EXPLORE—HYBRID EXPERT SYSTEM FOR WATER NETWORKS MANAGEMENT

Discussion by M. L. Kansal and Geeta Arora

The authors have done a commendable job in gathering information from operators of the Seville City water supply system to develop an expert system. The discussers feel that such an expert system can be made more robust and have wider acceptability if the basic assumptions made in its development are more convincing. The present discussion highlights the additional features that the authors may like to consider for upgrading EXPLORE.

The authors have formulated system rules to prevent the degradation of water quality in the storage tanks. Another component of the distribution system that leads to prominent deterioration in water quality is the distribution pipeline network. The discussers would like to draw attention to the lack of system rules in EXPLORE for controlling the deterioration of water quality in the distribution network.

The authors have attempted to consider degradation of water quality in tanks by restricting the storage time to 3 h. However, in the discussers’ opinion, time of storage is not the sole parameter governing quality degradation. It is also the volume of water in the tank at any instant of time and fill and drain patterns of a storage tank that also affect storage water quality. A better criterion would be to have a flexible time limit based on the minimum concentration of residual disinfectant that can be allowed at the outlet of a storage structure.

Chlorine is the widest-used disinfectant in the world, and decay of residual chlorine concentration with water age has a direct bearing on storage time. The minimum concentration of residual chlorine has to be flexible in relation to distribution network size, decay kinetics of chlorine in the storage structure and distribution system, and the minimum residual disinfectant required to be maintained as per the regulations.

The optimization of pumping schedule as considered by the authors is of a conventional type, with the objective of minimizing pumping costs (Sabet and Helweg 1989). The discussers feel that in light of water-quality awareness, modern optimization problems should be of the multiobjective programming type where at least one criterion pertains to the maintenance of residual chlorine concentration within the limits required by regulatory authorities. The other objectives of such problems can be minimization of pumping cost or minimization of the capacity of storage structures. Such multiobjective optimization problems may be more relevant for countries that practice a uniform power tariff rate throughout the day.

The permanent storage of the tank and the pumping schedule of filling can lead to different types of decay patterns (Rossman 1995; Kansal and Arora 2000). For example, Fig. 16 shows variations in the residual chlorine concentration appearing in the storage tank effluent corresponding to different pumping schedules (Kansal and Arora 2000). In their study, the discussers have considered four different pumping schedules of filling the tank (Fig. 16). The tank considered was supplying a total of 2,592 m$^3$/day of water as per the daily demand shown in Fig. 17.

The residual chlorine concentration in the influent water was 1 mg/l. Total pumping hours for all the schedules was 8 h and pumping time for the four schedules is listed in Table 1.

From Fig. 16, it is quite apparent that for pumping schedule D, the mean value of residual chlorine concentration in the tank effluent is the maximum with minimum variance about the mean. Out of the four pumping schedules investigated, schedule D requires minimum capacity of storage structure, thus making the construction economical. This can be considered the best pumping schedule as far as capacity of tank and water quality under the prevailing practice of uniform power tariff.

Recent research has shown that, due to incomplete mixing

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**FIG. 16.** Variation in Residual Chlorine Concentration in Storage Tank Effluent for Different Pumping Schedules

<table>
<thead>
<tr>
<th>Time (hrs.)</th>
<th>0-2</th>
<th>2-5</th>
<th>5-8</th>
<th>8-11</th>
<th>11-14</th>
<th>14-17</th>
<th>17-20</th>
<th>20-23</th>
<th>23-24</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand (l/s)</td>
<td>21</td>
<td>27</td>
<td>38</td>
<td>34</td>
<td>32</td>
<td>28</td>
<td>32</td>
<td>28</td>
<td>21</td>
</tr>
</tbody>
</table>

**FIG. 17.** Daily Water Demand Supplied by Tank in Discussers’ Study
TABLE 1. Pumping Schedules

<table>
<thead>
<tr>
<th>Pumping schedule</th>
<th>Pump-on period (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0–8</td>
</tr>
<tr>
<td>B</td>
<td>0–4, 12–16</td>
</tr>
<tr>
<td>C</td>
<td>0–2, 6–8, 12–14, 18–20</td>
</tr>
<tr>
<td>D</td>
<td>0–1, 3–4, 6–7, 9–10, 12–13, 15–16, 18–19, 21–22</td>
</tr>
</tbody>
</table>

with dead zones and short circuiting in the storage tanks, compartmentalization of various zones of water quality may occur in the tank reactors (Boulos et al. 1996; Clark et al. 1996; Grayman et al. 1996). The discussers strongly recommend incorporation of these effects in the storage tanks corresponding to the estimated inner hydraulics of functioning tanks (Grayman and Clark 1993; Mau et al. 1995).

Another part of the EXPLORE on which the discussers have reservations is the method of forecasting the water demand. The assumption that water demand for any day will be the same as that during the same day of the previous week is, somehow, not convincing. The authors, although relishing the simplicity of their assumption, seem to be dissatisfied due to the error in forecasting. With the availability of the historical data on water demand for each tank, efforts should be made to produce a time-series model for forecasting of water demand.

REFERENCES


Closure by Carlos León, Sergio Martín, José M. Elena, and Joaquín Luque

With reference to the constraint that water must not be stored in a tank for more than 3 h in order to avoid degradation of water quality, it is important to notice that this is an explicit condition directly suggested by EMASESA operators in the case of high-capacity storage tanks. The writers agree with the discussers that other factors could be considered for controlling water quality. Due to EXPLORE characteristics, it would be easy to modify quality rules for including other factors that can be used for calculating pumping schedules. In this way, the discussers present some of the conclusions on pumping-schedule influence on residual chlorine concentration obtained in a recent paper (Kansal and Arora 2000). These conclusions are valid only if there is a uniform power tariff, whereas in our case the aim of the expert system is to deal with a complex and heterogeneous power tariff situation. In addition, these results fail to consider that pumps cannot be turned on and off in a continuous manner in order to avoid a degradation.

Another issue raised relates to the method used for forecasting water demand. In order to improve the results obtained by the method proposed in the paper, the writers are now developing an artificial neural network for forecasting water demand. This approach has been applied to short-term electric load forecasting with good results (AlFuhaid et al. 1997; Hisham et al. 1997). In an initial phase, using the historical data, the days are clustered using a Kohonen self-organizing neural network, so several clusters that contain days with the same characteristics are obtained. This phase is necessary because the calendar is complicated—for example, Easter holidays dates are not fixed. In a second phase, for each day class, a backpropagation neural network that will carry out the forecast dates are not fixed. In a second phase, for each day class, a backpropagation neural network that will carry out the forecast will be built and trained. Preliminary tests display good results.

REFERENCES


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