Modified Date Palm Leaflets for the Treatment of Brackish Water

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Oman belongs to the arid to semi-arid regions

Average Precipitation

~ **50-100** mm per year\(^1\)

- Seawater \(\text{TDS} > 15,000\) mg/L
- Brackish water \(\text{TDS} 1000-15,000\) mg/L
- Fresh water \(\text{TDS} < 500\) mg/L

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\(^1\) Siebert, S., Nagieb, M., Buerkert, A., AGR WATER MANAGE 89 (2007) 1–14.
• Oman East cost is affected by the salinity since 1990s as a result of seawater intrusion.

Effects of Salinity on crops production
Deficit in water resources gives warning.
# Water Resources and Scarcity

## Water balance in million cubic meters per year

<table>
<thead>
<tr>
<th>Year</th>
<th>Water demand</th>
<th>The available water resources</th>
<th>Deficit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Agriculture</td>
<td>Drinking</td>
<td>Underground water</td>
</tr>
<tr>
<td>1990</td>
<td>1152</td>
<td>73</td>
<td>899</td>
</tr>
<tr>
<td>1995</td>
<td>1152</td>
<td>156</td>
<td>949</td>
</tr>
<tr>
<td>2000</td>
<td>1250</td>
<td>185</td>
<td>1004</td>
</tr>
<tr>
<td>2020</td>
<td>1250</td>
<td>460</td>
<td>1004</td>
</tr>
</tbody>
</table>

Qassim Al Jabry  *Water resources evaluation and conservation in Oman, proceedings of the first Regional conference on water demand management, conservation and control, WHO/UNEP, Jordan 2001.*
Current Technologies of light metals removal

- Desalination technologies
- Electrochemical precipitation
- Adsorption via ion exchange
- Capacitive deionization
- Thermal processes
- Membrane processes
• The required characteristics for effective technology:

✓ Relatively simple
✓ Economic viable
✓ Low energy
✓ Environmentally friendly
✓ Sustainable
✓ Reusable

• However, most current technologies lack some of these features
Date palm (*Phoenix dactylifera* L.)

Leaflets in Oman

- It is the most important crop grown in Oman with more than 9 million trees.
- About 180,000 tons of dry palm leaflets are produced annually and it is burnt in the farms leading to air pollution.
- GCC states produce 3 million tons per year.
Analysis of brackish water

<table>
<thead>
<tr>
<th>Well Farm</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barka</td>
<td>23.935° N, 58.619° E</td>
</tr>
<tr>
<td>Al-Musanaah</td>
<td>23.788° N, 57.515° E</td>
</tr>
<tr>
<td>As-Suwaq</td>
<td>23.504° N, 57.250° E</td>
</tr>
<tr>
<td>AlKhaburah</td>
<td>23.991° N, 57.090° E</td>
</tr>
<tr>
<td>Saham</td>
<td>24.136°N, 56.884° E</td>
</tr>
<tr>
<td>Sohar</td>
<td>24.278° N, 56.7999° E</td>
</tr>
<tr>
<td>Liwa</td>
<td>24.559° N, 56.565° E</td>
</tr>
<tr>
<td>Shinas</td>
<td>24.806° N, 56.426° E</td>
</tr>
<tr>
<td>Water Source</td>
<td>Conductivity (ms/cm)</td>
</tr>
<tr>
<td>--------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>Barka</td>
<td>11455</td>
</tr>
<tr>
<td>Al Musanah</td>
<td>1878</td>
</tr>
<tr>
<td>Al Suwayq</td>
<td>12007</td>
</tr>
<tr>
<td>Al Khabura</td>
<td>28739</td>
</tr>
<tr>
<td>Saham</td>
<td>2139</td>
</tr>
<tr>
<td>Sohar</td>
<td>1195</td>
</tr>
<tr>
<td>Liwa</td>
<td>22866</td>
</tr>
<tr>
<td>Shinas</td>
<td>1478</td>
</tr>
</tbody>
</table>

K 0.2 – 27 mg/L, Fe 0-0.47, Zn < 0.35 mg/L, Cr < 0.3 mg/L
Carbon ion exchanger

Palm leaflets $\xrightarrow{\text{Chemical carbonization}}$ DC $\xrightarrow{\text{sulfonation}}$ SDC

Chemical structures:
- DC
- SDC containing $\text{SO}_3\text{H}$ groups
## Characterisation of DC and SDC

<table>
<thead>
<tr>
<th></th>
<th>Apparent density</th>
<th>Ash content</th>
<th>moisture</th>
<th>EDS Elemental analysis (%)</th>
<th>CEC</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC</td>
<td>0.36</td>
<td>17.6%</td>
<td>17%</td>
<td>C</td>
<td>59.8</td>
</tr>
<tr>
<td>SDC</td>
<td>0.44</td>
<td>15.1%</td>
<td>18%</td>
<td>O</td>
<td>54.7</td>
</tr>
</tbody>
</table>
The diagram shows the effect of pH on metal removal. The ordinate represents the metal sorbed (mg g⁻¹) and the abscissa represents the initial pH. The curves indicate that as the pH increases, the amount of metal sorbed increases for all elements. The legend indicates that Ca is sorbed more than Mg, which is sorbed more than Na. The comparison is quantified as Ca > Mg >> Na.
Sorption favorability

In Charge density:
Mg(II) > Ca(II) > Na(I)
But due to hydration
Mg(II) > Ca(II) > Na(I)

Thus
Ca(II) > Mg(II) > Na(I)
Sorption from Sohar farm well

Mg 379 mg L\(^{-1}\), Ca 88.4 mg L\(^{-1}\), Na 393 mg L\(^{-1}\)
Sorption from Sohar farm well

Mg 350 mg L$^{-1}$, Ca 28 mgL$^{-1}$, Na 270 mg L$^{-1}$

Metal removal (%) vs Mass of carbon (g)
Recycle

Sohar

Mg 350 mg L\(^{-1}\), Ca 28 mg L\(^{-1}\), Na 270 mg L\(^{-1}\)
Recycle

Al-Khabora

Mg 1852 mg L\(^{-1}\), Ca 1546 mg L\(^{-1}\), Na 7863 mg L\(^{-1}\)
Column Work: Al Musanah well DC

- Na(I) 393 mg L$^{-1}$
- Mg(II) 379 mg L$^{-1}$
- Ca(II) 88.4 mg L$^{-1}$
Ca(II) 88.4 mg L$^{-1}$
Mg(II) 378 mg L$^{-1}$
Na(I) 393 mg L$^{-1}$

Column Work: Al Musanah well
SDC
Column capacities

- DC: Mg 96 mg/g, Na 69 mg/g, Ca 26 mg/g
- SDC: Mg 100 mg/g, Na 89 mg/g, Ca 35 mg/g

Estimated Cost

For a reuse of 10 times 0.6 $ / cubic meter
For a reuse of 50 times 0.22 $ / cubic meter
Current & Future work

- Removal of anions
For removal of metals

For removal of organic moieties
Conclusions

1. SDC carbon is more effective than DC in removing Na and other metals.

2. BDC is good for heavy metals and anions.

3. Ultimate goal is to prepare a multipurpose filter from cheap sustainable, reusable and effective resource of date palm leaflets.
Acknowledgment

- Amal Al- Hadi
- Mr. Abdulallh Al-Hamdy.
- Mr. Saif Al-Mamari , Department of Earth Science for X-ray diffraction analysis
- Mr. Mohammed Al-Kindi , College of Medicine for SEM and EDS analysis.
- Omani Research Council for Fund