DRINKING WATER QUALITY

STATISTICAL PROCESS CONTROL FOR IMPROVED WATER QUALITY

David Bartley

Most water utilities use some form of control chart to monitor their drinking water and treated sewage quality. These control charts help operators to keep their treatment processes in control and typically consist of critical limits and control or adjustment limits as shown in Figure 1.

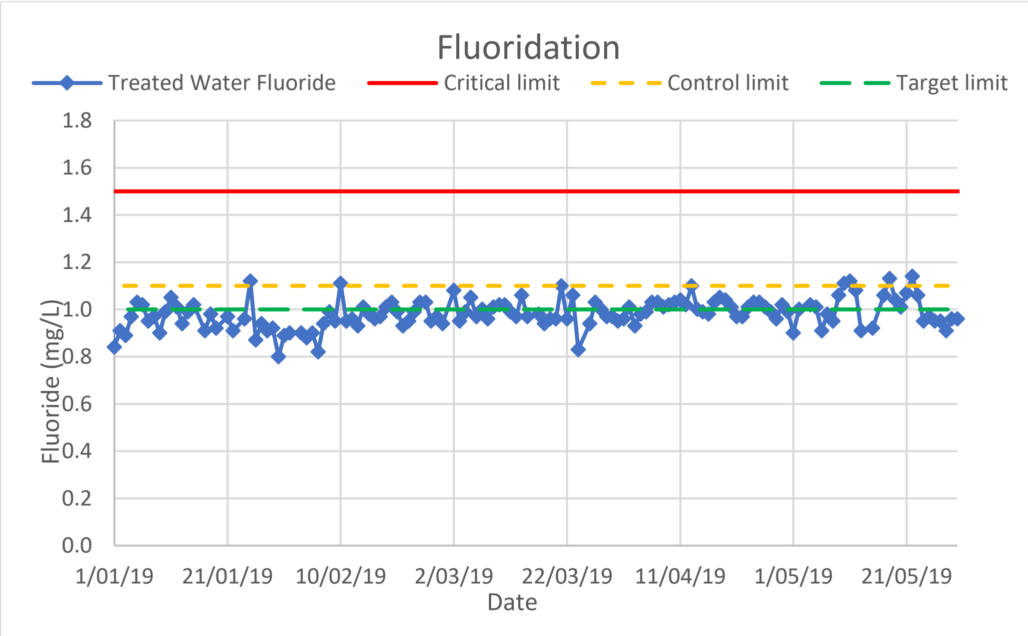

Figure 1. A typical water quality control chart. The same coloured lines for the critical limit and control limit are used in the following graphs as well.

Control limits provide early warning to operators that the parameter is trending unfavourably and heading "out of control". This gives the operator time to take corrective action(s) to prevent a breach of the critical limit and keep the process "in control".

Control limits are often set arbitrarily based on operational experience at a particular plant. Similarly, they are often set without full consideration of the performance of the overall plant and possibilities for improvement of that performance. This ad hoc method of setting control limits can cause the following problems.

If control limits are too close, most of the data will be outside the limits causing annoyance for the operator, particularly if alarms are linked to the control limits, and confusion as to which incidents require further investigation.

If control limits are too wide, by the time they are reached there may be insufficient time for operators to take action to prevent breach of the critical limits.
Setting arbitrary control limits does not allow for changes in process performance over time due to seasonal impacts or improved operation.

Statistical Process Control

Statistical process control began in the manufacturing industry in the 1950s. The use of control charts with statistical control limits was based on the theory that 99.999666% of a set of data will fall within three standard deviations either side of the mean or average. This approach allowed industries such as car manufacturing to reduce the variability in their processes and therefore reduce the amount of component reject.

The standard deviation is simply a number that relates to how much variation there is in the parameter that is being measured. It is therefore a measure of how "in control" the parameter is. If the standard deviation is low, all the data is in control. If the standard deviation is higher, the data is less in control. Figure 2 shows the standard deviation for two sets of data with the same mean but with Example 2 less in control than Example 1.

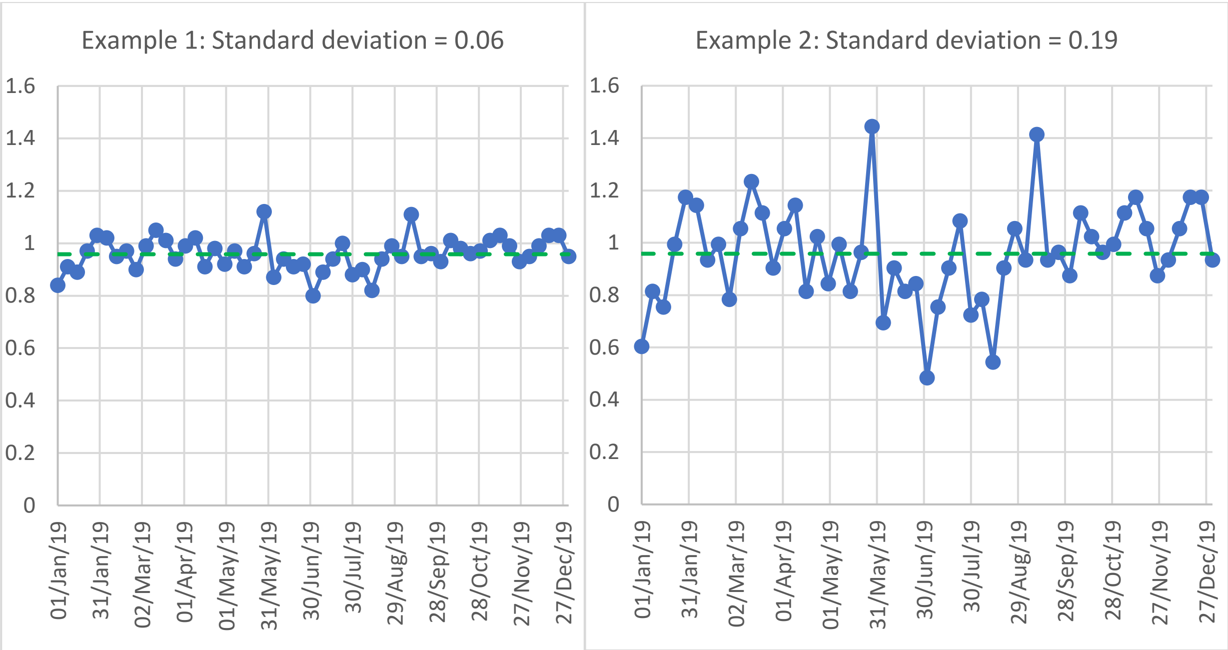

Figure 2. Examples of the standard deviation for data sets with the same mean but with different variability as shown by the standard deviation of 0.06 for example 1 and 0.19 for example 2.

What Happens if the Control Limits Are Too Wide?

When control limits are set too far from the mean, there is a risk that an unfavourable trend of instability may not be noticed until it is too late to prevent breach or high maintenance costs.

Figure 3 shows an example of data from a recycled water plant where the reverse osmosis (RO) electrical conductivity continued to rise to four times the average without reaching the upper control limit. Once the operators noticed the trend, the membranes were replaced and the conductivity returned to normal.

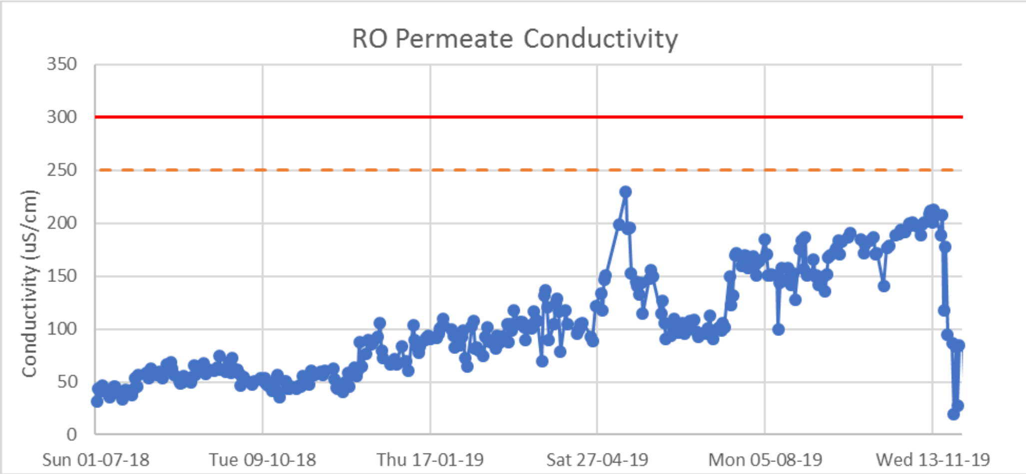

Figure 3. An example of a control chart with the control limits set too wide. The orange dashed line is the control limit and the red line the critical limit.

Figure 4 shows the same electrical conductivity data shown in Figure 3 with the control limit changed to three standard deviations above the mean for the period from July to October 2018. With this statistical control limit, the rising trend could have been noticed nearly a year earlier and potentially membrane cleaning could have extended the life of the membranes and saved the cost of replacing the membranes.

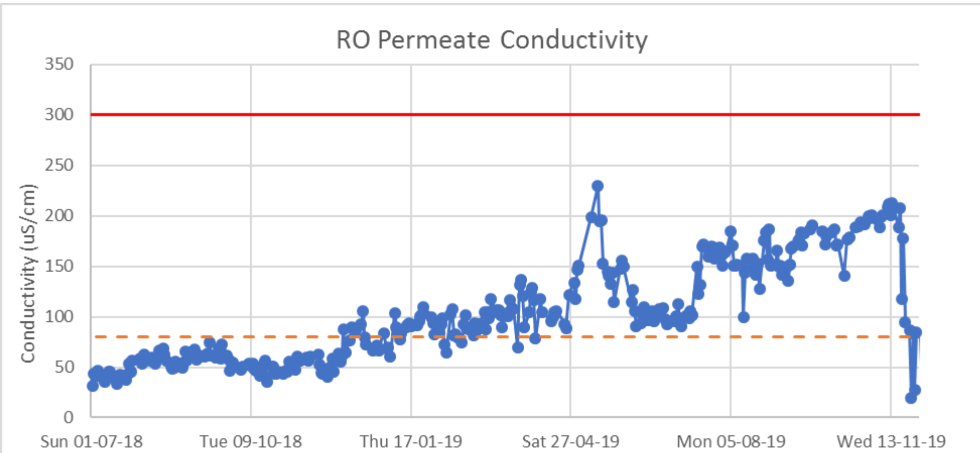

Figure 4. The same control chart as that shown in Figure 3 with the control limit adjusted to three standard deviations from mean for the data from July to October 2018. The orange dashed line is the control limit and the red line the critical limit.

What Happens if the Control Limits Are Too Narrow?

If the control limits are set too close to the mean, there can be so much data outside the limits that it is not possible for the operators to determine which events to investigate. This can result in unfavourable trends or instability going unnoticed. It can also result in the operators losing confidence in the control charts as a tool for improving plant performance.

Figure 5 shows an example of recycled water free chlorine residual where the upper control limit is so low that nearly all the data is above that limit.

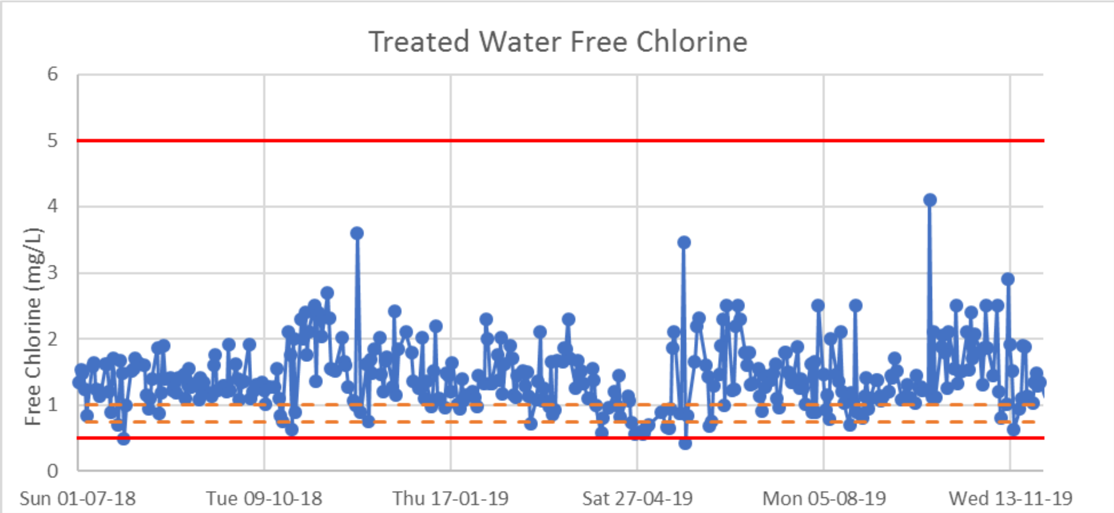

Figure 5. An example of a control chart with the control limit set too narrow. The orange dashed lines are the upper and lower control limit and the red lines the upper and lower critical limits.

Alarm limits are also often set based on the control limits. This is a very good practice. However, with the control limits set too narrow, the alarms will activate continually and "drive the operator(s) mad". What usually happens then is that the alarms are deactivated or the alarm limit adjusted way too high, or too low to prevent triggering of the alarm. This then increases the risk of producing unsafe drinking water from a WTP or out of specification effluent from an STP. The control limits and alarm limits need to be set "just right".

Figure 6 shows the same data as that shown in Figure 5 with the upper limit adjusted to three standard deviations above the mean. This control chart now directs the operator to focus investigation on the highest peaks that are closest to the critical limit.

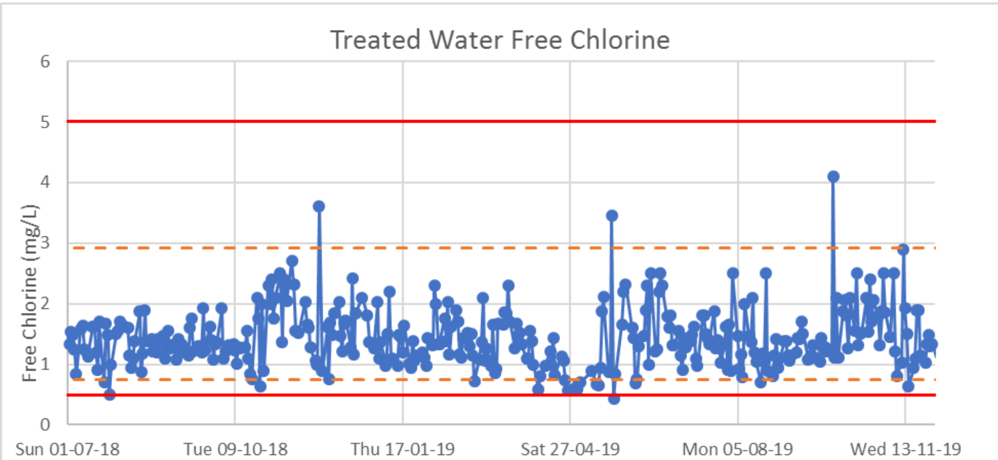

Figure 6. The same control chart as that shown in Figure 5 with the upper control limit adjusted to three standard deviations above the mean. The orange dashed lines are the upper and lower control limit and the red lines the upper and lower critical limits.

Continuous Improvement

By using the standard deviation calculated from the latest data, the control limits will automatically adjust as the performance of the process changes. Depending on the frequency of data collection and the rate of change, the mean and standard deviation should typically be based on the last one to three months.

If we look at the previous example of recycled water free chlorine and remove the peaks above the upper control limit, the limit drops from 2.9 mg/L to 2.5 mg/L automatically as the process becomes more in control (Figure 7).

This automatic adjustment allows operators to focus on the most important data that will improve the reliability of their processes and contribute to improved water quality outcomes over time.

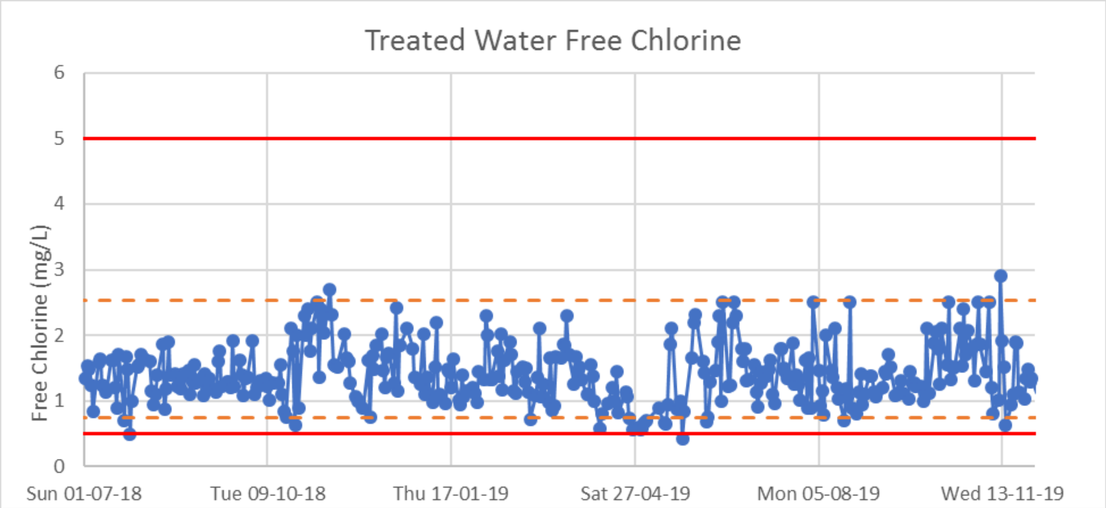

Figure 7. Automatic lowering of upper control limit as the high (spike) values are removed. The orange dashed lines are the upper and lower control limit and the red lines the upper and lower critical limits.

By setting control limits using simple statistical methods, unfavourable trends and unstable control are clearly identified allowing operators to focus on the problems that are most important. The statistical control limits will also automatically adjust as the process changes thereby ensuring operators are able to achieve continuous improvement in their water or effluent quality.

The Author

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