The Environmental Protection Agency

EPA DRINKING WATER ADVICE NOTE
Advice Note No. 5:
Turbidity in Drinking Water

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1 INTRODUCTION

A KEY requirement of drinking water treatment is to minimise turbidity of the final water. In the past, the control of turbidity was considered important for aesthetic reasons and the standards in the 1980 EU Drinking Water Directive set a figure of 4 NTU as unacceptable to consumers. The current EU Drinking Water Directive (98/83/EC) and their corresponding Irish regulations, the *European Communities (Drinking Water) (No.2) Regulations, 2007* state that the levels of turbidity at the tap must be *"Acceptable to consumers and no abnormal change"* and that *"in the case of surface water treatment, a parametric value not exceeding 1.0 NTU in the water ex treatment must be strived for"*.

A key disintction between levels of turbidity at the treatment plant and in the distribution network must be made as elevated levels of turbidity in the distribution network can indicate different problems (e.g. disturbance of sediment in the distribution network) than elevated levels of turbidity in the water leaving the treatment plant (e.g. filter inadequacy). Furthermore, the World Health Organisation (WHO, 2004) state that for effective disinfection to take place, the turbidity levels in the water to be disinfected must be <1.0 NTU. High levels of turbidity can protect microorganisms from the effects of disinfection and may also indicate *Cryptosporidium* can break through the filters and enter the water supply. A key review of *Cryptosporidium* in Water Supplies in the UK (Bouchier, 1999) indicated that *"The unifying factor in all outbreak situations is the potential for peaks in turbidity to be present in the treated water leaving the [water treatment] works"*. The Bouchier report recommended that *"Water treatment works should be operated at all times in a manner that minimises turbidity in the final water"*.

The EPA report *"The Provision and Quality of Drinking Water in Ireland: A Report for the Years 2007 – 2008"* indicates that turbidity levels in excess of 1.0 NTU were reported in approximately 36% of water treatment plants monitored while 45% of the treatment plants audited in 2008 were found to have turbidity levels in excess of 1.0 NTU in the water leaving the treatment plant.

This Advice Note sets out the EPA guidance on the actions that are necessary in water treatment plants where elevated levels of turbidity are detected.

2 TURBIDITY LEVELS TO BE ACHIEVED AT THE WATER TREATMENT PLANT

WHILE the *European Communities (Drinking Water) (No.2) Regulations, 2007* state that *"in the case of surface water treatment, a parametric value not exceeding 1.0 NTU in the water ex treatment must be strived for"*, this level is generally considered too high in supplies where there is a risk of the presence of *Cryptosporidium* in the raw water. The EPA recommend that treatment plants should be optimised to obtain a turbidity levels of <0.2 NTU in the final water.

3 ACTIONS TO BE TAKEN BY THE OPERATOR

THE key steps that should be taken following the detection of elevated levels of turbidity are outlined in the following sections and include:

1. Ensuring that adequate treatment is in place capable of removing turbidity;
2. Improvements in monitoring at the water treatment plant;
3. Optimisation and improved management of the existing treatment processes.

These steps are outlined in more detail in the sections that follow.

3.1 ENSURE ADEQUATE TREATMENT IS IN PLACE CAPABLE OF REMOVING TURBIDITY

Water sources that originate from surface water or those that are influenced by surface water (e.g. vulnerable springs and boreholes) must, in addition to disinfection, have at least one treatment barrier capable of removing C*ryptosporidium*, which in effect also means a barrier capable of removing turbidity. Supplies in catchments with a high risk of *Cryptosporidium* may need to have more than one treatment barrier capable of removing turbidity. The most common treatment barriers in place in Ireland in place for removing turbidity include:

- Slow sand filtration systems;
- Rapid gravity filtration systems;
- Membrane filtration systems;
- Pressure filtration systems;
- Coagulation and clarification systems;
- Dissolved Air Flotation systems.

3.2 IMPROVEMENTS IN MONITORING AT THE WATER TREATMENT PLANT

It is essential that the operator characterises the quality of water (and be aware of changes in the raw water quality) to be treated at each water treatment plant to ensure that it is capable of adequately treating the raw water under all circumstances. A key finding of the UK *Cryptosporidium in Water Supplies* report (Bouchier, 1999) was that *"Turbidity monitoring through the water treatment process is a vital element in checking that treatment barriers are working properly"*.

In order to characterise the variability in turbidity at the water treatment plant to ensure that the plant can deal with this varaibility the EPA recommend that all supplies that originate or are influenced by surface water should install turbidity monitors at the following locations:

- Raw water intake;
- After each filter;
- On the combined filtered water.

These monitors must be fit for purposes and capable of monitoring and recording turbidity continuously and measuring changes in turbidity of less than 0.1 NTU. Historically, daily spot samples of the raw and final water have been monitored for turbidity and used to manage the treatment process in many treatment plants. These samples are unsuitable for treatment process management as surface water sources can vary significantly over short periods of time. Daily spot samples do not permit an adequate response to changes in water quality, however, they can provide verification that the monitors are operating and recording correctly.

The location of the monitors is essential and failure to locate the turbidity monitor in an appropriate location may result in inaccurate or misleading results being recorded. Extraction points from the filtered water pipeline should not be sited at the top of the pipe (air can collect at the top and cause air bubbles which appear as turbidity spikes) or at the bottom of the pipe (solids can settle at the bottom of the pipe) or adjacent to points of high turbulence (immediately downstream of valves, on sharp bends or other restrictions). It is essential that the sample lines are kept clean and free from air and the flow to the sensor checked regularly. The monitors must be cleaned and calibrated in accordance with the manufacturer's instructions and records should be maintained to verify this. It is important that appropriate standard solutions are used for the calibration of the turbidity monitors (i.e. the standard solution should be within the range of turbidity levels normally experienced at the plant).

The results of monitoring should be used to:

1. **Assess the Adequacy of the Water Treatment Plant**

   The results of the assessment of the monitoring results on the turbidity monitors may indicate that further improvements to the infrastructure, operation and/or management of the water treatment plant are necessary. Where the results of the monitoring indicates unacceptable levels of turbidity in the filtered or final water the operator may need to either optimise the operation of the plant to improve filtered or final water turbidity levels or upgrade the treatment plant to provide an adequate barrier for the removal of turbidity.

2. **Set Appropriate Alarm Levels on the Stages of the Treatment Processes**

   Operators should assess the results of turbidity monitoring information and should define (for each of their treatment plants) the factors that change turbidity levels. Alarms should be set on the monitors to alert the operators of the treatment plants to deviations outside the acceptable range. The alarm settings will depend on the normal quality of the water and should be clearly defined with appropriate documented actions to be carried out in the event of the triggering of any of the alarm settings.

   The alarm on the raw water monitor should be set at a level above which the plant may be challenged. It may be appropriate to have an automatic shutoff on the raw water when the turbidity exceeds this alarm level. Where this is not possible, the operator must have an appropriate documented response procedure to ensure that the integrity of the treatment process is not challenged excessively by the deterioration in quality of the raw water and that there is no risk of turbidity breakthrough in the final water. The measures that may be necessary include adjusting the chemical dosing, restricting flow through the plant and increasing filter backwash frequency etc.

The monitoring results on the filtered water monitors should be used to optimise the operation of the filters and to identify turbidity breakthrough on any of the filters that may not be apparent by monitoring the combined fitrate alone. The management and optimization of the filters is dealt with below.

The alarm on the final water turbidity monitor should be set to ensure that the parametric value of 1.0 NTU is not exceeded. The alarm should be set at a level that allows the operator to respond to the alarm and implement the appropriate corrective actions before the parametric value of 1.0 NTU is exceeded. Therefore, the final water turbidity monitor alarm should be set having regard to the average turbidity levels. It may be appropriate that the alarm should be triggered by any increase in the final water turbidity of greater than 50% of the average turbidity levels experienced at the plant.

3. **Put in Place Procedures to Deal with Elevated Levels of Turbidity**

   Operators should have documented procedures to deal with variations of turbidity outside the normal acceptable ranges and to respond to alarms. The procedures should involve a review of the operation of the treatment plant, putting in place corrective actions and sampling for additional parameters (e.g. if there is elevated levels of turbidity *Cryptosporidium* monitoring may be carried out). All turbidity alarms should be responded to and the cause and corrective action taken should be documented to prevent a reoccurrence.

3.3 OPTIMISATION AND IMPROVED MANAGEMENT OF THE EXISTING TREATMENT PROCESSES

Management of filters is one of the key steps to reduce the levels of turbidity (and hence the risk of *Cryptosporidium*) in the final water. In order to optimise the operation of the filtration stages of the treatment plant operators should ensure that the filters are operating in accordance with best practice. The investigation to be carried out to ensure that this is the case may include the following steps below.

3.3.1 ASSESSING THE ADEQUACY OF FILTERS

The adequacy of filters should be assessed to ensure that:

1. The depth of media in the filters is adequate;
2. The filtration rates are not above the design specifications;
3. There are no preferential flow paths in the media;
4. There are no filtration process problems as outlined in Table 3 of the *EPA Water Treatment Manual: Filtration*.

3.3.2 MANAGEMENT OF THE BACKWASH CYCLE

Management of the time period before, during and immediately after the backwash cycle has taken place is key to the control of the turbidity levels in the final water. It is common practice for backwashing to be based solely on time in many water treatment plants in Ireland. It is best practice that a backwash be initiated if any one of the following criteria are exceeded:

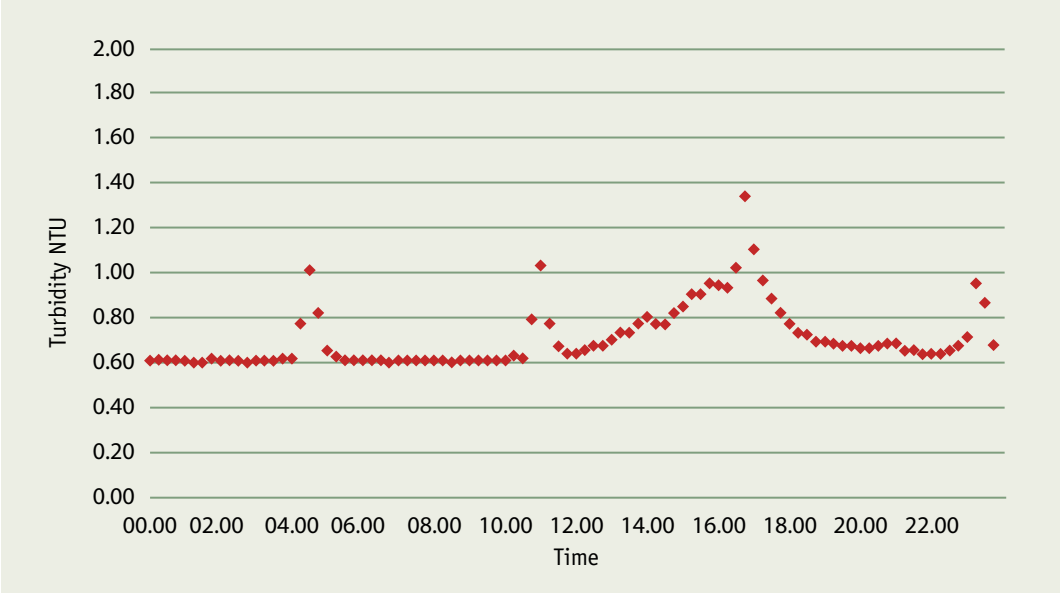
1. The turbidity levels rise above a predefined trigger or alarm level;
2. The headloss on the filter rise above a predefined trigger or alarm level;
3. A predefined time period elapses (this time will usually be based on the history of the filters and will be set at a level before which the turbidity or headloss triggers/alarms are normally expected to be breached);
4. A visual assessment by the operator of the plant indicates that a manual backwash is required (e.g. this could be before a period of bad weather is expected).

Documented procedures should be developed to outline when these criteria have been exceeded and wherever possible the backwashes should be automated.

The operator should ensure that when a filter is being backwashed the remaining filters in operation are not overloaded.

Turbidity breakthrough can occur from individual filters following a routine filter wash. This phenomenon puts the integrity of the treatment process at potential risk, particularly if the plant is subject to a challenge from *Cryptosporidium*. Following a filter wash the underdrain system will usually be full of clean backwash water but the filter media may contain residual loose dirt. On re-starting, the initial flow will have low turbidity but in a relatively short time turbidity may rise rapidly as residual dirt is flushed out of the media and into the filtrate stream. The peak is normally reached within a few minutes but the decay rate is generally considerably slower as the original background value is attained. This type of breakthrough has a distinctly characteristic curve (Figure 1).

Figure 1. Treated Water Turbidity - On-line Turbidimeter Archived Every 15 Minutes



The impact of this peak in turbidity should be managed by the operator to reduce the potential for turbidity breakthrough into the final water. Wherever possible the operator should run the first flush (i.e. until the turbidity of the filtered water has returned to acceptable levels) to waste. If this is not possible in the short term (e.g. the existing pipework arrangements may not permit this to occur) the operator should have a slow start on the filters to minimise the amount of this initial flush entering the final water. In water treatment plants where there is a high risk of *Cryptosporidium* in the catchment, it is advisable that the pipework should be rearranged to permit the first flush to be run to waste.

It is recommended that plant operators should witness a full filter cleaning cycle once a week to ensure that all parts of the sequence operate correctly and for the prescribed time, and that the filter has in fact washed clean.

3.3.3 MANAGEMENT OF THE FILTER BACKWASH WATER

It is not advisable to return untreated filter backwash water (or sludge supernatant) to the head of the works as this may lead to a concentration of *Cryptosporidium* oocysts. Consequently, this practice should be discontinued as soon as possible. Where the return of filter backwash water must be practiced (i.e. where discharge to receiving waters is not permitted and there is no sewer) the filter backwash water should be treated prior to recycling. The treatment process should aim to reduce the solids loading in the filter backwash water and minimise the concentration of oocysts being recycled to the head of the works. Under no circumstances should the filter backwash water be returned directly to the filters.

4 EPA ROLE IN DEALING WITH TURBIDITY IN DRINKING WATER

WHERE historical monitoring results indicated elevated levels of turbidity in the final water (i.e. exceed 1.0 NTU), these supplies have been included by the EPA on the Remedial Action List of Public Water Supplies (see "*Guidance Booklet No. 3: Guidance on the Development of the Remedial Action List*"). Water Services Authorities must prepare an action programme to ensure the water treatment plant complies with the 1.0 NTU parametric value for turbidity. Where the Water Services Authority is not proactively implementing measures to rectify the problem the EPA may issue a legally binding direction. Failure to comply with a direction is an offence.

5 REFERENCES AND FURTHER INFORMATION

1. Bouchier et al. (1999). *Cryptosporidium in Water Supplies*. Department of Environment, Transport and the Regions.
2. *European Communities (Drinking Water) (No. 2) Regulations, 2007* (S.I. 278 of 2007)
3. Environmental Protection Agency (2009). *The Provision and Quality of Drinking Water in Ireland. A Report for the Years 2007-2008*.
4. EPA Guidance Booklet No. 1 Guidance for Local Authorities on Regulation 9 and 10 of the *European Communities (Drinking Water) (No. 2) Regulations 2007* (S.I. No. 278 of 2007). (*http://www.epa.ie/downloads/pubs/water/drinking*)
5. EPA Guidance Booklet No. 3. Guidance for local authorities on the development of a Remedial Action List for public water supplies. (*http://www.epa.ie/downloads/pubs/water/drinking*)
6. World Health Organisation (2004). *Guidelines for Drinking Water Quality (3rd Ed).*

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