Viacheslav Ermolaev

OBTAINING GOOD WATER QUALITY WITHOUT USING BIG TREATMENT PLANTS

Treatment installations in buildings

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MIKKELIN AMMATTIKORKEAKOULU
Mikkeli University of Applied Sciences

DESCRIPTION

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Abstract

The subject of this thesis is use of small water treatment installations in single family houses. Usually centralized water supply is used for such cases, but this solution can be acceptable, too. Nowadays more and more homeowners decide to provide their houses with water that is being treated in the basement of their own house. This gives them independence from community water treatment plants and also this gives them an opportunity to choose the quality of the water they are using. In this thesis different ways of water treatment will be shown, and certain purification installations for different cases will be presented

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1 INTRODUCTION

During the last few years construction has been considered to be the most intensively growing sector of the economics. Although the global economical crisis has hurt this field, we may estimate that in the next few years previous positions will be restored. It must be very interesting for construction companies.

From their point of view, the markets of developing countries, such as India, China, or Russia, are very significant. The economics of these countries is growing in parallel with the wealth of people, and the demands grow up, too. The trend is so that many people prefer buying their own house rather than just a flat. This is the chance for the companies that are willing to gain profit from the presence in the market. One of the ways of gaining additional money and meeting the customers' requirements is supplying the detached houses with individual water treatment installations

Single-standing detached one family houses are becoming more and more popular in comparison with traditional multi-flat dwellings. They provide some advantages, such as large living area (often even 2-3 floors), own parcel of land, variety of different floor plans, ability to make unique home design, ability to use own engineering communications, prestige.

However, living in a single-family house does not give you only pluses. There are the most significant disadvantages: problems with undeveloped infrastructure, costs of upkeep, and difficulties with utility services.

The last point of the list can be interesting. Sometimes, especially when situated in highly urbanized districts, single-family houses are already provided with utility services for water supply, water disposal, heating, and electric supply. But nowadays the tendency is so that detached houses are built in new districts or even rural areas, and connecting their engineering systems with old pipe and electric lines seems to be impossible, or, at least, very complicated, due to the distance between new buildings and surrounding habitation.

It would be very attractive to write about all problems that the company dealing with the engineering systems will face with when designing and constructing communications for detached houses. But if you try to make a short review of all the literature concerning this theme, you will see that the topic is too large. It seems to be better to describe a certain part of the utility services, and providing the house with drinkable water is one of the most important of them.

That is why I decided to choose it as a theme of my bachelor's thesis. In most cases the householder can make a heating of the house by himself, without using any special knowledge. If the heating system is installed incorrectly, it may result in decreasing the average temperature at the room. On the other hand, if the homeowner will try to install a system that is making the raw water pure enough, i. e. water treatment, by himself, it may lead to much worse consequences. In order to prevent such situation, I will make a short overview or purification installations for drinking water in buildings. I hope this will help to make the right decision of what kind of treatment method and treatment plant must be chosen in each specific situation.

There is another point of view on these treatment solutions. Sometimes, it is said that buying clear water in bottles is cheaper than purifying the raw water. In my thesis I am going to compare estimate the costs of such installations and try to show that they are not so expensive according to the price of the whole house.

Now it is time to describe the contents of my thesis. After the Introduction comes Water quality. Different ways of water obtaining will be shown and the most common types of impurities we can meet will be presented there, too. Also, the most common water quality standards that can be used by the householder to estimate the needs in water treatment will be shown.

Next part is Solutions. It can be called the main chapter of whole Thesis. This is a description of treatment methods that are used when purifying the water in small filtering installations.

Estimation of costs is the final analysis of reasonability of using such systems. The prices of installations will be shown, and then the example of cost estimation will be given.

Finally, the Conclusion. A total summary of the information of treatment installations, and conclusion about the reasonability of their application.

2 WATER QUALITY

Before talking about water treatment technologies and equipment, it may be useful to know more about different types of impurities than can be met in water. The probability of such meeting highly depends on the source that is used for water supply. That is why this chapter starts from the description of different water sources. After that, impurities will be described. In the end of the chapter the ecological standards of European Union about permissible containing of impurities will be described.

2.1 Water sources

These are the sources that can be used as the sources of water for the detached single family house:

- constant functioning pipe-lines;
- season-to season functioning pipe-lines;
- surface water sources
- shallow well (groundwater);
- deep well (ground water).

Also combined water supply can be used.

2.1.1 Constant functioning pipe-line

It is the most desirable choice. In spite of the difficulties with receiving an acceptance for connecting your house to the municipal pipe-line, this is the least expensive and the most comfortable way of water supply for your house. All costs for investigation, development and maintenance are taken care of the municipal operating organization. Householder has only to get permission, pay for the connecting, lead the water into the house properly and build the pipes to the water intake points. In that case special attention must be paid to two things the constructor cannot influence. These are the incoming pressure and water quality.

Probably the operating organization has taken into account all construction standards and requirements to the quality of water. On of the basic issues is building regulations is the number of water consumers. Most likely that with growth of modern building industry, the number of consumers connected to previously built pipe-line system, has significantly grown, too. Besides that, the desirable attention to preventing the damage of pipes is not paid due to the economic situation. This may result in significant water leakages, and the working pressure in common water supply system may be much less than needed. Also, in such situation it is not the constant value that may lead to additional problems. If proper working of the equipment situated in local private water supply system depends on the working pressure in the system, corresponding measures must be taken.

In Nordic countries pipe-lines always mean acceptable water quality, but anyway there are some regions where situation is often more troublesome. When choosing the water source, maintaining organization must meet the existing requirements to water quality. It often happens that the consumer gets the untreated water from his tap. Usually this problem happens because of unacceptable quality of water mains that may be too old. In that case the water running in them becomes saturated with the material that those pipes made of. This means that before using the water from community pipe-lines, the householder has to consult with the specialist. He will investigate the water source, the quality of pipes that lead the water into the house and will recommend the chemical analyses that need to be done. As a result of these analyses a conclusion of the suitability of this water for the drinking will be drawn.

2.1.2 Season to season functioning pipe-lines

Season to season functioning pipe-lines for common use can be met rarely nowadays, but in the areas where they are present, they may be good choice. These pipe-lines have the same problems as constant functioning ones. Usually maintaining organizations are even poorer and when designing the water supply system fewer requirements to the quality are made, and more problems with equipment may occur due to non-functioning in the cold seasons of the year. Because of this the situation with the working pressure and water quality in the system is even more significant in this case. Besides, when using season-to season functioning pipe-lines as the water source, the water supply system must be dimensioned in such way that the discharge of all water from the system can be made. This must be done in order to prevent the damage of pipes, armature, and equipment due to freezing in the cold time of the year. And, of course, there is no possibility to install water supply and water-based heating system in the cold seasons when using this option.

2.1.3 Surface water

Surface water includes water from lakes, rivers, and those waters stored as ice or snow. Using the last two seems to be fantastic, but lakes and rivers may serve as good and reliable water source in case of absence of others. The trouble is that the quality of water in the surface water is not only highly unacceptable, that means large costs of treatment equipment, but also unstable during the year and this result in large variety of purifying devices required for the certain season.

2.1.4 Shallow well

When it is impossible to connect the house to water mains, alternative water sources have to be found. In that case the first thing that comes to the mind is a well. Sometimes taking water from the well is perfect decision, because in some cases it is pure enough to use it without special filtering systems. But, while developing industry and agriculture, man has spoiled not only surface water available for water supply. This also refers to groundwater from first water bearing levels from the surface, where the wells are dug. Despite that, they still can become good sources of fresh water. To choose a well for you house’s water supply, a number of investigations must be carried out. Analysis must be done for capping water bearing level, water quality and their ability to meet to declared requirements. There are the situations, when the wells can be used for water supply without any water purification measurements.

Water supply is needed to provide household water use for domestic purposes, except drinking and cooking. The householder’s needs water only for irrigation, car and dish washing, sauna etc. In that case the demands for pressure and amount of water are minimal. If there are no dumping places, burial grounds for animals, aeration fields and other large sources of contamination in the area of groundwater horizon where your well will be situated, then, most likely, the well can be used for capturing the water. But, anyway, the chemical analysis of water in the period of peak contaminant concentration in the water bearing levels is needed. Usually, it is in the maximum water flows period in the end of the spring or in the summer. Only the specialist is able to solve this problem. If in the period of maximum contaminant concentration of the impurities the requirements for technical water are not exceeded, the well, being the cheapest of alternative sources of water, can be used for water supply even without additional water treatment.

Water source is situated in the nearby the river. Sometimes different compounds in the soil in such areas may work like filtering media for water that flows nearby. In such case the use of the well is possible even for drinking water supply with minimal treatment, i.e. after carrying out water analysis in the periods of peak concentrations and in dry weather period the conclusion of possibility of such water for detached house water supply and of treatments systems that may be needed will be done.

These cases are rather good for the householder but they are not common. Usually water from the well needs purification.

When using wells as water supply sources, the installation of pumps for delivering the water to the house is possible. It mainly refers to the warm time of the year. Theoretically, this can also be done for winter time, but it is difficult engineering task that must be performed perfectly.

Other options of using wells for water supply are possible, too. If the water in the area is situated too deep to dig a well, 10 meters or more, it is often reasonable to drill a deep well. To find out the depth of occurrence of groundwater on designing stage, geophysical methods should be used.

2.1.5 Deep well

It is not always possible to make connection between the house and water mains, but the water supplied to the apartments must be drinkable. Also, water quality in the water bearing levels that are available for capping will require significant expenses for treatment. And the water is needed in large volumes not only in summer, but in winter, too. In such case it is possible to make the own water source (well) and water supply pipe-lines. And, although its self-cost will be much lower that the centralized water supply (since it will have lower power demand, lower pipe diameters etc), the requirements to the water quality will be the same. Technology of hydrogeological exploration, which is widely used in centralized drinking water supply is applicable for private sector.

Since water intake from such kind of water well is becoming more and more significant, it is desirable to make a little bit more detailed overview.

The water sources in that case may be subdivided into two types. We will look through them and show important features of the water systems that take the water from that kind of sources.

First, water bearing levels are relatively low. The depth of a well that is needed to obtain the water is maximum 40-60 m. The amount of that water source will be rather low, and the water may be tied with the surface water. Consequently, the water will have the following features:

- Low cost of well;
- Low cost of water-lifting equipment;
- Large expenses on the water quality investigations;
- Large expenses on the water treatment equipment;

Another case is when water levels are high. Their depth may reach several hundred meters (in most cases it varies in the range of 40-180 m). Basic characteristics of drinking water in that area are large reserve of groundwater, and its immunity to contamination because of large distance between the water level and ground surface. These properties mean the following set of features:

- Higher cost of well due to higher depth and more complex water supply equipment required;
- Higher cost of water lifting equipment because more powerful pumps are needed to lift up the water from the higher depth and higher length of water mains;
- Lower expenses on investigation and prediction of water quality;
- Lower expenses on water treatment equipment (in some case water quality is meets the requirements without and treatment)

Another important thing is that the householder makes sure that the well is situated according to the sanitary standards. They mention the minimal distance between the water source and possible sources of contamination: septic tanks, sewerage pipe-lines, car washing place and so on.

Well structure must protect the infiltration of surface water to water bearing levels. Also, all drilling operations must be done carefully to protect the future contamination of water source.

Water treatment equipment must be chosen in such way that it will purify the whole amount of water taken from the well. Filter type must be chosen properly in order to provide required water quality. Water lifting equipment must provide the supply of water with required pressure and flow rate.

2.1.6 Combined water supply

Sometimes, in order to decrease the expenses on water supply system construction, using several water sources is possible. In that case the water supply scheme consists of several systems using different water sources, pipe-lines and pumping equipment. Also another variant is possible, when only one water source is used, but the water in water mains goes to two different purposes. Some amount is supplied to the treatment devices and after purification goes to the drinking purposes. The rest water is used for the technical purposes, i.e. car washing, without treatment. This helps to decrease the costs on treatment equipment.

2.2 Impurities

There is a large variety of water treatment methods and equipment. The trouble is that they are not universal. This means that for each certain case different methods should be applied. These methods highly depend on the types of impurities that can be met in water and on water quality. To describe water quality, the following major characteristics are used:

- Physical characteristics;
- Chemical characteristics;
- Biological characteristics.

2.2.1 Physical characteristics

"Most of our impressions of water quality are based on physical rather then on chemical or biological characteristics. We expect water to be clear, colorless, and odorless. Most natural waters are at best cloudy; they are often colored by tannins and other organic materials picked up from decaying plants; and backwaters, sloughs, and swamps are noted for their characteristic odors. Quantitative measurement of these characteristics is necessary for the determination of water quality" /2, p. 86/. Physical characteristics include such indicators.

- Turbidity
- Solids
- Odors
- Temperature
- Color

Here is the table showing the common analysis of physical impurities in water /2, p 57/.

Table 1. Physical impurities of water

Test	Abbreviation/ definition	Use
Turbidity	NTU	To asses the clarity of water
Solids		
-Total solids	TS	To determine the most suitable process for treatment
-Settleable solids	mL/L	To determine those solids that will settle by gravity in a specified time period
Color	Various light-yellow hues	To assess the presence of natural

		and synthetic coloring agents in water
Temperature	°C	To design and carry on treatment processes; to determine the saturation concentrations of various gases

Turbidity

Characterizes the presence of suspended particles of sand, sludge, clay, algae in the water. Usually turbidity is the first thing that indicates the quality of water. Measurements of turbidity are performed with devices that determent light transmission using standard light sources /2, p 57/.

Solids

"Solids" is a term used to describe all contaminants of water, other than dissolved gases. Solids can be classified by their chemical characteristics, and by their size distribution.

Odors

Odors and tastes that can be met in natural waters may have natural (presence of iron, manganese, hydrogen sulfide) or artificial (discharge of industrial waste) origin. Four basic water tastes are usually marked: salty, bitter, sweet, and sour. Numerous shades of tastes, combined from the basic, are called smacks /1, p. 21/.

Salty taste is usually specified by the presence of sodium chloride, bitter – by magnesium sulfate. Soar taste is explained in most cases by excess of dissolved carbonic acid (in mineral waters); ferriferous smack in water is given by dissolved salts of iron, alkaline – by soda; astringent – by calcium sulfate, manganese salts.

The word “natural” is usually referred to the odors like earthy, fishy, rotten, etc. “Artificial” odors are chlorine, phenol, chlorine-phenol and so on.

The most common offensive odors and the reasons of their present are shown in the table below /2, p. 64/.

Table 2. Offensive odors in water

COMPOUND	TYPICAL FORMULA	DESCRIPTIVE QUALITY
Amines	$CH_3(CH_2)_nNH_2$	Fishy
Ammonia	NH_3	Ammoniacal
Diamines	$NH_2(CH_2)_nNH_2$	Decayed flesh
Hydrogen sulfide	H_2S	Rotten egg
Mercaptans	CH_3SH; $CH_3(CH_2)_nSH$	Skunk secretion
Organic sulfides	$(CH_3)_2S$; CH_3SSCH_3	Rotten cabbage
Skatole	$C_8H_5NHCH_3$	Fecal

Temperature

Water temperature for underground sources is rather constant and usually about 8...12 ºC. Water temperature of surface sources varies during the seasons of the year and depends on the inflow of underground water and on the discharges of used cooling water. Optimal temperature for domestic and potable water is 7...11 ºC.

Color

Usually most part of colors that are associated with water is not “true” colors. It is the result of colloidal suspension. A good example of such suspension could be a tea. Real colors usually result from organic dissolved materials. In natural waters coloration in most cases is caused by presence of dissolved tannins obtained from decaying plants. The tint is slightly brown. Also it is important to say that many industrial wastes are colored so the coloration of water may be caused by the wastewater stream that has not been treated carefully /2, p. 65/.

Color is usually measured in degrees of platinum-cobalt scale. In order to measure water color different devices like spectrophotometer are used. The principle of their operation is based on the measuring the optical density of water /1, p. 21/.

2.2.2 Chemical characteristics

Chemical characteristics are as important for the drinkable water, as physical. Sometimes they can affect the organoleptic characteristics making water being no suitable for drinking, but sometimes their presence can not be noticed by human sense organs, although it makes the water harmful. That is why analysis of water is very important to find out which chemical impurities may be contained in water and how they affect on its quality. In this thesis the following characteristics will be described.

- Total residue
- Chlorides and sulfates
- Alkalinity
- Hardness
- Iron and manganese
- pH
- Nitrogen containing substances
- Radioactivity

Chemical origin impurities analyses are presented in the following table /2, p.67/.

Table 3. Chemical impurities in water

Test	Abbreviation/ definition	Use
Dissolved cations		To determine the ionic chemical composition of water and to assess the suitability of water for usage
Calcium	Ca^{+2}	
Magnesium	Mg^{+2}	
Iron	Fe^{+2}, Fe^{+3}	
Manganese	Mn^{+2}, Mn^{+3}	
Dissolved anions		
Chloride	Cl^-	
Hydroxide	OH^-	
Nitrate	NO_3^-	
Sulfate	SO_4^{-2}	
pH	$pH=\log 1/[H^+]$	To measure the acidity or basicity of aqueous solution
Alkalinity	$\Sigma(HCO_3^- + CO_3^{2-} + OH^-)$	To measure the capacity of water to neutralize acids
Hardness	Σ(Multivalent cations)	To measure the soap-consuming capacity and scale-forming tendency of water
Radioactivity	Ci	To estimate the presence of radioactive substances

Total residue

This term allows to estimate the amount of salts and concentration of impurities containing in the natural waters. Total residue characterizes the amount of impurities of non-organic origin. If this value exceeds the permissible level, special measures must be taken. When drinking such water hypermineralization may occur, that causes different diseases /1, p. 23/.

Chlorides and sulfates

Due to their high solubility chlorides and sulfates are present in all natural waters, usually in the form of sodium, calcium, and magnesium salts. Presence of high concentrations of sodium sulfate in water disturbs the activity of gastrointestinal tract, while magnesium sulfates and chlorides affect on water hardness /1, p. 24/.

Alkalinity

Alkalinity determines with total amount of hydroxyl ions containing in water and anions of acids like carbonic or organic.

Hardness

Water hardness is caused by the calcium and magnesium salts. Hardness is not harmful for human health. On the contrary, calcium assists exhausting cadmium from the body. But, anyway, high hardness makes water unsuitable for household water use, since it makes deposits on the kettles and domestic equipment like washing machines, and may injure them.

Iron and manganese

Iron and manganese are present in both surface and, especially, underground waters. Drinking such water may result in liver diseases, this water has foul taste. /1, p.26/ Also, presence of iron and manganese in water may cause clogging the pipes and heat exchangers. That is why these characteristics' values are limited for drinking and domestic water.

pH

This value is negative decimal logarithm of multiplication of hydrogen and hydroxyl ion concentrations in the water. It shows if the water tends to be acid or alkaline. For neutral water, this value is 7. Natural waters usually have values of 6,5…8,5 that are acceptable.

Nitrogen containing substances

These substances are generated in water as a result of natural processes or by the chemical processes in non-treated wastewater. In the second case the water may be dangerous from the sanitary point of view. The excess of permissible level of nitrates containing may cause disturbances of oxidizing function of blood, so the amount of these substances in water must be restricted /1, p.29/.

Radioactivity

Many natural waters may contain certain levels o radioactivity. It especially refers to the waters obtained from large depths. It is caused by the natural background radioactivity levels of the area. For example, radioactive substances may be present in soil and rocks. Also, radioactivity in surface water may have anthropogenic origin. Taking into account the effects of radioactive impurities on water quality is very important, especially if water is used for drinking.

In Finland major problem of radioactivity in water is concerned with radon /4, p. 4/. It contains in water in gaseous form. If the analyses showed the presence of radon in water that is meant to be used for household water supply, certain treatment measures must be taken.

2.2.3 Biological characteristics

The last, but not the least, are biological characteristic of water. Their significance based on the fact that, although they are extremely important for drinking water, the only way to check if the water is acceptable according to biological parameters is making an analysis. Biological characteristic describes the presence of water-living organisms, i. e. hydrobionts in the water. Some of them are dangerous for human health, some of them are harmless, but their presence means that water is biologically polluted with dangerous biological organisms. The following characteristics are represented here.

- Coliform bacteria
- Escherilla coli (E. coli)
- Plate counts
- Faecal streptococci
- Cryptosporidium parvum
- Clostridium perfrigens

Coliform bacteria

Coliform bacteria are rod-shaped bacteria that can be found in natural environment. They may be derived from the human gut or from the guts of other warm-blooded animals. This means that their presence may indicate the pollution of water source with biological waste. After the analysis the most probable number (MPN) of bacteria is found. The final result is a number of coliforms per 100 ml.

Escherichia coli (E. coli)

If the presence of coliform bacteria is detected, it is important to find out the ones the only source of which can be the guts of warm-blooded animals. E. coli test confirms that the coliforms are of faecal origin. Actually, coliform bacteria can arise from other sources that faecal contamination, so the presence of such bacteria could be permissible in a small amount of samples. The presence of E. coli is always unacceptable in drinking water.

Plate counts

Plate counts show the total number of bacteria incubated in a sample of water. This value is useful for detecting the changes in water quality.

Faecal streptococci

As well as coliform bacteria, faecal streptococci derive from guts of warm-blooded animals. Since they are more persistent than E. coli and coliform bacteria, they may be used for indication of remote pollution.

Cryptosporidium parvum

This is a very persistent protozoa. It gives rise to severe diarrhea which cannot be medically treated.

Clostridium perfringens

These bacteria are associated with faecal pollution, too. Any amount of that kind of bacteria indicates the presence of pathogens resistant to disinfection /3, p. 24/.

Now we now what water sources can be used for water supply for detached house and what impurities can be met in the water. Table 4 will compare different water sources according to the contaminants that can be there /1, p. 78/.

Table 4. Comparison of water sources

	Constant functioning pipe-lines	Season to season functioning pipe-lines	Surface water sources	Shallow well (ground water)	Deep well (ground water)
Turbidity	Low	Low/ medium	High	Low/ medium	Low
Colour	Low	Low/ medium	High/ medium	Low	Low

Odour	Low	Low/ medium	High/ medium	Low	Low
Iron/ manganese	Low/ medium	Low/ medium	Medium	Medium	High/ medium
Chlorides	Low	Low	Low/ medium	Low/ medium	Low/ medium
Sulfates	Low	Low	Low/ medium	Low/ medium	Low/ medium
E. coli	Low	Low/ medium	High	Low	Low

2.3 Quality standards

Requirements to the water quality have been growing during all XX century /3, p.13/. Now the trend is reducing the number of parameters analysed for all supplies. When designing water supply system for the single family house, no restrictions of water quality are actually made. This means that theoretically the householder may provide his house with water of any quality. Of course, in practice this is a very poor idea. No one wants to use untreated water for drinking and domestic purposes. And, in order to estimate the quality of water that can be called acceptable, some standards must be used to compare the existing quality with permissible levels. In this chapter different water quality standards are briefly described. It is recommended for householder to choose one of them and purify the water according to given requirements. The following standards are presented in this thesis.

- European standards
- WHO standards
- USA standards

<u>European standards</u>

Directive on the quality intended for human consumption was invented in 1998 (98/83/EC). Directive divides the quality parameters into three parts: part A sets mandatory microbiological parameters, part B sets mandatory chemical parameters and part C sets indicator parameters, physical, chemical and microbiological.

The requirements given in Directive are mandatory for all European Union countries. The only changes that can be made in the standards are toughening the requirements /3, p.16/.

WHO standards

The last revision of water quality standards by WHO is the third edition of WHO Guidelines for Drinking-Water Quality (2004), with an Addendum in 2006. It contains much less strict limitations for the water quality characteristics that other standards. For example, no guideline values are set for colour and turbidity /3, p.14/.

Anyway, these recommendations can be used by the householder that it is going to provide his detached house with pure water. It is an international water quality standard and can be used for evaluating water quality as well.

USA standards

US water quality standards are National Primary and Secondary Drinking Water Regulations. Primary standard regulate contaminants that can affect public health. Secondary standards refer to aesthetic parameters /3, p.17/.

This table shows the values that are set for different water quality characteristics by above-mentioned quality standards (units are µmg/l if not specified) /3, p.286/.

Table 4. Water quality standards

Selected parameter	WHO Guideline value (2006)	EU – 1998 (98/83/EC)	US Federal standards (state standards may be tighter)
Turbidity (NTU) Colour (mg/l Pt/Co) Taste	None set None set None set	Acceptable (C) Acceptable (C) Acceptable (C)	1 15 None set
pH Iron Manganese Nitrates (as NO_3) Sulfates	None set None set 400 50 mg/l None set	6,5-9,5 200 (C) 50 (C) 50 mg/l (C) 250 mg/l (C)	6,5-8,5 300 50 62 mg/l 250 mg/l
E. coli (No./100 ml)	0	0	0

3 SOLUTIONS

When purifying the water for the single-family housed, it is always very important to choose the right treatment method according to the impurities that are present in the water. Methods that will be discussed in my thesis are:

- Aeration
- Filtration (pressure or gravity)
- Sorption (activated carbon)
- Ion exchange
- UV disinfection

After description of each method, a treatment installation that uses such technology will be shown and its principle of operation will be explained.

Table 5 shows how different treatment methods are effective against certain impurities. This will help for the choosing the right technology /3, p. 251/.

Table 5. Treatment methods

Treatment process	Bacteria/ viruses	Turbidity	Colour	Iron, Manganese	Radon	Nitrates	Taste and odour
Aeration				*	**		*
Filtration	*	*		*	*		
Sorption			*		*		*
Ion exchange						**	
UV disinfection	**						

* indicates partially effective processes

** indicates effective processes

3.1 Aeration

Aeration, i. e. oxygenizing the water, is usually used to release CO_2 and hydrogen sulfide from the water. Also it is used in treating high levels of iron and manganese. Aeration is a cheap method of controlling the tastes and odours caused by hydrogen sulfide and reducing the corrosiveness of water due to excess levels of CO_2. It is important to notice, that aeration is preliminary treatment. This means that after aerating, water will usually need additional purification.

The reasons of using aerators are the following:

- Hydrogen sulfide (causing tastes and odours) – to exhaust the dissolved gas;
- CO_2 (due to corrosive tendencies) – to exhaust the excessive gas;
- Iron and manganese presence – to encourage oxidation of reduced soluble forms of iron and manganese;
- Low levels of dissolved oxygen – to increase the oxygen content.

Also, aeration shows good effect in radon removal. Aeration is usually used for groundwater treatment /3, p.57/.

This picture shows the typical aerator for the single family house.

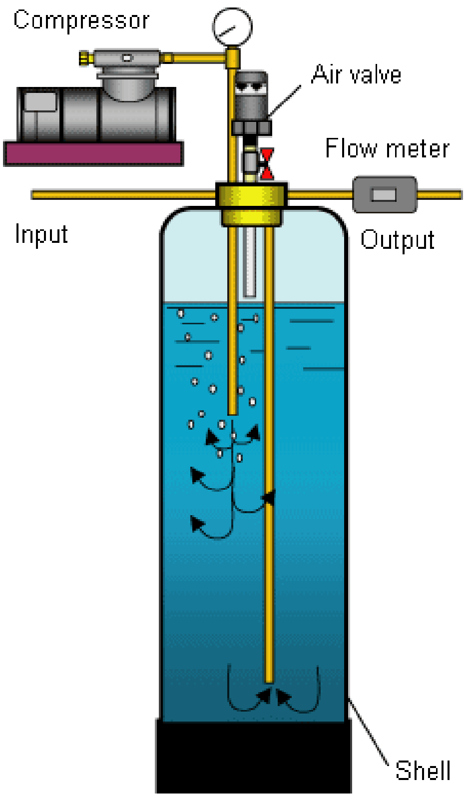

Figure 1. Aeration treatment installation

Water is being transferred to the aeration plant by means of the excessive pressure, and after that it is being aerated with the compressor. This system is used when the flow and incoming pressure of water is enough. In the other case, the following system is more preferable.

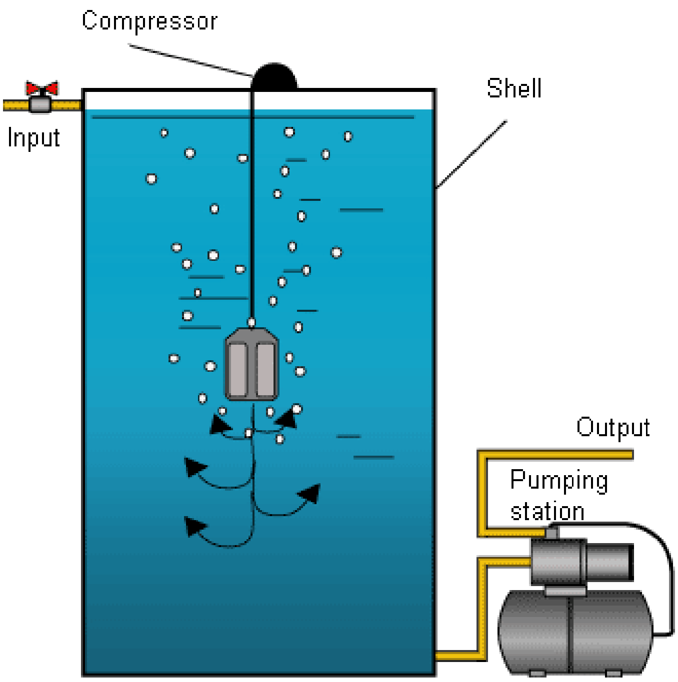

Figure 2. Aeration treatment installation with pumping station

The principle of working is the same, but if there is not enough pressure to deliver the water to the pot or to the next stage of treatment, a pump is used.

3.2 Filtration

The process of filtration consists of passing water through the granular bed, of sustainable medium (usually sand). The media retains most solid matter while permitting the water to pass, and filtrate from a filter will have a turbidity about 0,1 NTU /3, p.141/.

Usually in treatment practice the clarification stage must come before filtration. But when talking about water treatment for single family house, water is clean enough in most cases to pass it through filters without additional treatment.

In our case two types of filters can be used: gravity filter and pressure filter. In most situations the water is be delivered to the house by means of the pumps, so pressure filters are very wide spread.

This picture shows typical pressure filter, with both sand load and active carbon load that makes organoleptic characteristics of water better (see "sorption" below).

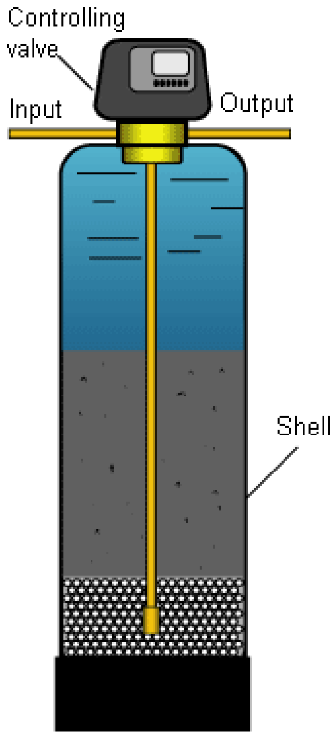

Figure 3. Pressure filter

Controlling valve regulates the amount of water passing through the filter and controls backwashing.

<u>Backwashing</u>

During the process of water purification, different impurities are accumulated in the filter media. This makes filtration less effective, less impurities are taken by the filter and head losses increase. To clean the bed, the process called "backwashing" is commonly used. This means that the water or air is passing through the filter media in the direction opposite to the normal. Then the dirt is washed out of the bed. The easiest way to make the backwashing is to use water. Backwashing starts according to different parameters being analysed for the filter: head loss, loss of effectiveness or simply by time.

Scheme of filter backwashing is shown in the picture below.

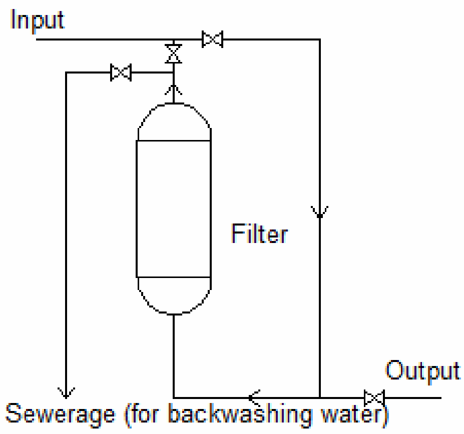

Figure 4. Filter backwashing

Water goes through the bypass line to the opposite side of the filter, washes the media and then flows to the sewerage.

Iron and manganese removal

When choosing proper media, this kind of filters can be also used for iron and manganese removal in case their concentration in raw water is not too high. The principle of removal is that ions of iron and manganese are oxidized by the oxygen of air and turn into insoluble compounds which are easily taken out of water by means of filtration. Catalysts are used in filter media. When the media exhausts its catalyst ability, it is replaced with new one /1, p. 305/.

Often the removal of iron and manganese is performed in two stages. First, the aeration of water of made. The second stage is passing the water through the filtration media. In that case two types of systems is used, for the case when the pressure in the system is enough and for the case when additional pressure is needed.

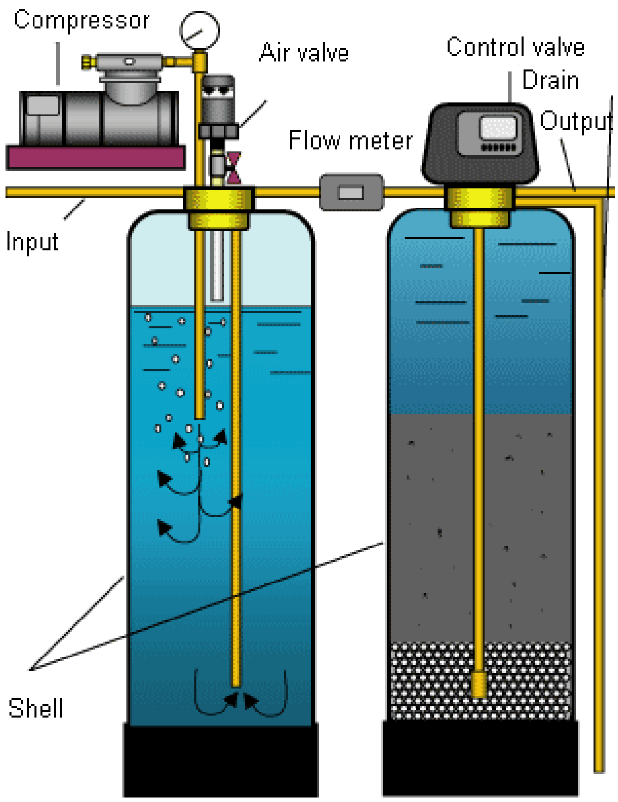

Figure 5. Iron and manganese removal installation

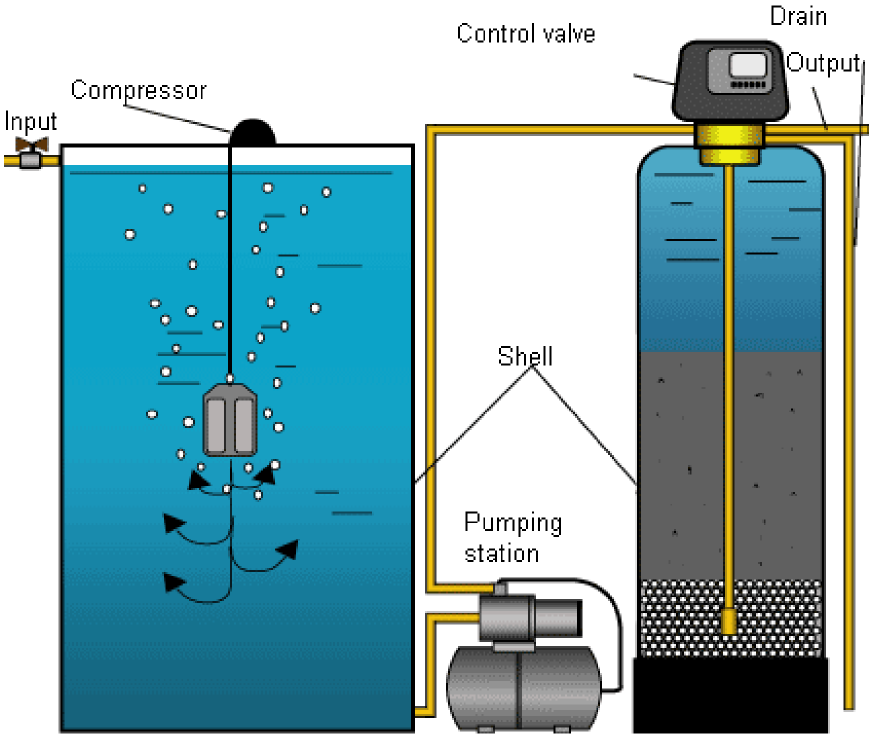

Figure 6. Iron and manganese removal installation with pumping station

In the most difficult cases, with large amounts of iron and manganese in water, oxidization with reagents is used. Such are also good in sulfur sulfide removal. They represent filter with catalyst media and a tank with solution of $KMnO_4$ that is used as a reagent. Oxidization goes more effective, and also there is a possibility to regenerate the catalyst ability of media by feeding it with new amounts of solution.

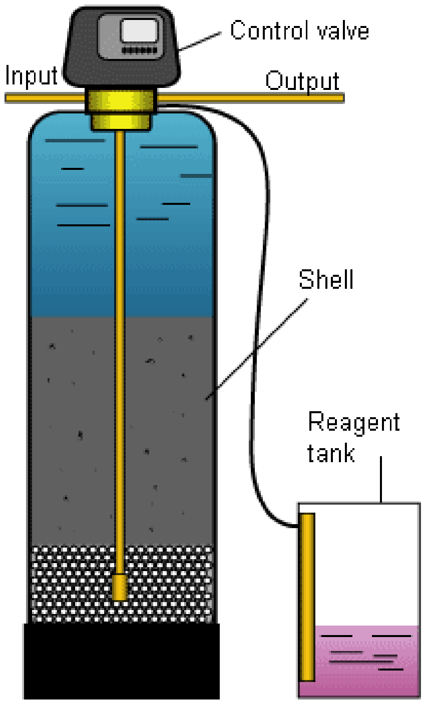

Figure 7. Iron and manganese removal installation with reagent tank

3.3 Sorption

Sorption, i. e. the process, when the substance accumulates the particles of another matter, is widely used in water treatment. Different impurities are extracted from water by this method.

The most commonly used sorbent is activated carbon. In raw water treatment it is used mostly for desodoration. It is also effective in radon removal processes /3, p.183/.

In water treatment for single family houses activated carbon is used in granules as a media. An example of sorption filter is shown here.

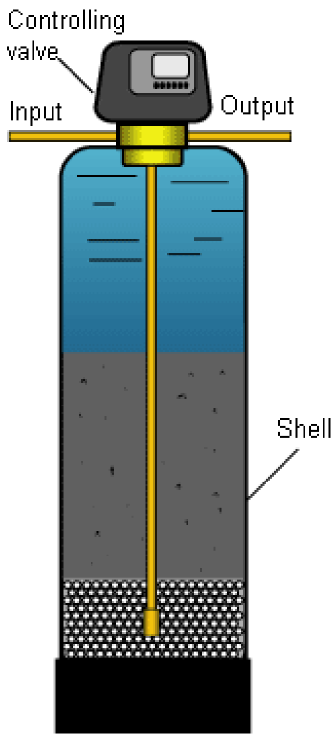

Figure 8. Sorption filter

The problem with such filters is that they lose their adsorbing ability during the time. In large water treatment plants regeneration of activated carbon by different methods (chemical, thermal, and biological) is used, but it is too expensive, so usually after some time new media is loaded into the filter instead of the old one.

3.4 Ion exchange

The principle of ion exchange treatment is removing the ions those presence is undesirable and replacing them with other ions. It is being achieved by passing the water through a layer of insoluble material made of synthetic resin. The resins are subdivided into cation-exchange resins (they contain exchangeable cations and used for removing cations from water) and anion-exchange resins (contain exchangeable anions and used for removing anions from water). The main uses of ion-exchange technology in potable water treatment are softening and removal of nitrates /3, p.195/.

The key components of an ion-exchange system are the following.

- Ion-exchange beds, pressure filters with resin used as a media;
- Regeneration tank with solution for the regeneration of the resin;
- Tank for used regenerant;
- Valves.

Softening

The resin used for softening is cation-exchange resin. When the water passes through the bed, sodium is released from the resin and replaced by calcium and magnesium that are present in water. The water will have zero hardness. After some time the resin is regenerated by strong solution of sodium chloride /3, p. 204/.

Nitrate removal

Anion-exchange resins are used for nitrate removal. The principle of operation is the same as for softening, but now nitrates are replaced with anions of the resin. The only problem of this method that in most cases resins remove sulfate ions prior to nitrate ions, so it is better to remove a sulfates preliminary in order not to lower the performance of nitrate removal, or choose specific resin that removes nitrates prior to sulfates /3, p.207/.

Regeneration

The resin tends to exhaust its ion-exchanging capacity. To prevent this, regeneration is used.

"In softening, sodium ions within the resin are released into the water and replaced by cations from the water being treated. Regeneration involves introducing sodium ions into the resin, displacing the ions removed from the water. In nitrate removal, choride ions within the resin are released into the water and replaced by anions (predominantly nitrate) from the water being treated. Regeneration involves introducing the regenerant solution into the resin, displacing the ions removed from water" /3, p. 195/. This means that in both cases the same solution (e.g. sodium chloride) may be used as regenerant.

This picture shows the example of ion-exchange installation (for softening or nitrate removal).

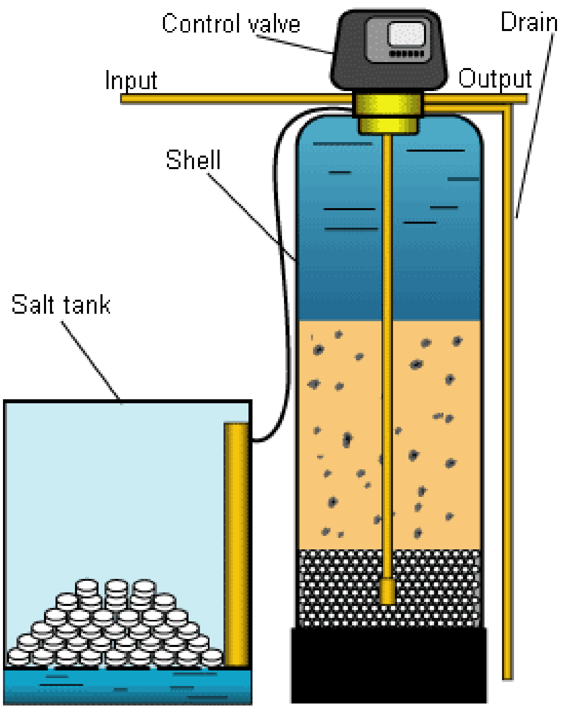

Figure 9. Ion-exchange treatment installation

3.5 UV disinfection

During the filtration only small amount of bacteria are killed, and there is a chance that pathogenic bacteria and viruses are still present in the water. There are a lot of methods, physical or chemical, of disinfection of water. Significant advantage of using ultraviolet lamps for water disinfection against of using chemical like chlorine and ozone is, first of all, safety. Both chlorine and ozone are dangerous for human health. Another significant advantage is that such system is easy to maintain. It only needs electricity and no chemicals are needed, so being installed once, it will not require any attention during all time life cycle. The disinfection is performed quickly, and water is ready for usage since the end of disinfection. The only drawback of UV disinfection is that it lasts rather short time, so the water after disinfection must be used quickly /1, p. 269/.

This picture represents UV disinfection device.

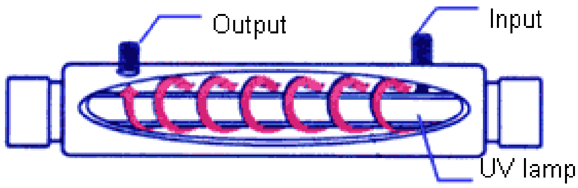

Figure 10. UV-disinfection installation

3.6 Controlling

Different equipment is used for controlling the treatment processes. Usually in single family houses the purification installations are fully automated, with all processes controlled by electronics.

The simple example is filter backwashing. It is possible, for example, to set up a time relay that will turns the backwashing process on after some period of time (e.g. every 24 hours). Another option is installing two manometers, one before, and one after the filter. The difference between their indications shows the pressure loss in the filter. When it reaches excessive values, this means that filter media is has taken too much impurities and it is hard for the water to pass through. Then electronics puts the filter to the backwashing.

Another case is UV lamp. It takes the energy when works, so it would be a good idea to connect it to with the flow meter. When the flow is zero, there is no need to keep the disinfection on, so electronics will switch it off.

As was briefly described above, treatment plant automation system is rather complicated, so it would be better to give this work to the specialists.

4 COST ESTIMATION

This chapter of my thesis is attempting to evaluate the point of use of small water treatment plants for single family houses. The alternative to that option could be buying the bottled water to use it for both drinking and household purposes. Let's take some initial data first.

- Single family house with 2 inhabitants;

- A possibility to drill a well nearby with a depth of approximately 10 meters;
- Water analysis shows typical for such kind of water sources quality: low turbidity, absence of tastes and odours, but high hardness, excessive levels of iron and manganese and radon presence;
- No ways of taking the water from another source (e.g. lake).

Solution

First, we estimate the water consumption for the house. It is possible to say that for the new houses the water consumption for 1 person in Finland tends to decrease during the last years. Now it is about 120 l/day per 1 person /4, p. 23/. This makes water consumption for 2 persons 240 l/day.

Then treatment methods must be chosen. First, iron and manganese will be removed in iron-removing filters. Next stage is softening. Then, the radon will be removed by sorption. After that, UV lamp is preferable to be sure that water does not contain any viruses or bacteria. The prices for such treatment plants are the following /5/:

- Iron removal plant – 496 euro;
- Softening plant – 278 euro;
- Sorption filter – 397 euro;
- UV lamp – 212 euro.

Total is 1383 euro.
Now we may estimate the investments that householder must make to purify the water for his house. The formula for total investments is to following:

$$T = C + M \cdot t \qquad (1)$$

where:

T=total investments during life cycle;
C=capital expenses (when you buy the devices);

M= maintenance expenses during life cycle (for example for electricity; also costs for repair are included);
t=life cycle time (usually 10-20 years).

When calculated C, we are taking into account the fact that besides our costs on treatment installations, also controlling equipment and pipes must be bought. For that purposes we add 15%.

$$C = 1{,}15 \cdot 1383 = 1590 \text{ euro}$$

Maintenance expenses M include costs of electricity, amortization expenses, and additional costs like replacing the filter media with new one. These costs usually do not exceed 10. Let's assume for our case M is 10% of capital expenses.

$$M = 0{,}10 \cdot 1383 = 138 \text{ euro}$$

Life cycle time C will be about 15 years. Then, total investments are

$$T = 1590 + 138 \cdot 15 = 3660 \text{ euro}$$

In that case yearly expenses will be 3660/15= 244 euro. That is reasonable price.

5 CONCLUSION

In my made a short overview of the problems concerning water quality in single family house and the ways of their solutions. Nowadays new technologies are becoming more available and reasonable and the standards of water quality are becoming stricter and stricter. The topic is very large, so only the basics are given. But the key is that soon these systems will become more and more widely spread and in the future each householder will probably use such systems.

Although sometimes people say that such kinds of systems are too expensive, the calculations show that taking into account high reliability of such systems and their long life cycle, annual costs can be called acceptable.

To conclude, I want to say that providing houses with pure water by treating the water in small treatment installations is reasonable solution. Also, large amount of new technologies and services is going to be introduced in the future, and this will make such systems even more effective, reliable, and available.

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