IS IT REAL OR ISN'T IT? ADDRESSING EARLY WARNING SYSTEM ALARMS.

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Abstract

The concept of utilizing the measurement of multiple bulk parameters to recognize and identify water quality excursions is rapidly gaining ground as the method of choice for on-line water quality monitoring. These monitoring systems may or may not be equipped with event detection software to help in interpreting signals that indicate potential water quality anomalies. All of these monitoring systems rely upon basic water quality monitoring technology and instrumentation to provide the baseline data that is utilized in the determination of water quality excursions. With or without software, all of these systems have some potential to generate false alarms. No one wants to spend all of their resources responding to false or unimportant alarms. It is important for operators to understand that all such early warning systems are inferential in nature. With all inferential systems, certain questions need to be answered in the shortest amount of time possible. Is the alarm real? Is the root cause in the water, the sampling system, or the measurement system? The answer to these questions is crucial to the timely implementation of response procedures. Addressing and eliminating possible sources of error in a systematic and focused manor is the best practice in such situations to quickly arrive at the appropriate answer to these questions. Some of the critical factors to be addressed include operator interpretation of signal patterns (the duration, magnitude and shape of an alarm signal), verification of instrumental readings, knowledge of external factors and other procedures. These concepts can help in interpretation and verification of these signals. Simple rules and procedures including checklists are suggested along with things to consider when alarms happen. Following these simple guidelines, regardless of the type of instrumentation or software being utilized, will help reduce the time and effort expended in responding to alarms of all types.

1. INTORDUCTION
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The concept of utilizing the measurement of multiple bulk parameters to recognize and identify water quality excursions is rapidly gaining ground as the method of choice for on-line water quality monitoring. These monitoring systems may or may not be equipped with event detection software to help in interpreting signals that indicate potential water quality anomalies. All of these monitoring systems rely upon basic water quality monitoring technology and instrumentation to provide the baseline data that is utilized in the determination of water quality excursions. With or without software, all of these systems have some potential to generate false alarms. No one wants to spend all of their resources responding to false or unimportant alarms. It is important for operators to understand that all such early warning systems are inferential in nature.

Inferential systems are monitoring systems that do not have sensors for the specific compounds of interest, but rather they rely upon a number of surrogate indicators, changes in which denote or infer the presence of the compound in question. Most drinking water early warning systems are inferential in nature. With all inferential systems, certain questions need to be answered in the shortest amount of time possible. Is the alarm real? Is the root cause in the water, the sampling system, or the measurement system? The answer to these questions is crucial to the timely implementation of response procedures.

Addressing and eliminating possible sources of error in a systematic and focused manor is the best practice in such situations to quickly arrive at the appropriate answer to these questions. Some of the critical factors to be addressed include operator interpretation of signal patterns (the duration, magnitude and shape of an alarm signal), verification of instrumental readings, knowledge of external factors and other procedures. These concepts can help in interpretation and verification of these signals. Simple rules and procedures including checklists are suggested along with things to consider when alarms happen. Following these simple guidelines, regardless of the type of instrumentation or software being utilized, will help reduce the time and effort expended in responding to alarms of all types.

2. WARNING SYSTEMS AND ALGORITHMS:

The purpose of drinking water early warning systems that rely upon multi-parameter monitoring is to trigger an alarm if water quality deviations on the sensors become excessive. In some cases these software programs are capable of analyzing these deviations to see if they match an agent fingerprint from a library. It is important to understand that these sorts of systems are only capable of a presumptive classification. Any match is only indicating that the water quality sensors readings have changed in the same manner that they would be expected to if the agent in question were indeed present.

In other words the presence of the agent is being inferred from the changes in sensor readings. The actual agent may or may not be present. Occasionally more than one agent may be indicated. This is simply a signal to investigate further and can act as a guideline to that investigation. If the system were indicating cyanide might be present, it would not be wise to start an investigation on the presence of heavy metals as a first step.

3. TRIGGER SHAPE AND DURATION:

There is a lot of valuable information that can be gleaned from paying attention to the duration and the shape of alarm signals. Spikes or alarms of a few minutes duration are of less concern because they affect only a small quantity of water. See Figure.1. A change that is continuous and persistent is of more concern due to the large volume of water affected. See Figure. 2.

An actual agent will usually present a characteristic rise time and a plateau of stabilization. Then a drop off will occur when the contaminated water has moved past the sensors. See Figure. 3. It is possible that this kind of pattern will produce classification of different agents on the signal rise, plateau, and fall. This is caused by differences in sensor response times. Classifications on the rise and fall are not as reliable as those from the plateau of the response. This should be taken into account during the interpretation of the alarm.

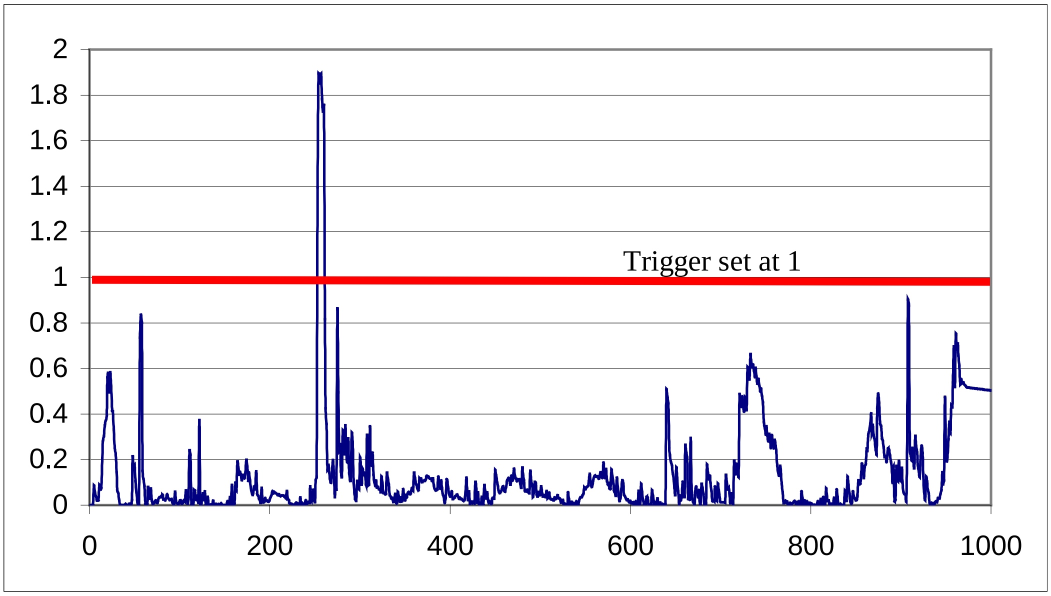

Figure.1 Short duration spikes that exceed the trigger level tend to be of less concern.

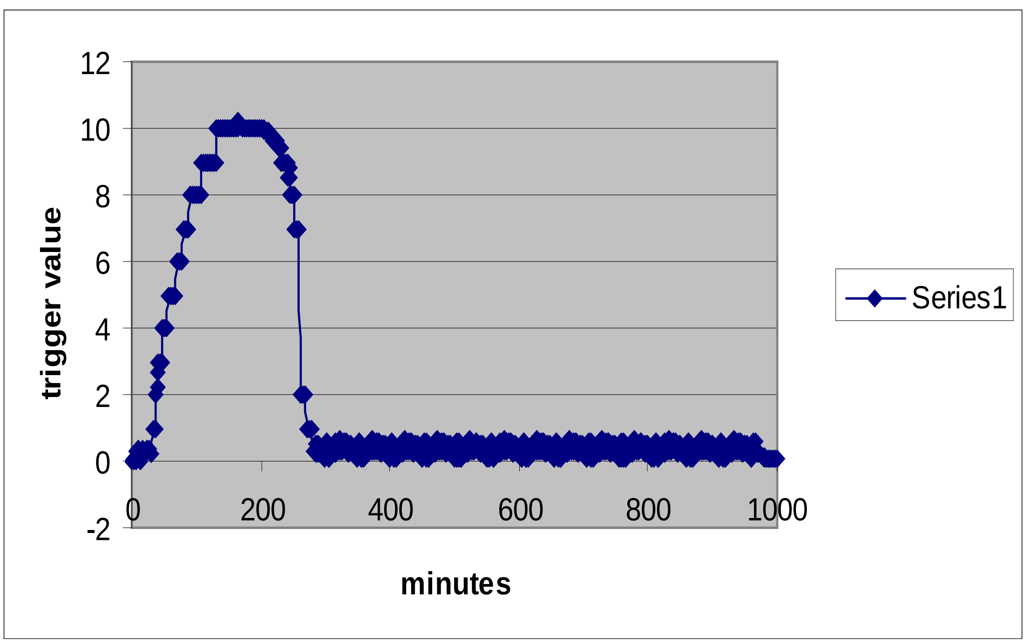

Figure. 2. Persistent changes that occur for a longer period of time are more of a threat.

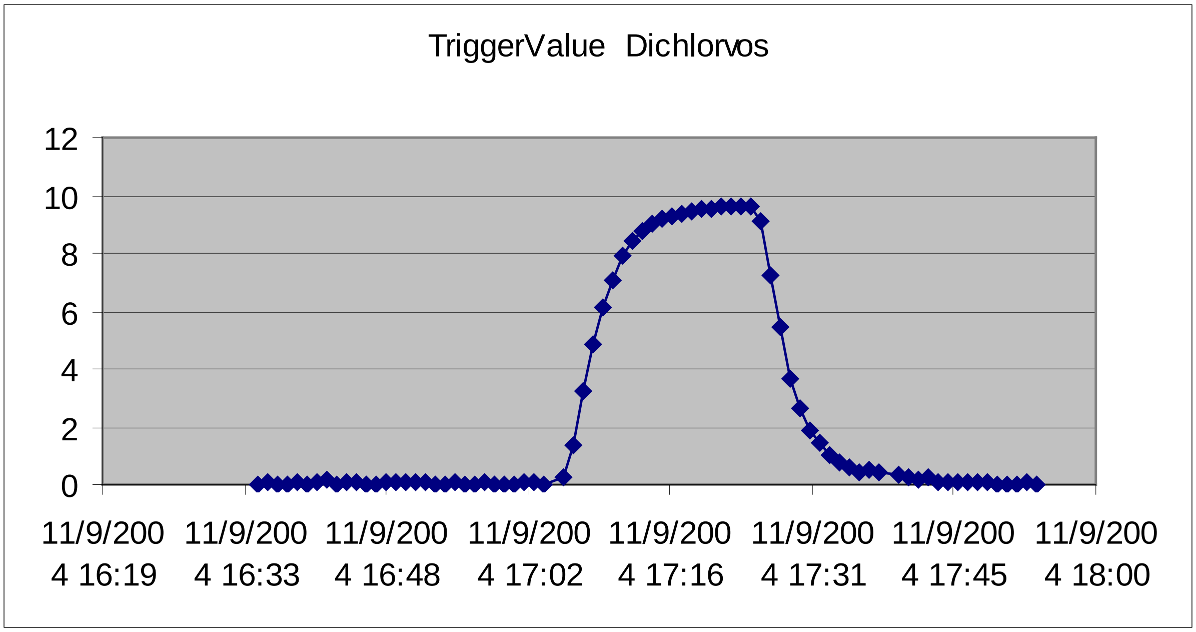

Figure. 3 An actual agent will usually present a characteristic rise and a plateau of stabilization. Then a drop off will occur when the contaminated water has passes.

4. RESPONDING TO UNKNOWN ALARMS

The USEPA has performed extensive research in the area of response protocols and has developed a number of useful tools for formulating response plans. Chief among these is a manual entitled "Response Protocol Toolbox: Planning for and Responding to Drinking Water Contamination Threats and Incidents." When utilizing this tool or other response protocols, when the initial warning is from on-line water quality monitroiing systems, there are a number of considerations that should be kept in mind.

When a trigger occurs (water quality readings have exceeded a threshold) there could be any number of causes, most of them of no great consequence to the end consumer. Some analysis must be done to understand the problem and qualify the result. Is the alarm real? Is the root cause in the water, the sampling system, or the measurement system?

4.1 The Sensor Set:

The first concern with a validation of an alarm is the sensor set. There are a number of things that should be considered.

- Are there any sensor alarms on the instruments that might be the cause of the trigger alarm such as a frozen sensor?
- Are all sensors functioning normally? Examine the graphs of the sensor values prior to the alarm. Is there anything unusual?
- Have the sensors been properly calibrated? Do the sensors give similar results to those obtained with independent verification techniques such as handheld pH meters etc? There are a number of useful field kits available for evaluating and verifying sensors.
- Have the sensors been properly maintained?

- Have any reagents run out? Running out of reagents on some instruments can dramatically shift readings. Those shifts can trigger an alarm.
- Have flow rates to the instruments changed? If available it is a good idea to check pressure readings to see if there has been any unusual pressure changes that might affect flows.

4.2 The Sampling System:

If all of the sensors are operating without problems, then the sampling systems should be checked.

- Are there any blockages or leaks in the sampling system?
- Has the sampling system been shut off for some reason?
- Are there air bubbles in the sample line?
- Has the system been tampered with or vandalized?

4.3 The Algorithm and computer systems:

- Is there a loss of communications?
- Are there sensor alarms (Hi, Low, Frozen)?
- Low-pressure alarms from any of the instruments?
- Are there any sensor diagnostic messages?

If these systems are all in order, then it is likely that the alarm is caused buy a real change in water quality. A key question then becomes: Is the cause attributable to know operations or is it something unknown?

5. IDENTIFYING CAUSES OF WATER QUALITY CHANGES

When it has been determined that an actual change in water quality has occurred, data needs to be gathered regarding the operations upstream of the sampling point to see if there is any rational explanation for the change in the water quality parameters.

- Are there unusual weather conditions?
- Has work been done on or near water mains?
- Are there changes in treatment plant operations?
- Has there been a switch in source waters or a known change in these sources' quality?
- Are other monitoring sites responding in a similar manner and, is the response distribution such that it could indicate a change in the source water?
- Are different treatment chemicals being used?
- Is there maintenance occurring at the treatment plant or in the distribution system.
- Are there unusual water demands? (Major fire fighting for example.)
- A water main break? Hydrant flushing?
- Are control and feed systems for pH, chlorine, fluoride, ammonia or other treatment chemicals functioning normally?

These are just some of the possible causes that should be considered when investigating an alarm. Some early warning systems allow the operator to associate a name and an alarm priority with patterns produced by such events. The names and priorities cannot be logically assigned until the root cause of the event has been found. Once the root cause is known, these events should be named so that a recurrence can be classified quickly.

A real world event exemplifies this concept. A multi-parameter water panel coupled with a computer-based algorithm was installed at a location in a major east coast city just down stream from a water storage tank. The event monitor recoded a regular alarm. See Figure. 4.

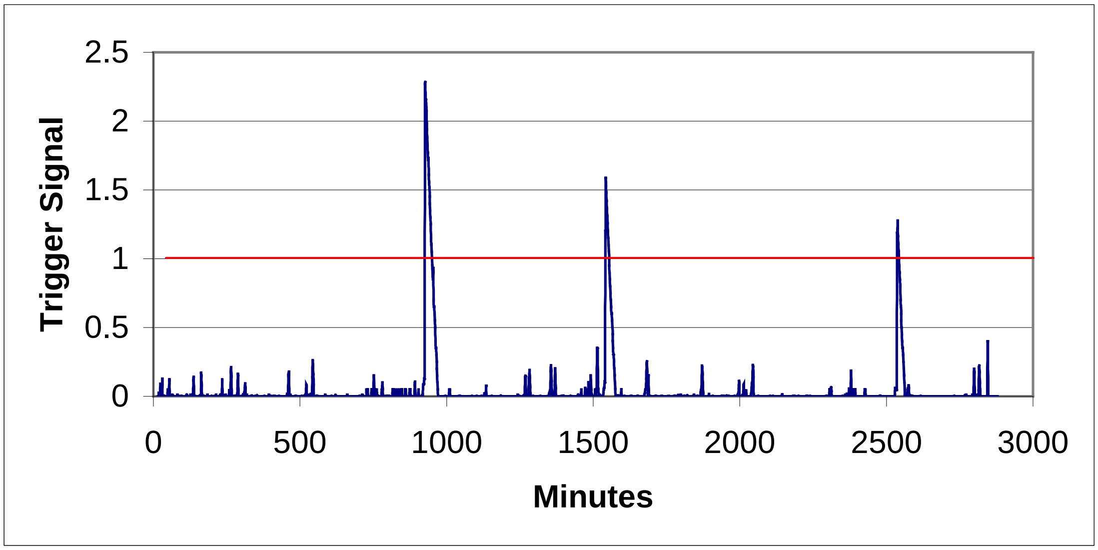

Figure. 4. Regular alarm triggers.

Careful evaluation of the baseline parameter data showed that a chlorine upset was triggering the alarms. The chlorine levels would gradually rise over time and then suddenly drop. It was this sudden drop that was triggering the alarm. A secondary water source for the tank has higher chlorine residual than its primary source. When the secondary source was used at times of peak demand to top off the tank, the chlorine level gradually creeps up. When the secondary source is turned off, due to hydrodynamic short-circuiting in the tank, the chlorine level rapidly drops back to the concentration of the primary source.

After the operators made this determination, the learning capability of this algorithm was used to name and classify the event as benign so that when it occurred again the alarm was recognized. The system would report an upset with this pattern as **Pump shut off Normal.** Information such as this can be very useful in deciding how to respond to an alarm.

6. ANALYSIS OF UNKNOWNS:

Further analysis of water quality triggers, both from classified and unclassified events, is a key component of the alarm response protocol. Many event detection systems are designed to be equipped with an automatic sampler that will draw a representative sample of the water when triggered to do so by an exceedence of the threshold level adequate to trigger an alarm. These samples can be used to perform further forensic analysis to determine the cause of an event. The utility should have adequate measures in place for analyzing samples that could be toxic or infectious.

If the system presents a classification of a likely agent, this classification should be treated as tentative until verified by further testing. As was previously stated, classification of an agent by this type of system offers a valuable first pass at determining a cause of a water quality upset and can be used to direct further forensic analysis. Tests should be tailored to address the class of agent being presented by the match.

These matches are not necessarily exact. For example, a match to an agent such as ethoprophos may not necessarily be ethoprophos but it could be anyone of a number of organophosphates with profiles similar to ethoprophos that are not in the matching library. It would be a good idea in this case to begin testing to verify the class of compounds (organophosphates) and get more specific as testing continues.

The USEAPA offers guidance on forensic testing in their emergency response protocols. There are a number of ready to use kits designed for core field testing and advanced field-testing as defined by the USEPA. High consequence actions, such as alerting customers or shutting down water supplies, should not be taken until verification of the results form the early warning systems have been performed.

Just because an alarm is not classified by an event detection system with a match to a known agent does not mean that the alarm is benign. There are many thousands of possible contaminants that could be used in an attack or accidentally find their way into the water supply. Classification algorithms usually only contain a small subset of some of the most dangerous and likely compounds. Many others are not contained in the libraries for these systems. That these systems have the ability to trigger on such compounds even if they are not specifically found in the library is one of the great strengths of the multi-parameter inferential method.

While no classification is given on these types of alarm, the information presented by the individual parameter sensors can be important in guiding forensic analysis. For example if an alarm occurs that is the result of changes in conductivity alone with no noticeable changes in Total Organic carbon levels or chlorine residual, it would make no sense to waste valuable time in doing an analysis focused on organic contaminants. Such common sense direction of testing can save valuable time in an emergency.

7. CONCLUSION:

While not all inclusive, the concepts and considerations presented here should make interpreting and responding to alarms form early warning systems a more routine event. If followed with common sense these steps and procedures can result in increased reaction time and proper response to a variety of situations.