Introduction to Surface Water Treatment

Purpose of Treatment
Drinking water must be treated to make it potable by removing harmful organisms and chemicals and to make the water palatable by removing nuisance chemicals and gases.

Explanation of Terms

Maximum Acceptable Concentration (MAC)

Interim Maximum Acceptable Concentration (IMAC)

Aesthetic Objective (AO)

Apparent Colour Unit (ACU)

Nephelometric Turbidity Unit (NTU)

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Saskatchewan Environment
Environmental Protection Branch

Municipal Drinking Water Quality Objectives

The aesthetic objectives for several parameters including hardness (as $CaC0_3$), magnesium and total dissolved solids, take into consideration regional differences in drinking water quality. Bacteriological, chemical-health, chemical-pesticides and radiological parameters are the same as the Guidelines for Canadian Drinking Water Quality (6th Edition). The Canadian guidelines list additional radiological parameters and pesticides. Health Canada should be contacted when more information on the Canadian Guidelines is required.

Compliance with Drinking Water Quality Standards as stated in *The Water Regulations 2002* is mandatory although a phase-in period is provided for existing waterworks for all parameters other than bacteriological quality and chlorine residual. The objectives are to be used with judgement and discretion. When considering exposure to the various parameters through water consumption, understand that there is exposure to these parameters through air, soil, food and other natural and man-made products.

Materials Which Make Up Turbidity and Colour

Matter in water may be broadly classified as to its origin as organic or inorganic. Matter that produces turbidity is often inorganic. Matter which produces colour, odour and taste is often organic in nature. Particles that cause turbidity can further be divided by size. Particles larger than 1µ **(**micrometer**)** will settle in a relatively short time. Those particles smaller than 1µ are referred to as colloidal and will not settle under normal circumstances. Colour can also consist of colloidal particles but of a different nature than that of turbidity particles.

We further classify colloidal particles as to their hydrophobic (water-hating) and hydrophilic (water-loving) qualities. The process of water treatment is to remove these two types of materials from the water.

Hydrophobic particles are primarily clay particles and make-up turbidity. These particles have a negative electrical charge on the particle which repells each other, contributing to their staying in solution.

Hydrophilic particles are primarily organic material, which contribute to colour. These particles have a layer of water molecules around them that keep the particles from bumping into one another and thus growing larger and settling out.

Methods of Treatment

The removal of turbidity and colour and the reduction of virus and bacteria is normally accomplished by a process referred to as filtration.
The removal of harmful chemicals and removal of special turbidity and colour components can be accomplished through a series of processes referred to as coagulation, flocculation, adsorption and filtration. These processes will also reduce the bacterial and virus level below straight filtration.

The conventional treatment process will remove bacteria, viruses, some chemicals, turbidity and colour. The degree of turbidity and colour removal are used as a measure of the effectiveness of water treatment.

The electrical charge on hydrophobic particles is reduced by the use of chemicals, allowing the particles to bump together. When this happens, the particles will stick and form a larger particle. These particles will continue to bump into one another and become large enough to settle out.

Coagulation - Flocculation

Chemicals, such as aluminum sulfate and ferric chloride, when added to water will combine with alkalinity in the water to form a positive-charged, sticky material. If insufficient alkalinity is available, lime or soda ash may have to be added in order for the chemical reaction to take place.

This sticky, positive-charged material will decrease the electrical charge on hydrophobic material and, due to its sticky nature, it will speed the process of gathering more and more small particles together.

The coagulated particles are then agitated to increase the frequency of collision and cause a grouping of the particles. Small feather-like gelatinous masses will be produced called floc. The mechanical agitation of coagulated particles is called flocculation.

The speed and degree of coagulation and flocculation, and the removal of turbidity and colour, is extremely pH sensitive. The only reliable method of determining the proper amounts of chemical agitation and pH is by experimentation. The testing unit for the experimentation is called a jar tester. It consists of six 1.5 litre beakers with paddles, the speed of which can be varied to duplicate the coagulation and flocculation process. The jar tester is used to duplicate the plant's treatment processes to determine the correct chemical dosage

After flocculation, the water is passed to a sedimentation basin. As the water becomes quiescent (still) or stops moving, the floc will settle, sweeping additional particles from the water.

In summary, the process of coagulation is a chemical process, whereas, the process of flocculation is physical. Coagulation is dependent upon pH, degree of agitation and dosage of chemicals. The floc is then allowed to settle in a sedimentation basis.

The Physical Equipment

Coagulation takes place in a matter of tenths of seconds. It is important that chemicals used for coagulation be added and dispersed quickly. This is accomplished in a unit called a flash mix. Various types of flash mix units exist; the most desirable would be a unit which allows the operator to control the mixing rate.

Flocculation takes place where the water may be passed through a chamber which has decreasing agitation along the direction of flow. Too little agitation will keep floc from forming, while too great of agitation will destroy the floc.

Various types of baffling systems as well as mechanical devices are in use. Each has its problems. However, the problems associated with short circuiting are common to all types of units.

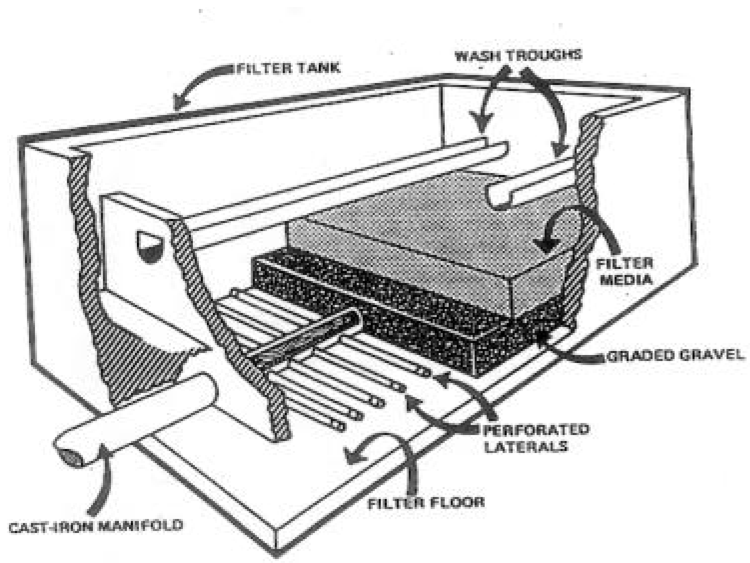
The sedimentation basin can be either rectangular or round. It should have sufficient size to allow settling of a major portion of the floc and should have a means of drawing off the sludge or settled floc.

The sludge from the sedimentation basin is disposed of by passing it to a lagoon for holding, directing it to the sanitary sewer or returning it to the plant's raw water. The settled water is then passed to the filter for further clarification. Only the slow sand filter and the diatomaceous earth filter may be effectively operated without these pretreatment steps.

In summary, a block diagram of a typical water treatment plant may help to explain the relationship of each unit to the others.

Filtration

The removal of colour and turbidity may be the main emphasis of this process. The process can be altered to remove some chemicals and reduce the bacteria and viral levels.



There are basically four types of filtration devices in use:

- slow sand filtration,
- rapid gravity filtration,
- pressure filters and
- diatomite filtration.

Each has its own advantages and disadvantages and special application problems. Regardless of the type of filter to be used, the process or removal of materials through filtration involves straining, sedimentation and adsorption.

Rapid Gravity Filters: Due to the tremendous land area necessary to house slow sand filters and their relative inefficiency to remove high turbidities, the rapid gravity filter was developed. The rapid gravity filter structure consists primarily of a structure to house the filter media, filter media; an under-drain system; valves and piping system; a filter wash system and a waste disposal system.

The filter media is usually two to three feet deep and supported by approximately one foot of graded gravel. The media may be made of fine sand or a combination of sand, granite and anthracite coal.

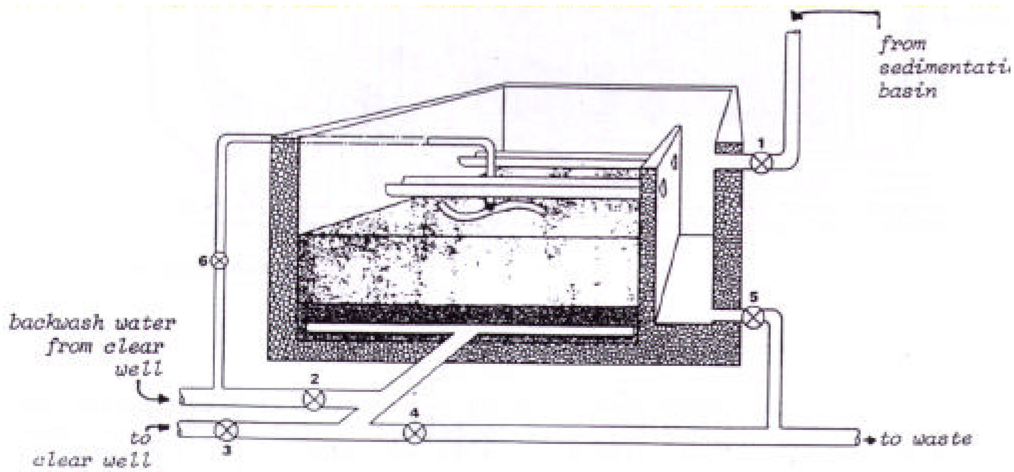
Operation of Rapid Gravity Filters: Water is usually applied to filters at a rate of 2-4 gpm/ft^2 of filter media surface. This is a considerably greater rate than slow sand filters, thus there is a decrease in the physical size of filter needed.

This filter style will produce water of 0.1 to 0.2 NTU from raw water up to 1200 NTU. This can only be accomplished with the aid of pretreatment with chemicals. Filter runs (the length of time the filter operates) usually last from 17 to 72 hours. The end of a filter run is signaled whenever the head loss approaches 6 to 8 feet.

When a gravity filter is in operation, water from the sedimentation basin enters the filter tank through the wash troughs, moves through the filter media and is collected by the underdrain system and directed via a system of pipes to the clear well for storage.

The head loss increases as the filter removes the fine particles from the water passing through the media. Then the filter media must be cleaned before the head loss becomes too great and debris (that has collected on the filter) is driven through the filter into the finished water, thus allowing high concentrations of bacteria and virus to enter the finished water.

Cleaning the Filter: The filter media is washed by passing water up through the media and agitating the top of the media with a surface wash device and conducting this water away to waste via the wash troughs.



Basically this is the sequence of events that occurs during the cleaning process once the head loss indicates the end of the filter runs:

- the valve (#1) bringing water from the sedimentation basin to the filter's inlet gallery is closed, allowing the filter to start draining down (water is still flowing to the clear well);
- as the water in the filter drains down to just above the filter media, the valve (#3) leading the filtered water to the clear well is closed;
- valve #5 at the bottom of the inlet gallery is opened to allow backwash water to go to waste;
- valve #6 is opened to activate the surface wash, to break up any caking that may have occurred on the media surface;
- treated backwash water (Valve #2) from the clear well is introduced, slowly at first, through the underdrain system allowing the water to pass up through the filter media into the wash troughs (launders) and then to waste via Valve #5. The backwash rate is usually around 15 gpm/ft^2 of filter surface area and the media will be lifted approximately 40% of its height;
- the backwashing should only take a few minutes and the water passing out through the wash troughs can be observed as it clears;
- when it has cleared of most of the material, the flow of the backwash water (Valve #2) is stopped and the surface wash (Valve #6) is also stopped;
- the filter is allowed to rest briefly to allow the filter media to settle back to its normal height;
- after all the dirty water has drained away from the wash troughs and the inlet gallery, the valve (#4) on the drain to waste is closed;
- the valve (#1) bringing water from the sedimentation basin to the filter's inlet gallery is opened allowing water to enter the filter;
- the valve (#4) on the filter outlet leading to waste is opened, allowing the filter to operate and to rinse to waste any material still in the filter;
- this rinse should only take a few minutes and if there is an on-line turbidity meter one would notice an increase then a decrease in turbidity. It is preferable to rinse to waste, not to the clearwell; and
- the valve to waste (#4) is closed and the valve to the clear well (#3) is opened, placing the filter back into service.

Advantages and Disadvantages: The main advantages of rapid gravity filters are the low construction cost and the relatively high quality water that water may be produced from relatively low quality water. The operation of the filter and the condition of the filter media during operation and backwash can be observed at all times. The largest disadvantage is the increased operation and maintenance cost.

Pressure Filters: These filters are becoming increasingly more popular because they may be placed directly in a pumping line with little head loss. The pressure filters are manufactured in virtually the same pattern as the rapid gravity filter. The main advantage of this unit is the low initial cost. The disadvantage is that the operator is unable to observe the filter media and therefore, unable to determine the condition of the media.

The other major operational problem is that unless the unit has automatic shut-down on turbidity, there is the possibility of driving material that has accumulated on the filter through the media into the finished water. This is called filter breakthrough, which can be avoided by good operational controls.

Filter Problems: These problems are usually divided into two categories: those caused by too long of a filter run; and those caused by inefficient backwash.

Some problems caused by too long of a filter run are:
- breakthrough: when the headloss developed, it can push debris collected on the filter media through the media into the finished water;
- air binding: if the filter becomes sufficiently clogged, the water in the center of the media may fall away faster than it can be replaced from above. This causes a partial vacuum in the media and allows trapped gases in the water to fill the void, thus binding the filter. During backwash, the release of this gas may cause violet upheaval in the media and destroy some of the media or underdrain system

Some common problems attributed to poor backwash are:
- mud balls: they are the result of accumulated silt on top of the filter. When the filter is backwashed, if the upward velocity is not sufficient to remove the silt, it may be rolled into clumps that can then be rolled downward into the media during the backwash. These clumps or mud balls will eventually clog the filter completely.
- filter cracking: poor agitation of the surface of the filter will leave silt surrounding media particles. As headloss increases, the silt and media particles are compressed together making a crust on top of the filter. The crust increases headloss and will eventually crack under the increased head pressure.

Treatment Plant Records

Like any mechanical device, certain records should be kept in order that the plant performance be maintained. Some of these records beyond those required of Section 42 of *The Water Regulations* include:
- plant flow;
- amount of each chemical used per day;
- continuous record of turbidity – raw and unfinished water;
- amount of backwash water used;
- rate of filtration;
- rate of backwash;
- time of backwash;
- pH of raw and finished water;
- alkalinity of raw water;
- coliform count of raw and finished water;
- maintenance records of equipment;
- power consumption;
- man hours; and
- chemical analysis as necessary to maintain water quality.

Glossary of Terms:

Adsorption: (1) The adherence of a gas, liquid or dissolved material on the surface of a solid. (2) A change in concentration of gas or solute at the interface of a two-phase system. Should not be confused with absorption.
Aeration: The bringing about of intimate contact between air and a liquid.
Bicarbonates: Calcium and magnesium compounds such as $CaSO_4$ and $MgSO_4$. The concentration usually determined by the difference between an alkalinity test and a hardness test.
Coagulation: In water and wastewater treatment, the destabilization and initial aggregation of colloidal and finely divided suspended matter by the addition of a floc-forming chemical or by biological processes.
Colloidal: Any substance in a certain state of fine division in which the particles range in diameter from 0.2 to 0.005 micron.
Colour: Primarily, organic colloidal particles in water.
Disinfectant: A substance used for disinfection.
Dissolved Oxygen: The oxygen dissolved in water, wastewater or other liquid usually expressed in milligrams per litre, parts per million or percent of saturation. Abbreviated DO.
Filtration: The process of passing through a filtering medium (which may consist of granular material such as sand, magnetite or diatomaceous earth, finely woven cloth, unglazed porcelainor specially prepared paper) for the removal of suspended colloidal matter.
Floc: Small gelatinous masses formed in a liquid by the reaction of a coagulant added thereto, through biochemical processes or by agglomeration.
Flocculation: In water and wastewater treatment, the agglomeration of colloidal and finely divided suspended matter after coagulation by gently stirring by either mechanical or hydraulic means. In biological wastewater treatment where coagulation is not used, agglomeration may be accomplished biologically.
Groundwater: Subsurface water occupying the saturation zone, from which wells and springs are fed. In a strict sense, the term applies only to water below the water table. Also called phreatic water, plerotic water.
Inorganic: Matter which produces turbidity.
Launders: Sedimentation tank effluent troughs.
Microorganisms: Minute organisms, either plant or animal, invisible or barely visible to the naked eye.
Organic: Matter which produces colour, odour and taste.
Oxidize: The addition of oxygen, removal of hydrogen or the removal of electrons from an element or compound. In wastewater treatment, organic matter is oxidized to more stable substances.
Palatable: In relationship to drinking water, it is that water which does not give off unpleasant taste and odours, is cool in temperature, has low colour and low turbidity. Water that is pleasant to drink.
Potable Water: Water that does not contain objectionable pollution, contamination, minerals, or infective agents and is considered satisfactory for domestic consumption.
Precipitation: The phenomenon that occurs when a substance held in a solution in a liquid passes out of solution into solid form.
Raw Water: Water that has not been treated and is to be used, after treatment, for drinking water.
Septum: Filter media on which diatoms are collected during filtration with a diatomaceous earth filter. Usually made of nylon, plastic, stainless steel or brass.
Softening: The process of control or reduction of hardness.
Turbidity: (1) A condition in water or wastewater caused by the presence of suspended matter, resulting in the scattering and absorption of light says. (2) A measure of fine suspended matter in liquids. (3) An analytical quantity usually reported in arbitrary turbidity units determined by measurements of light diffraction.
Zeolites: Natural or man-made minerals containing high concentrations of loosely held sodium ions.