Republic of Belarus

Dusty Blot
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Describe and explain the dynamics of the pattern you observe when some dry dust (e.g. coffee powder or flour) is poured onto a water surface. Study the dependence of the observed phenomena on the relevant parameters.
Floating

Wettable speck

Unwettable speck
Two wettable specks

Two unwettable specks
Some substances, having been poured by a pitch, disperse on the surface and form a round blot.
experiment

- video camera
- tripod
- thermocouple
- liquid
VIDEO
Dependence of the radius of the blot on time

Radius, m

time, s
Dependence of the blot broadening rate on time
complex compound
<table>
<thead>
<tr>
<th>Black pepper</th>
<th>Coffee</th>
</tr>
</thead>
<tbody>
<tr>
<td>• piperinum</td>
<td>fats, <strong>albumens</strong>, carbohydrates</td>
</tr>
<tr>
<td>• piperidinum</td>
<td>• mono- и disaccharides</td>
</tr>
<tr>
<td>• <em>ether</em> and fat oils</td>
<td>• food fibers</td>
</tr>
<tr>
<td>• starch</td>
<td>• <strong>organic acids</strong></td>
</tr>
<tr>
<td>• <em>albumen</em></td>
<td>• ash</td>
</tr>
<tr>
<td>• vitamins</td>
<td>• iron</td>
</tr>
<tr>
<td>• steroid saponina</td>
<td>• potassium</td>
</tr>
<tr>
<td>• <em>alkaloid capsaicinum</em></td>
<td>• calcium</td>
</tr>
<tr>
<td></td>
<td>• magnesium</td>
</tr>
<tr>
<td></td>
<td>• sodium</td>
</tr>
<tr>
<td></td>
<td>• phosphorus</td>
</tr>
</tbody>
</table>
Main assumptions:

1. The blot is round and plain (the only spatial coordinate is \textit{radius});

2. The dependence of surface tension on SAS concentration is linear (and decreasing):

\[
\sigma = \sigma_0 (1 - \alpha \gamma)
\]  

where \(\sigma_0\) – surface tension of pure water (with no SAS); 
\(\gamma\) – SAS concentration on the surface (mol/m\(^2\)); 
\(\alpha\) – some constant coefficient.
Main assumptions (continues):

3. The force affecting a speck is proportional to the gradient of surface tension, to speck’s area and is directed against the gradient

\[ F_s = -S \frac{\partial \sigma}{\partial r} \]
Main assumptions (continues):

4. The viscous friction force is proportional to the velocity (Stoke’s law):

\[ F_{fr} = -\beta v \]  \hspace{1cm} (3)

5. We use a quazi-static estimation:

\[ F_{fr} = F_s \Rightarrow \beta v = -S\alpha\sigma_0 \frac{\partial \gamma}{\partial r} \]  \hspace{1cm} (4)
Main assumptions (continues):

6. The dissolution:

\[
\frac{\partial \gamma}{\partial t} = Cn(\gamma_{\text{lim}} - \gamma)
\]  

(5)

where \( n \) – specks’ concentration on the surface (1/m\(^2\));
\( \gamma_{\text{lim}} \) – limiting SAS concentration on the surface (mol/m\(^2\));
\( \gamma \) – current SAS concentration;
\( C \) – some constant coefficient.
Resulting system of equations:

\[
\begin{align*}
\frac{\partial n}{\partial t} &= \frac{\mu}{r} \frac{\partial}{\partial r} \left( nr \frac{\partial \gamma}{\partial r} \right) \\
\frac{\partial \gamma}{\partial t} &= C n (\gamma_{\text{lim}} - \gamma)
\end{align*}
\]

This system is non-linear and has to be solved numerically!
numerical solution

Specks’ concentration
SAS concentration

numerical solution
Many substances stop dispersing in soap water and oil.

Insoluble substances do not disperse.

Heating can fasten the process.
Alteration of $\beta$ is 48%  \quad T_1=20^\circ C  \quad$Alteration of $\sigma$ is 13%  
$T_2=80^\circ C$
Dependence of radius on time for different temperatures

76°C
60°C
20°C
Rate of broadening for different temperatures

- 76°C
- 60°C
- 20°C
Dependence of the radius on time for different substances:

- soap with pepper
- pepper
- washing powder
- coffee powder
The specks can be held at the surface by the surface tension forces.

- The movement of the specks is caused by surface distortions, changes in surface tension and flows in liquid.

- The most important parameters are: specks’ compound, surface tension and viscosity of liquid.
WE:

✓ Gave the explanation to the dust behavior on the surface of water;
✓ Carried out several series of experiments;
✓ Gave a clear mathematical description of the phenomena observed;
✓ Plotted some theoretical graphs;
✓ Compared the theory and the practice;
✓ Investigated some additional dependences.
Thanks a lot for your attention!