CHAPTER IV

HYDRAULIC CONDUCTIVITY OF MIXED SOILS

IN RELATION TO FERTILIZER SOLUTIONS
HYDRAULIC CONDUCTIVITY OF MIXED SOILS IN RELATION TO FERTILIZER SOLUTIONS

A key problem in the utilisation of salt affected soils is the maintenance of sufficient permeability to permit salinity control and reclamation.

The hydraulic conductivity of the soil, primarily depends on amount of clay and type of clay present. In addition saturation of the soil base complex changes the hydraulic conductivity behaviour. The hydraulic conductivity results can be used to understand the behaviour of nutrients availability of plants under specific root growth of different plants. Martin and Richards (8) have studied influence of exchangeable H, Ca, Na, K and NH₄ on physical properties of soils. According to Shainberg and Caiserman (13) the hydraulic permeability of the Na-montmorillonite membrane can be predicted from the cozeny equation, modified to include a correlation for absorbed water whose mobility is less than that to bulk water. They have studied Na/Ca montmorillonite system for their hydraulic conductivities. Ahmed et al (1)
studied the effect of absorbed cations on physical properties of soils and found that percentage stable aggregates of artificially prepared aggregates and hydraulic conductivity were affected by the four cations in the order Ca>Mg>K>Na and were also significantly affected by clay type. Combination of the four cations generally gave intermediate effect with Ca-saturated soil were more susceptible to determination by K or Na than Mg saturated soil.

A study was made by Moustaga, A.T.P., EL Abedine (9) regarding the effect of exchangeable cations on water permeability and found the same order. They have also showed that soil saturated with Na were not permeable at any soil bulk density. In Ca-saturated soil, medium permeability was reached in a shorter time while in Mg and K saturated soil it took a longer time to achieve maximum permeability.

Kaurie, C. (5) has shown that percolation of sandy loam calcareous soils with (NH₄)₂SO₄ led to NH₄ adsorption and Ca leaching during NH₄ nitrification. He has also observed
that when the doses of \((\text{NH}_4)_2\text{SO}_4\) increased there was proportionate increase in Ca leaching. Aseed, M., Abdio G. S., Omer, S (2) has studied the pore size distribution and saturation hydraulic conductivity in calcareous soils as affected by calcium monobasic phosphate to sample of a sandy loam reduced both total pore space and the size of individual pores.

The treated soil hold moisture at a comparatively higher tension than untreated soil due to the reduction on pore size. The treated soil has a lower hydraulic conductivity and this reduction was proportional to the rate of phosphate added. They have also observed that in the treated soil the flux versus hydraulic gradient was linear i.e. flow was Darcin in the treated soil flow did not obey Darcy's law.

Okjima, H., Imat, H., (10) have observed than the nutrient concentration of the soil solution was mainly controlled by the type and amount of anions. They have shown that the concentration of \(\text{SO}_4\) derived from applied \((\text{NH}_4)_2\text{SO}_4\) was relatively low, because adsorption due to allophane nature of
the soil. Kanwar, J.S. et al (7) while studying the availability of phosphorus in fertilizer mixture containing calcium, ammonium nitrate have observed that, available $P_2O_5$ in slightly alkali and acid soils than gypsum pressed and lime stone, while ammonium sulphate proved better for more calcareous and alkali soils. Shah, J.N. (12) has showed that the recovery of nitrogen from ammonium sulphate was highest in acidic as well as in the neutral soils and minimum in highly alkaline soils. Goswami, N.N. et al (6) while studying the effect of rate of addition of phosphorus on the uptake of soils and fertilizer phosphate has showed that, phosphorus uptake from fertilizers was very low as compared to that from the soil.

Basar, B.W. and Ram Deo (4) while studying the effect of superphosphate on the uptake of micronutrients have observed that uptake of micronutrients was increased where as Cu and B contents were decreased with higher doses of superphosphate treatment in certain soils.
Subramanian, T. R. et al (14) while studying the effect of Chilean nitrate, ammonium sulphate, urea or calcium ammonium nitrate on soil characteristics observed that, ammonium sulphate, urea or calcium ammonium nitrate were superior than chilian nitrate. They have also observed that the pH of soils in ammonium sulphate treated plot was less than in those with calcium ammonium nitrate. Rao, F.S. et al (11) while studying the restoration of permeability to water of soils rendered impermeable earlier by sodium carbonate, have showed that, NH₄Br and NH₄NO₃ were most effective, Calcium chloride and barium chloride slightly less effective, NH₄Br, and (NH₄)₂SO₄ were nearly 30 percent as effective as ammonium chloride, ammonium per phosphate was particularly ineffective.

Botking (3) has studied the effect of constituents of fertilizers soil amendments on the permeability of certain fine textured soils. Vostad J. et al (15) have given the following order while studying the effect of K₂HPO₄, KCl and K₂SO₄ on nitrogen fertilizer transformation in soil.

Urea ammonium nitrate ammonium sulphate potassium sulphate.
In the present work mixed soil samples were prepared and a study of hydraulic conductivity have been made with 0.5\%, 1.0\% and 2.0\% solutions of Urea, ammonium sulphate and di-ammonium phosphate.

Results are tabulated and graphical representation is also made.
Hydraulic Conductivity (K = Cm/dry) of Mixed soils for Fertilizer solution.

<table>
<thead>
<tr>
<th>Table 10. (4.1A)</th>
<th>Table 10. (4.1B)</th>
<th>Table 10. (4.1C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5 % D.A.P.</td>
<td>1.0 % D.A.P.</td>
<td>2.0 % D.A.P.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Days</th>
<th>Normal soil Na</th>
<th>Ca</th>
<th>Normal soil Na</th>
<th>Ca</th>
<th>Normal soil Na</th>
<th>Ca</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5.59</td>
<td>14.67</td>
<td>4.48</td>
<td>15.42</td>
<td>19.40</td>
<td>26.47</td>
</tr>
<tr>
<td>2</td>
<td>2.34</td>
<td>0.28</td>
<td>1.34</td>
<td>8.11</td>
<td>11.67</td>
<td>9.27</td>
</tr>
<tr>
<td>3</td>
<td>1.80</td>
<td>0.25</td>
<td>1.04</td>
<td>6.40</td>
<td>10.38</td>
<td>6.08</td>
</tr>
<tr>
<td>4</td>
<td>1.44</td>
<td>0.25</td>
<td>0.59</td>
<td>5.52</td>
<td>12.97</td>
<td>4.00</td>
</tr>
<tr>
<td>5</td>
<td>1.26</td>
<td>-</td>
<td>0.35</td>
<td>4.94</td>
<td>10.38</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>1.11</td>
<td>-</td>
<td>0.35</td>
<td>2.01</td>
<td>9.74</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>1.11</td>
<td>-</td>
<td>2.01</td>
<td>9.74</td>
<td>7.57</td>
<td>51.22</td>
</tr>
</tbody>
</table>

102
Hydraulic Conductivity (K= cm/day) of Mixed Soils for Fertilizer solution.

<table>
<thead>
<tr>
<th>Days</th>
<th>0.5% D.A.P.</th>
<th>1.0% D.A.P.</th>
<th>2.0% D.A.P.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15% Na</td>
<td>25% Na</td>
<td>40% Na</td>
</tr>
<tr>
<td>1</td>
<td>61.36</td>
<td>32.18</td>
<td>29.54</td>
</tr>
<tr>
<td>2</td>
<td>22.72</td>
<td>21.09</td>
<td>16.20</td>
</tr>
<tr>
<td>3</td>
<td>6.49</td>
<td>16.80</td>
<td>8.11</td>
</tr>
<tr>
<td>5</td>
<td>5.19</td>
<td>7.09</td>
<td>5.84</td>
</tr>
<tr>
<td>6</td>
<td>3.89</td>
<td>7.00</td>
<td>4.87</td>
</tr>
<tr>
<td>7</td>
<td>1.62</td>
<td>6.84</td>
<td>3.24</td>
</tr>
</tbody>
</table>
Hydraulic Conductivity \((K = \text{Cm/day})\) of Mixed Soils for Fertilizer solutions.

<table>
<thead>
<tr>
<th>Days</th>
<th>Normal soil</th>
<th>Na soil</th>
<th>Ca soil</th>
<th>Normal soil</th>
<th>Na soil</th>
<th>Ca soil</th>
<th>Normal soil</th>
<th>Na soil</th>
<th>Ca soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>95.93</td>
<td>77.92</td>
<td>-</td>
<td>11.59</td>
<td>3.24</td>
<td>36.42</td>
<td>45.43</td>
<td>103.80</td>
<td>64.93</td>
</tr>
<tr>
<td>2</td>
<td>23.15</td>
<td>8.87</td>
<td>-</td>
<td>4.63</td>
<td>2.43</td>
<td>4.87</td>
<td>38.96</td>
<td>85.71</td>
<td>10.32</td>
</tr>
<tr>
<td>3</td>
<td>5.64</td>
<td>1.08</td>
<td>-</td>
<td>3.71</td>
<td>1.62</td>
<td>3.65</td>
<td>69.87</td>
<td>110.38</td>
<td>8.77</td>
</tr>
<tr>
<td>4</td>
<td>4.23</td>
<td>0.86</td>
<td>-</td>
<td>3.71</td>
<td>1.63</td>
<td>3.35</td>
<td>63.07</td>
<td>90.40</td>
<td>7.57</td>
</tr>
<tr>
<td>5</td>
<td>1.41</td>
<td>0.64</td>
<td>-</td>
<td>4.63</td>
<td>1.29</td>
<td>3.24</td>
<td>40.31</td>
<td>70.37</td>
<td>7.93</td>
</tr>
<tr>
<td>6</td>
<td>1.41</td>
<td>0.38</td>
<td>-</td>
<td>3.71</td>
<td>1.15</td>
<td>2.84</td>
<td>31.58</td>
<td>55.09</td>
<td>7.21</td>
</tr>
<tr>
<td>7</td>
<td>1.27</td>
<td>0.30</td>
<td>-</td>
<td>2.78</td>
<td>0.81</td>
<td>2.84</td>
<td>30.43</td>
<td>48.91</td>
<td>6.49</td>
</tr>
</tbody>
</table>
Hydraulic Conductivity \((K = \text{Cm/day})\) of Mixed soils for Fertilizer solutions.

<table>
<thead>
<tr>
<th>Table No. (4A)</th>
<th>Table No. (4B)</th>
<th>Table No. (4C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5% Urea</td>
<td>1.0% Urea</td>
<td>2.0% Urea</td>
</tr>
<tr>
<td>Days</td>
<td>15% Na</td>
<td>25% Na</td>
</tr>
<tr>
<td>1</td>
<td>8.94</td>
<td>7.20</td>
</tr>
<tr>
<td>2</td>
<td>4.87</td>
<td>6.69</td>
</tr>
<tr>
<td>3</td>
<td>3.25</td>
<td>6.14</td>
</tr>
<tr>
<td>4</td>
<td>3.04</td>
<td>5.89</td>
</tr>
<tr>
<td>5</td>
<td>2.84</td>
<td>4.13</td>
</tr>
<tr>
<td>6</td>
<td>2.74</td>
<td>3.39</td>
</tr>
<tr>
<td>7</td>
<td>2.64</td>
<td>3.13</td>
</tr>
</tbody>
</table>
Hydraulic Conductivity ($K = \text{cm/day}$) of Mixed soils of Fertilizer solution

<table>
<thead>
<tr>
<th>Table No. (4.5A)</th>
<th>Table No. (4.5B)</th>
<th>Table No. (4.5C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5% Ammonium Sulphate</td>
<td>1.0% Ammonium Sulphate</td>
<td>2.0% Ammonium Sulphate</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Days</th>
<th>Normal soil</th>
<th>Na soil</th>
<th>Ca soil</th>
<th>Normal soil</th>
<th>Na soil</th>
<th>Ca soil</th>
<th>Normal soil</th>
<th>Na soil</th>
<th>Ca soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>23.37</td>
<td>175.00</td>
<td>6.95</td>
<td>20.47</td>
<td>16.23</td>
<td>3.78</td>
<td>46.22</td>
<td>85.09</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>15.83</td>
<td>150.00</td>
<td>3.71</td>
<td>15.07</td>
<td>34.43</td>
<td>-</td>
<td>44.09</td>
<td>70.62</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>9.74</td>
<td>34.91</td>
<td>3.71</td>
<td>13.43</td>
<td>23.57</td>
<td>3.24</td>
<td>39.95</td>
<td>54.90</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>8.11</td>
<td>59.94</td>
<td>3.33</td>
<td>16.46</td>
<td>16.23</td>
<td>2.70</td>
<td>34.36</td>
<td>40.12</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>11.03</td>
<td>58.44</td>
<td>2.78</td>
<td>18.55</td>
<td>14.61</td>
<td>2.16</td>
<td>26.32</td>
<td>36.66</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>7.79</td>
<td>52.44</td>
<td>2.55</td>
<td>16.67</td>
<td>12.93</td>
<td>1.94</td>
<td>22.32</td>
<td>32.12</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>7.14</td>
<td>47.45</td>
<td>1.74</td>
<td>18.55</td>
<td>11.36</td>
<td>1.62</td>
<td>18.01</td>
<td>26.28</td>
<td>-</td>
</tr>
</tbody>
</table>
Hydraulic Conductivity (K = Cm/dry) of Mixed soils for Fertilizer Solution.

<table>
<thead>
<tr>
<th>Days</th>
<th>1% Ca</th>
<th>25% Ca</th>
<th>40% Ca</th>
<th>60% Ca</th>
<th>15% Ca</th>
<th>25% Ca</th>
<th>40% Ca</th>
<th>60% Ca</th>
<th>15% Ca</th>
<th>25% Ca</th>
<th>40% Ca</th>
<th>60% Ca</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9.74</td>
<td>18.19</td>
<td>11.63</td>
<td>3.67</td>
<td>16.06</td>
<td>14.50</td>
<td>12.23</td>
<td>66.66</td>
<td>10.52</td>
<td>7.46</td>
<td>9.02</td>
<td>7.46</td>
</tr>
<tr>
<td>2</td>
<td>5.41</td>
<td>16.21</td>
<td>11.03</td>
<td>3.20</td>
<td>14.61</td>
<td>13.09</td>
<td>10.06</td>
<td>25.97</td>
<td>6.63</td>
<td>6.75</td>
<td>6.49</td>
<td>79.20</td>
</tr>
<tr>
<td>3</td>
<td>3.24</td>
<td>11.23</td>
<td>10.38</td>
<td>2.59</td>
<td>12.71</td>
<td>12.81</td>
<td>7.79</td>
<td>14.43</td>
<td>6.13</td>
<td>8.25</td>
<td>7.01</td>
<td>68.09</td>
</tr>
<tr>
<td>4</td>
<td>3.24</td>
<td>8.10</td>
<td>10.03</td>
<td>1.03</td>
<td>14.06</td>
<td>11.54</td>
<td>7.14</td>
<td>15.15</td>
<td>5.62</td>
<td>7.25</td>
<td>7.46</td>
<td>59.46</td>
</tr>
<tr>
<td>5</td>
<td>4.32</td>
<td>7.35</td>
<td>12.90</td>
<td>1.29</td>
<td>16.23</td>
<td>9.64</td>
<td>7.79</td>
<td>14.43</td>
<td>5.05</td>
<td>7.94</td>
<td>7.14</td>
<td>40.09</td>
</tr>
<tr>
<td>6</td>
<td>4.32</td>
<td>7.35</td>
<td>9.09</td>
<td>0.86</td>
<td>13.52</td>
<td>8.24</td>
<td>5.64</td>
<td>11.54</td>
<td>4.68</td>
<td>7.12</td>
<td>6.16</td>
<td>38.84</td>
</tr>
<tr>
<td>7</td>
<td>3.84</td>
<td>6.35</td>
<td>7.79</td>
<td>0.77</td>
<td>10.32</td>
<td>8.20</td>
<td>5.19</td>
<td>11.54</td>
<td>4.90</td>
<td>6.24</td>
<td>5.84</td>
<td>35.09</td>
</tr>
</tbody>
</table>
HYDRAULIC CONDUCTIVITY OF AMRELI SOILS FOR DIFFERENT CONCENTRATIONS OF DAP SOLUTION.

A. HC (K = Cms/day) For 0.5% DAP Soil
- Normal Soil
- Na Soil
- Ca Soil

B. HC (K = Cms/day) For 10% DAP Soil
- Normal Soil
- Na Soil
- Ca Soil

C. HC (K = Cms/day) For 20% DAP Soil

Diagram 4.1
HYDRAULIC CONDUCTIVITY OF AMRELI SOILS FOR DIFFERENT CONCENTRATIONS OF DAP SOLUTION.

**Diagram 4.2**

**A**

HC (K = Cms/day) for 0.5% DAP Soil

- --- 10% + 85%
- --- 25% + 75%
- --- 40% + 60%
- --- 60% + 40%

**B**

HC (K = Cms/day) for 1.0% DAP Soil

- --- 10% + 95%
- --- 25% + 75%
- --- 40% + 60%
- --- 60% + 40%

**C**

HC (K = Cms/day) for 2.0% DAP Soil

- --- 10% + 85%
- --- 25% + 75%
- --- 40% + 60%
- --- 60% + 40%
HYDRAULIC CONDUCTIVITY OF AMRELI SOILS FOR DIFFERENT CONCENTRATIONS OF UREA SOLUTION.

A

HC (K = cm/s/day) for

0x Urea Soil

- Normal Soil
- Na Soil
- Ca Soil

B

HC (K = cm/s/day) for

10x Urea Soil

- Normal Soil
- Na Soil
- Ca Soil

C

HC (K = cm/s/day) for

20x Urea Soil

- Normal Soil
- Na Soil
- Ca Soil

Diagram 4.3
HYDRAULIC CONDUCTIVITY OF AMRELI SOILS FOR DIFFERENT CONCENTRATIONS OF UREA SOLUTION.

A

HYDRAULIC CONDUCTIVITY (K * C * m / s / w) FOR O.5% UREA SoIL

- - 15% + 85%
- - 25% + 75%
- - 40% + 60%
- - 60% + 40%

DAYS

B

HYDRAULIC CONDUCTIVITY (K * C * m / s / w) FOR 1.0% UREA SoIL

- - 15% + 85%
- - 25% + 75%
- - 40% + 60%
- - 60% + 40%

DAYS

C

HYDRAULIC CONDUCTIVITY (K * C * m / s / w) FOR 2.0% UREA SoIL

- - 15% + 85%
- - 25% + 75%
- - 40% + 60%
- - 60% + 40%

DAYS
HYDRAULIC CONDUCTIVITY OF AMRELI SOILS FOR DIFFERENT CONCENTRATIONS OF (NH₄)₂ SO₄ SOLUTION.

A. BE (A = cm/day) for
0.5(NH₄)₂ SO₄ Soil

- Normal Soil
- Na Soil
- Ca Soil

B. Ce (C = cm/day) for
1.0(NH₄)₂ SO₄ Soil

- Normal Soil
- Na Soil
- Ca Soil

C. HC (K = cm/day) for
2 Ca(NH₄)₂ So₂ Soil

- Normal Soil
- Na Soil
- Ca Soil

Diagram 4.5
HYDRAULIC CONDUCTIVITY OF AMRELI SOILS FOR DIFFERENT CONCENTRATIONS OF \((\text{NH}_4)_2\text{SO}_4\) SOLUTION.

**Diagram 4.6**

A. \(HC (k = \text{Cms/day})\) for 0.5 \((\text{NH}_4)_2\text{SO}_4\) Soil

- \(15\% + 0\%\)
- \(25\% + 75\%\)
- \(40\% + 60\%\)
- \(60\% + 40\%\)

B. \(HC (k = \text{Cms/day})\) for 1.0 \((\text{NH}_4)_2\text{SO}_4\) Soil

- \(15\% + 0\%\)
- \(25\% + 75\%\)
- \(40\% + 60\%\)
- \(60\% + 40\%\)

C. \(HC (k = \text{Cms/day})\) for 2.0 \((\text{NH}_4)_2\text{SO}_4\) Soil

- \(15\% + 0\%\)
- \(25\% + 75\%\)
- \(40\% + 60\%\)
- \(60\% + 40\%\)
DISCUSSION

Diagram 4.1 A, B, and C indicates that when 0.5% diammonium hydrogen phosphate is the solution the hydraulic conductivity is extremely low for all the three types of soils, i.e. Normal, Sodium and Calcium soil for Amreli district. When the diammonium hydrogen phosphate solution concentration is 1.0%, the hydraulic conductivity increases and it still further increases for the 2.0% diammonium hydrogen phosphate solution. Very low hydraulic conductivity for 0.5% diammonium hydrogen phosphate solution may be due to the ammonium saturation of the soil, and the increase in case B and C is due to additional effect of electrolyte.

Diagram 4.2 A, B and C indicates, a triple effect of sodium saturation, ammonium saturation and the electrolyte effect, which shows unpredictable pattern of increase and decrease in the hydraulic conductivity for different percentage of Na-saturation soils. Here sodium and ammonium would try to decrease the hydraulic conductivity, while Ca-saturation and the electrolyte concentration would increase the hydraulic
conductivity of course for forty percent Na-saturation
hydraulic conductivity is low in general.

Diagram 4.3 A, B, and C indicates hydraulic conductivity for urea (Fertilizer) solution. It can be traced that for 0.5% and 1.0% concentration of urea solution the hydraulic conductivities are very low after third day. But when the concentration of urea is 2.0%, hydraulic conductivity is very much higher than for the 0.5% and 1.0% concentration of urea.

Diagram 4.4 A, B, and C indicates that, for the mixed Na and Ca soils hydraulic conductivity are very low for 0.5% urea solution, but the hydraulic conductivity are higher for 1.0% and 2.0% urea solutions. It is difficult to explain that for 1.0% urea solution, 60% Na-saturation soil has a lowest hydraulic conductivity but for 2.0% urea solution it has the highest value of hydraulic conductivity. Thus, here also a triple effect of Na-saturation, \( \text{NH}_4 \)-saturation and urea leading to ammonium saturation (most probably). The urea concentration play a significant role in the Na and Ca saturation soil of Amreli.
In diagram 4.5 A, B and C hydraulic conductivity values for 0.5%, 1.0% and 2.0% ammonium sulphate \((\text{NH}_4)_2\text{SO}_4\) are shown. For 0.5% ammonium sulphate concentration, Na-soil has the highest hydraulic conductivity followed by normal soil and then Ca-soil has the lowest hydraulic conductivity. The same order is followed for 1.0% ammonium sulphate. But for 2.0% ammonium sulphate concentration, Ca-soil has probably very low hydraulic conductivity. This indicates that Ca-soil is ammonium saturated and therefore there is a low hydraulic conductivity.

The mixed Na and Ca soil have very low hydraulic conductivity with 0.5%, 1.0% and 2.0% solutions, except the 60% Na-saturation soils which have some high hydraulic conductivity for 1.0% and 2.0% ammonium sulphate solution.

Considering the continuous chain of nitrogenous fertilizers from year to year in order to get higher crop-yields. The agricultural scientists should inform the farmers about maintaining proper water movement level in soil. If this factor is not kept in mind than 5 or 6 years the rate of
production will diminish and it will be costly affair to improve a highly deteriorated soil.
REFERENCES

   'Effect of absorbed cations on physical properties of tropical red e rths and hydraulic conductivity' 1969, J. Soil. Sci. 20 (2) 225 - 68.

2. Assef, M. Adbigawad, G. Omar, S. 'Pore size distribution and saturated hydraulic conductivity study in calcareous soil as affected by Ca-monobasic phosphate application'.


