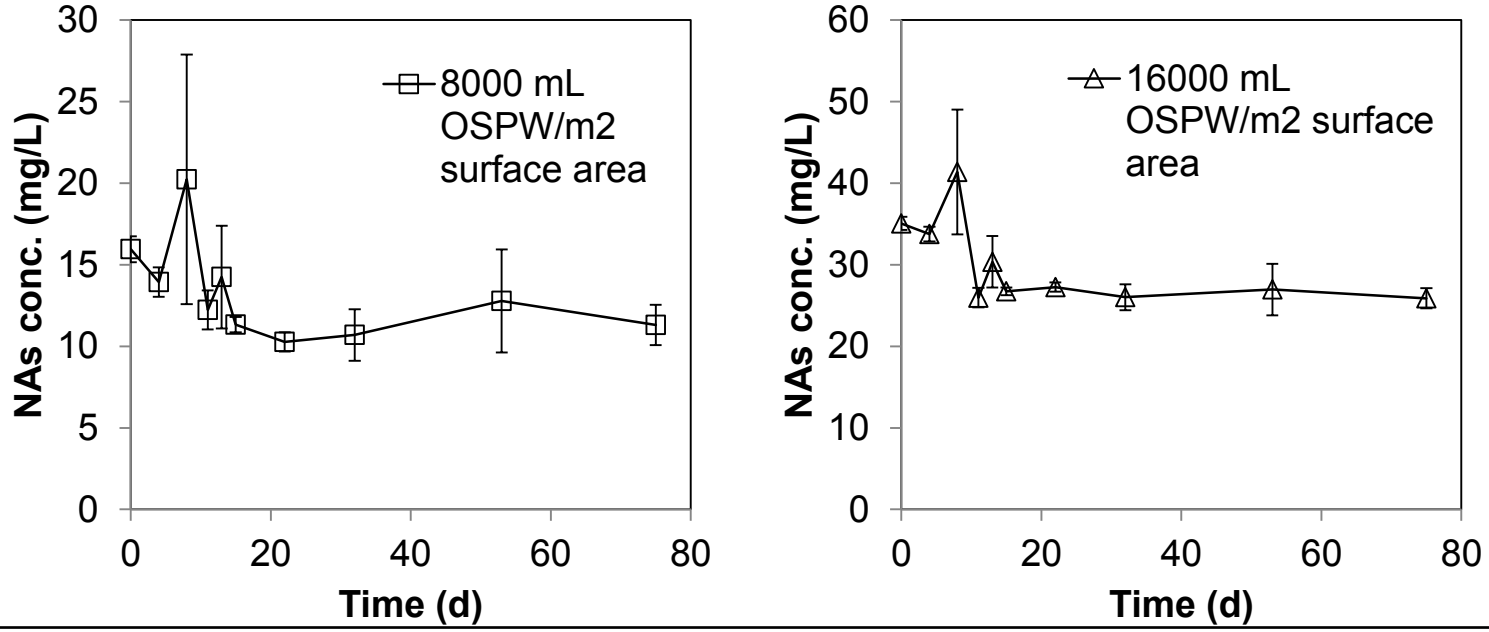




OSPW to surface area ratio (mL OSPW/m^2)	Initial COD (mg/L)	Residue COD (mg/L)	Removal rate (%)
8000	138	74	46
16000	241	126	48

(3) Acclimatized biofilm – A further confirmation

NAs removal in bioreactors using acclimatized biofilm



OSPW to surface area ratio (mL OSPW/m^2)	Initial NAs (mg/L)	Residue NAs (mg/L)	Removal rate (%)
8000	35	25	29
16000	16	11	26

Conclusions

1. **MFT harbors active and diverse microbial communities that could utilized organic compounds in OSPW to support different microbial activities.**

2. **Using MFT in bioreactors to treat OSPW presents difficulties in operations and process monitoring, because the residue NAs in bitumen carried by MFT would interfere with process monitoring**

3. **Indigenous microorganisms can be cultivated and recolonize on carriers to treat tailings water, indicating using biofilm reactor to remove organic compounds from OSPW is feasible.**

Acknowledgement

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Thank You!

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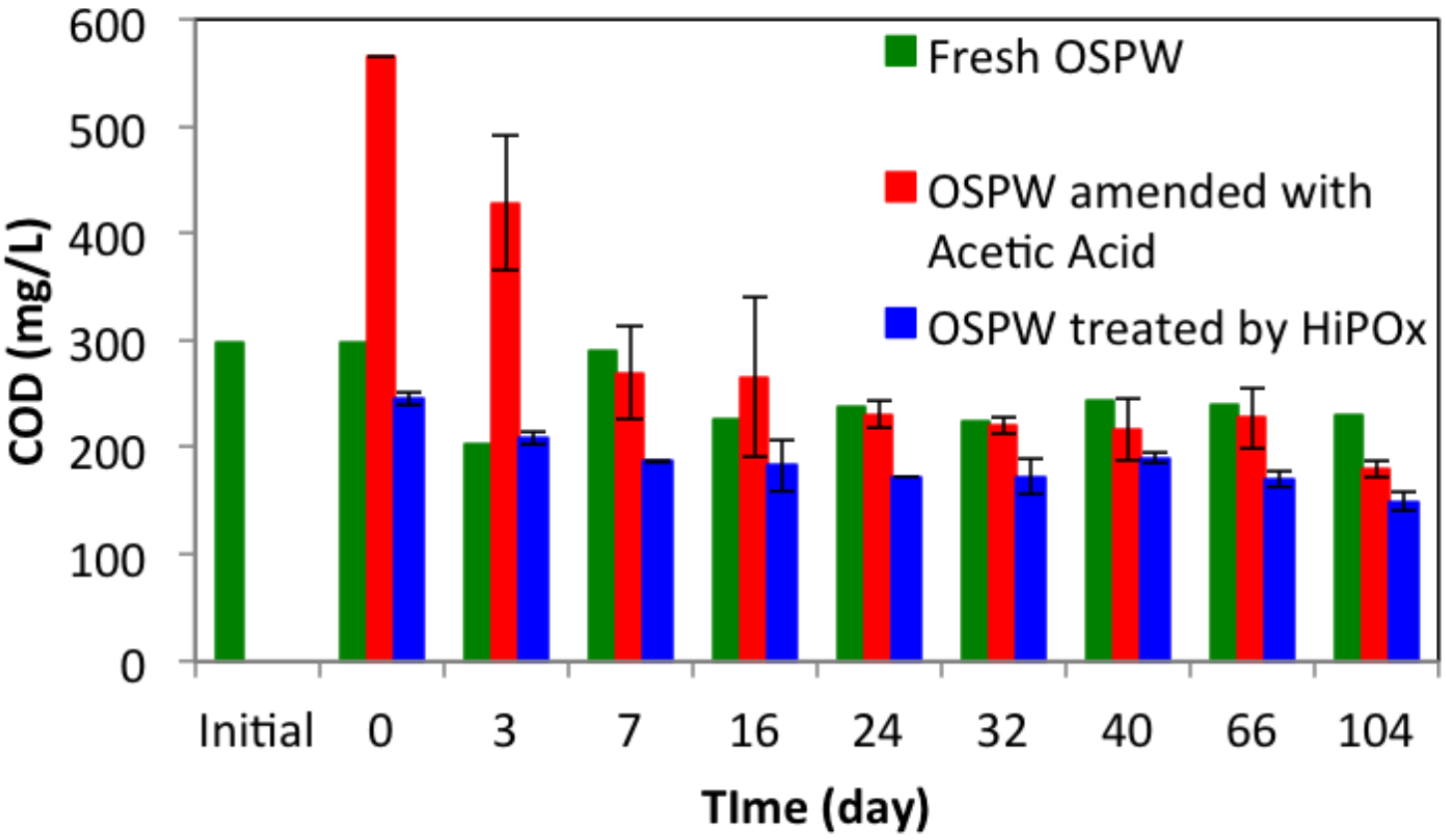
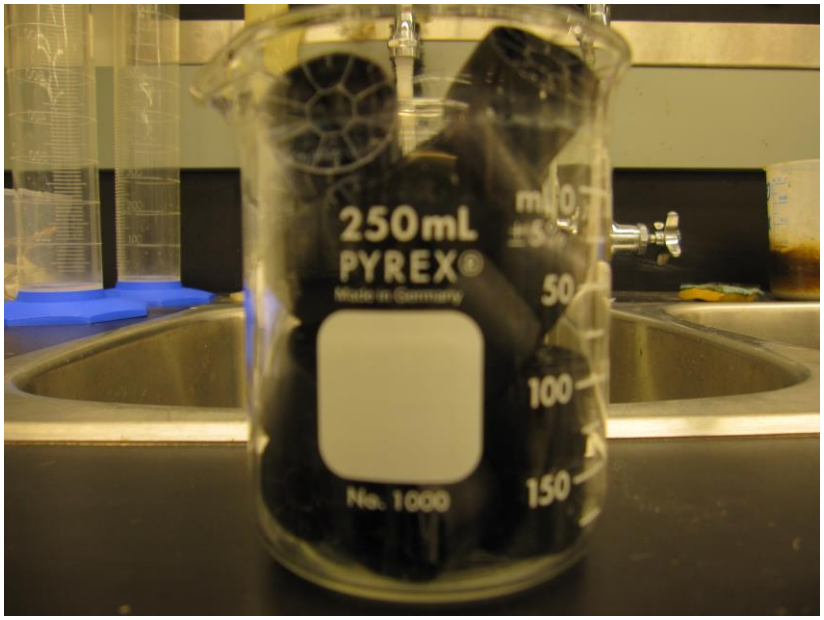

600
500
400
300
200
100
0
COD (mg/L)
Fresh OSPW
OSPW amended with Acetic Acid
OSPW treated by HiPOx
Initial
0
3
7
16
24
32
40
66
104
TIme (day)


250mL
PYREX
Made in Germany
No. 1000
50
100
150