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RESEARCH ARTICLE

A guide to theory and practice of drinking water: PURE-H2O approaches

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ABSTRACT

The quality of drinking water that is essential for life is a powerful environmental determinant of health. Engineering works in all fields have been constructed to distribute water from places of abundance to places in need. All water sources contain suspended and particulate inorganic/organic substances that must be dispelled during water treatment process to yield pure water that is fit for drinking and any other usage. Treatment procedures should be chosen in order to improve water stability. Many treatment processes (sometimes called unit processes and unit operations) are linked together to form a treatment plant in order to produce water of the desired quality. Unit operations, which are physical and chemical (aeration, adsorption, membrane processes, ion exchange, coagulation and flocculation, chemical oxidation and water softening) and mechanical (sedimentation and filtration) should be taken into consideration for producing clean drinking water. Choosing the suitable treatment process is a critical step in the procurement of safe, reliable, high quality drinking water at a cost-effective price for green/sustainable engineering.

As a main part of the EU Project titled as "Implementation of ECVET for Qualification Design in Drinking Water Treatment Plants and Sanitation for Pure Drinkable Water-PUREH2O" that includes environmental planning, training in the field of drinking water, sustainable development, sound practices not only in the field of drinking water but also affiliated treatment facilities, this study focuses on selection of the water source, unit operations for drinking water and choosing water treatment processes.

Keywords: Drinking water, environmental engineering, PURE-H2O project, sustainable development, unit operations

1. INTRODUCTION

Recently, the state of the infrastructure has been extensively accentuated in light of the significance of safe drinking water for the necessities of society and industrial development [1]. The environmental impact of water production industry in coming few years will be higher due to population growth. Therefore, most developed countries interest with the sustainability as an environmental protection strategy to increase the efficiency of environmental preservation and energy [2].

Water called the universal solvent that can be consumed in any desired amount without concern for adverse health impacts is termed *potable* water. As production increases, while plant capacity remains the same, the task of producing potable water becomes increasingly difficult. The scientific community is continually making advances in identifying contaminants and discovering potential long-term health effects of constituents that had not been previously identified [3].

By 2050, with an additional 2.3 billion people living on earth, the expected scenario of global freshwater resource consumption is estimated to present that 40% of the population will be living in acute water stress situation [4]. Several treatment processes can be applied to obtain water for consumption with various qualities. The source of water such as groundwater, seawater and surface freshwater reservoir each have different qualities together with the adopted treatment methodology [5].

Water generally hosts biological and chemical agents that impact the environmental health. A wide range of communicable diseases can be spread through elements of the environment by animal and human

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waste products. In order to protect the environment from its adverse effects, water quality standards have been designated, treatment facilities have been built up, and treatment technologies have been discovered [6]. Variability of water treatment technologies between countries based on a wide range of factors such as water resources, geographical location, climate conditions, style of culture, and economical issues [2].

On the other hand, lifelong learning is perceived as a lifestyle, a profession based training which is one of the cores of lifelong learning perception is accepted as being important by workers, employees, and companies. Profession's training and education contain all the activities so that one person gets the necessary skills, knowledge, competencies, and information for a job or job group. Individual profession's training enables an individual get ready for work-life, increase his/her eligibility for companies by bridging theoretical education and the occupational area. Beyond working life, it supports the development of the individuals in other areas of life and supports their active skills in life. For this reason, in order to develop partnerships for professional training in Europe, some instruments have been developed. Europass [7], Youthpass, European Qualification Framework (EQF), Educational Credit Transfer in Vocational Education Training (ECVET), Educational Quality Assurance in Vocational Educational Training (EQAVET) [8], and networks through EU in order to support these materials can be counted, between these instruments. The basic idea behind these transparent instruments is to develop policies in order to increase the number of these for lifelong education and training, to apply and assess them; to continue to give extensive education and training and distant training services [9, 10].

In the direction of these facts, the project titled as "Implementation of ECVET for Qualification Design in Drinking Water Treatment Plants and Sanitation for Pure Drinkable Water-PUREH2O" was promoted to maintain an instrument that advances straightforward environmental planning and training in the improvement of manageable and sound practices in the field of drinking water and related treatment plants. The PURE-H2O project came about with the comprehension that advanced water technology enables a rise of green jobs and the coveted improvement of the sector's training capacity and employability. An investigation concerning the drinking water supply division indicated that in Turkey and many EU nations, including PURE-H2O partners, the national educational module for professional instruction needs educational means to furnish target mass with the necessary green competencies. The justification of the project is upgrading the quality and execution of VET system enhancing training in drinking water supply and improvement. It would be accomplished through advancing imagination, novelty and transfer of EQF/NQF principles in the instruction of the primary target group in the sector [10].

PURE-H2O project's main focus is to develop and launch a strategic partnership in the field of sustainable development of drinking water & treatment plants sector, establish a joint trans-European innovative competency-based training VET model and develop VET courses in accordance to the definition of qualification model and implement EQF/ISCO/ESCO principles [10].

To facilitate the improvement of VET system in Europe, the PURE-H2O consortium brings together six partners from Turkey, Bulgaria, and the Netherlands. The participating universities, R&D centers, and SMEs provide the PURE-H2O partnership with expertise, enriched by the competence of the associated members [9, 10].

In this study, the PURE-H2O Project that includes environmental planning to strengthen cleaner production principles, training in the field of drinking water sustainable development, sound practices not only in the area of drinking water and but also related treatment plants were given in detail from the perspective of Environmental Engineering approaches in pure water (selection of the water source, unit operations for drinking water and choosing water treatment processes, Fig. 1).

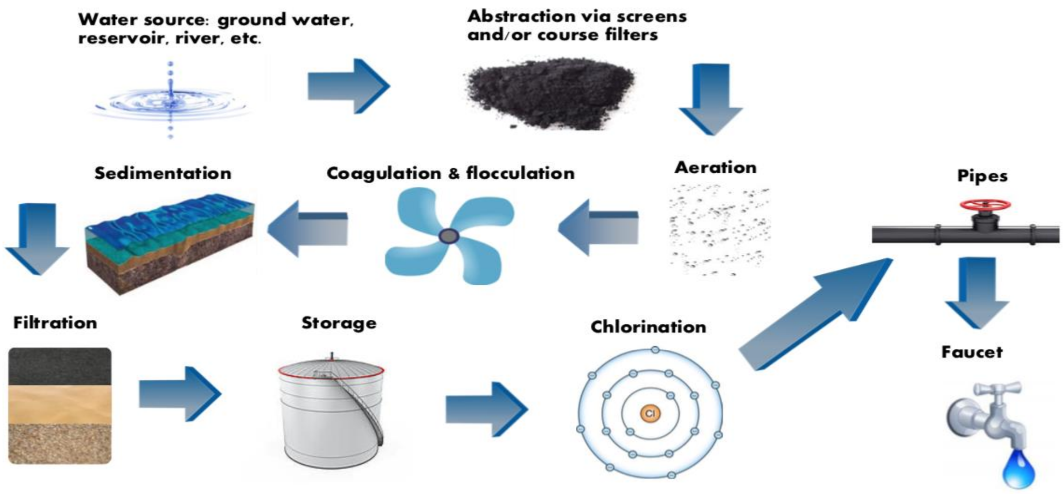


Fig 1. Drinking water processes [9]

2. WATER: SOURCES, QUALITY AND STANDARDS

Water is a substantial resource [11, 12] that can be crystal-clear, icy green in a mountain stream, whereas dark and opaque in a still water swamp. Approximately 2 billion people, one-third of the world's population, reside in countries with an inadequate amount of drinking water. Some experts estimate this figure would be twice as much within the next 25 years [13].

The materials found in water may be divided into living organisms and solid or dissolved organics and inorganics. Not all of these are harmful, and some may even be desirable for health, aesthetic, or technical reasons. Potable water is one that is reliable to drink, pleasant in taste, and suitable for domestic purposes. Contaminated or polluted water is one that contains suspended or dissolved material which makes it inappropriate for its intended usage. Potable water may be considered contaminated concerning some industrial uses [14].

The nature of water conveyed to consumers can be significantly impacted by different segments of a water-distribution system. The key variables influencing water quality in distribution systems are the nature of the treated water sustained into the system; the material and state of the pipes, valves, and storage facilities that make up the system; and the duration that the water is kept in the system. The main procedures that influence water quality inside the distribution system, for the most part, incorporate the loss of disinfection residual, with resulting microbial regrowth, and the development of disinfection by-products such as trihalomethanes. The deterioration of water-quality is frequently commensurate with the time during which water is resident in the distribution system. The longer the water is in contact with the pipe walls and held in storage plants, the higher the probability for water-quality to vary [15].

Water quality of both surface and groundwater can be affected by many things. Natural forces such as rainfall, geological characteristics, and seasonal changes can have a significant impact. Human activities, including overuse, pollution, changes in water-flow patterns, the introduction of non-native species, and dams on rivers can have unintended consequences. These factors can affect how water is treated and the results of water treatment [16].

Water-quality requirements transmute in accordance with the intended usage of the water. They should not be confused with water-quality standards. Determined by the prospective user, water-quality requirements depict an obvious or assumed necessity on the basis of the water user's prior experiences. Water-quality standards are prepared by a governmental agency and embody a legal requisition [17].

The quality of water in a lake or reservoir depends considerably on the season of the year. Municipal water-quality control starts with management of the river basin to protect the source of water supply. Highly polluted waters are both difficult and costly to treat [18]. The uses we make of water in lakes, rivers, ponds, and rivers are significantly affected by the water quality they acquire. Activities such as fishing, swimming, boating, shipping, and waste disposal have quite different requirements in terms of water quality. The water of particularly high quality is needed for potable water supplies. Water quality management involves the control of contamination from human actions with the goal that the water would not be degraded to the point that is not appropriate for intended usages [3].

One of the key factors that affect the quality of water is the geological nature of the area where the groundwater or surface water exists. Surface water composition is affected by contact with the soil or rock of the watershed that supplies either a river or lake. Groundwater is dependent on the type of rock through which rainwater permeates when entering the aquifer [16].

Drinking water standards around the world are in a continuous state of evolution as more information becomes available and is evaluated. No single standard for drinking water quality suffices for all countries, but there is a considerable degree of agreement on contaminants and their allowable concentrations. Different approaches to regulation and different conditions in countries will maintain differences in standards currently enforced. Although standards and monitoring programs are in place for most public water supplies around the world, bottled water, which is increasingly popular, is often not regulated [19].

Water quality criteria do not offer the same degree of protection for all forms of life in an ecosystem. Large degrees of response variation occur in different life forms and among different individuals of a species. Therefore, testing must include a wide range of biological processes. Values of society as well as scientific information influence standards. Often there is a conflict between the desire for a more comfortable existence for humans and the preservation of part of an ecosystem. Complex interrelationships among species and the environment market the task of establishing environmental standards very difficult [19].

3. SELECTION OF THE WATER SOURCE

The source of the raw water may be a river, lake, artificial reservoir, groundwater, and in some cases, reclaimed sewage or seawater. Data on the surface water quality, taken over a sufficient period (5 to 10 years), should be both reviewed and evaluated to assess the physical, chemical, microbiological and radiological properties of the raw water. A risk assessment must also be made regarding possible contamination of the water supply by chemical spills of radioactive wastes. Moreover, the degree of present and future land development in the watershed must be studied [20].

Raw water quality is a variable issue that depends on water sources. If the source is surface water, the water quality will change seasonally [2, 21]. If groundwater is selected as the source of the raw water, the same considerations associated with surface water applications [20]. The identification of potential ground-water sources for a public water supply broadly involves the following three steps: (1) identifying regions that have low pollution potential, high recharge capability, and a favourable location to the utility and its customers; (2) performing field investigations to confirm site-specific characteristics; and (3) dealing with land-use and wellhead-protection issues [15].

Even though iron and manganese are most regularly found in groundwater, surface waters may sometimes contain considerable amounts [14, 22]. They are minerals that cause staining of plumbing fixtures and laundered clothes as well as produce distinct tastes and odors in a drinking water. Iron and manganese also increase the hardness of water. These are aesthetic problems; there is no health risk associated with excessive amounts of iron and manganese [19].

Hardness in water is related to divalent cations such as calcium and magnesium and a lesser extent to aluminium, iron, and other divalent and trivalent cations resulting from water coming in contact with geologic formations. These, while not undesirable from a health standpoint, may make the water less suitable for some non-potable uses. Hardness concentration also influences the tendency of water to protect or corrode distribution pipes. Industries are especially concerned with the scale formation potential of water. Hardness ions can also contribute to color or taste of products made out of the water, which are important considerations for certain industries [18, 19].

Physical features characterize those properties of water that react to the faculties of sight, touch, taste, or smell. Suspended solids, turbidity, color, taste and odor, and temperature fall into this classification [17].

Suspended solids in water may be comprised of organic/inorganic particles or immiscible fluids. Inorganic solids and organic material are common in surface water. Suspended solids (organics) are regularly normal contaminants associated with the erosive activity of water flowing over surfaces. On account of the filtering capability of the soil, the suspended materials are rarely the components of groundwater. Most suspended solids can be removed from water via filtration [17].

Turbidity is a measure of the degree to which light is either absorbed or scattered by the suspended materials in water. Virtually all surface water sources contain perceptible turbidity. Most turbidity in surface waters is due to the disintegration of colloidal materials such as clay, silt, rock fragments, and metal oxides from the soil [17].

Pure water is colorless; however water in environment is regularly colored by foreign substances. Color contributed by dissolved solids that stay present after the removal of suspended material is known as true color [17]. Dissolved organic material from decaying vegetation and certain inorganic material cause color in the water. In certain occasions, excessive phytoplankton blooms or the growth of aquatic microorganisms may also impart color. Although color itself is not typically questionable from the aspect of health, its presence brings forth the necessity of proper water treatment [3].

Taste and odor of water can be caused by a foreign material, for example, organic compounds, inorganic salts, or dissolved gases which may have been originated from domestic, agricultural, or natural sources. Drinking water must be free from any repulsive taste or odor at the point of utilization [3].

Temperature is not utilized to assess specifically either potable water or wastewater. Nonetheless, it is a standout amongst the most imperative parameters in natural surface-water systems. The temperature of surface waters regulates the presence and activity rates of the biological species to a large extent. Temperature influences most chemical reactions taking place in natural water systems. In addition, it pronouncedly affects the solubilities of gases in water [17].

The evaluation and selection of the proper water source should be based on the following issues: (i) quantity of water required, (ii) quality of the raw water, (ii) climatic conditions, (iv) potential difficulties in constructing the intake, (v) operator safety, (vi) providing minimal operations and maintenance costs for the treatment plant, (vii) possibility of future contamination of the water source, and (viii) ease of enlarging the intake if required at a future date [20].

4. UNIT OPERATIONS FOR DRINKING WATER

There are two main unit operations for producing clean drinking water. These are physical-chemical processes and mechanical processes. Physical and chemical processes divide mainly seven parts that are aeration, adsorption, membrane processes, ion exchange, coagulation and flocculation, chemical oxidation, water softening and disinfection. On the other hand, mechanical processes consist of sedimentation and filtration.

4.1. Physical-chemical processes

Aeration is a process sometimes used in preparing drinking water. It is used in water treatment to change the concentration of dissolved gases, to strip volatile organics, and to reduce tastes and odors. The last generally involves removal of dissolved gases (such as hydrogen sulfide or chlorine) or volatile organic materials. The tastes and odors associated with algal growth are not appreciably reduced by aeration [14, 17].

Adsorption is generally utilized as a part of water treatment. It is a phase transfer process that is generally utilized as a part of dispelling substances from gases or liquids. Likewise, it can be seen as a characteristic process in various environmental compartments. Adsorption has been demonstrated as an effective removal process for a variety of solutes in water treatment [23]. Recently, the applications of adsorption in water treatment are predominately for taste and odor removal. However, adsorption is increasingly being considered for removal of synthetic organic chemicals (SOCs), volatile organic compounds (VOCs), and naturally occurring organic matter, such as trihalomethane (THM) precursors and disinfection by-products (DBPs) [3].

Membrane processes are utilized to separate dissolved and colloidal constituents from water. Water or constituents in it are forced through a membrane under the driving force of pressure, electrical potential, or concentration gradient in membrane treatment. Necessarily particulates are also trapped in the fine openings of membranes. Significant advances have been made in the design of membranes for selectivity and efficiency over the past two decades. The main application of membrane technology in water treatment is in the desalination of brackish waters, with over 4000 land-based plants. However, membrane treatment has been used for filtration, extraction of microorganisms, hardness, volatile organics and other dissolved organics, and biological treatment [19].

Ion exchange is primarily used for hardness removal in water treatment. Ion-exchange processes look much like filters in that they contain a bed of granular material, an influent structure which distributes the flow, and an effluent structure which collects the product. In the ion exchange process, an insoluble resin removes ions of either positive or negative charge from solution and releases other ions of equivalent charge into solution with no structural changes in the resin [19]. A wide variety of dissolved solids, including hardness, can be removed by ion exchange [17].

Coagulation and flocculation are utilized as parts of both water and wastewater treatment processes. It is generally cost-effective for performing coagulation and flocculation to dispel colloidal and little particles that settle gradually in water treatment. Also, coagulation-flocculation can be conducted to improve the removal of solids. Usually, pre-sedimentation without coagulant addition or a roughing filter is utilized to remove high concentrations of settleable solids prior to coagulation-flocculation-sedimentation [19].

Chemical oxidation is a process involving the transfer of electrons from an oxidizing reagent to the chemical species being oxidized. Oxidation-reduction (redox) reactions that may always be coupled establish the basis for many water treatment processes tending to an extensive variety of water quality goals. These reactions may consist of removal of iron, manganese, sulphur, color, tastes, odor, and synthetic organics such as pesticides and herbicides. Oxidants such as chlorine, chlorine dioxide, permanganate, oxygen, and ozone utilized as a part of water treatment processes [24].

Water Softening or the reduction of hardness, a process commonly practiced in water treatment process [17, 25], is the removal of certain dissolved minerals in water that results in scaling in boilers, from deposits on pipes, and cause excessive consumption of soaps made out of natural animal fats. The minerals responsible for these phenomena are referred to as hardness ions [19].

Disinfection is the process of utilizing chemical or physical methods to deactivate detrimental microorganisms that could be detected in water and to eliminate distributed water from pathogen (disease-causing microorganisms) regrowth or recontamination [26]. In the process, coliform bacteria and other indicator species will be killed as well, and the total bacterial count will be substantially reduced [14]. Unlike disinfection, sterilization is inferred as the destruction of every single living organism. Drinking water is not required to be sterilized [3]. The eradication of waterborne pathogens is the most imperative phase in water treatment [19].

4.2. Mechanical processes

Screening and sedimentation are inexpensive physical processes that are widely incorporated into treatment operations for water, wastewater, and storm water runoff. Screens and bar racks are placed at outlets from rivers, lakes, and reservoirs for water treatment plants or at the wet well into which the primary trunk sewer discharges for a wastewater treatment plant [19].

Sedimentation or clarification, is the removal of particulate material, chemical floc, and precipitates from suspension through gravity settling. This process is a standout amongst the most vital phases in the treatment of raw water [18, 27]. Sedimentation in drinking water treatment process is usually the next phase after chemical coagulation and flocculation, which leads to the grouping of particles together into a bigger size flocculent mass. This expands the settling velocity of suspended solids and permits settling colloids [9, 11].

Filtration is the principal treatment of raw water with the content of high suspended solids. Removal in a filter is exceedingly reliant on the surface area of the media particles. In the filtration process, the water is passed through permeable filter layers [19, 27]. While bigger particulates are restrained by a sedimentation process, the colloidal matter is held by adsorption, or coagulation and sedimentation [28].

5. CHOOSING WATER TREATMENT PROCESSES

The basis for selecting treatment process alternatives is established by the properties of the raw water and the finished water quality goals [20]. Choosing the suitable treatment process is a crucial phase in giving safe, reliable, high-quality drinking water at financially effective cost. The data on raw water quality is required for an adequately long period to demonstrate seasonal and extraordinary events to settle on a steady choice of suitable treatment procedures. Prior to any procedure is eventually chosen, it is vital to conduct treatability testing on the actual source water [29].

The choice of water treatment process is an unpredictable assignment. Conditions are probably diversified for each water utility, and it might be distinctive for each source used by one utility. Determination of at least one water treatment processes to be utilized at a given region is impacted by the requirement of compliance with administrative quality objectives, the desire of the utility and its clients to meet other water quality objectives, and the necessity to procure water service at the minimum rational cost [30].

The selection of treatment operations relies upon the quality and variability of the raw water source and the treatment goals, which may differ for industrial rather than municipal needs. An intensive study of the quality and amount of every single conceivable source is the first and most imperative phases in outlining a water supply process. Water treatment operations must be outlined to deal with the extreme cases of raw water quality variability to procure the adequate amount of water constantly [19].

Nowadays, water treatment plants are designed to meet potable water quality standard. The chosen source, water quality protection, treatment technologies and prevent re-pollution are the main considerations to achieve the optimum design of water treatment plants.

Factors that influence process selection are contaminant removal, source water quality, reliability, existing conditions, process flexibility, utility capacities, costs, environmental compatibility, distribution system water quality and issues of process scale.

Surface water must be treated for removal of turbidity, color, and bacteria [3]. The purpose of the municipal water treatment is to procure both chemically and microbiologically safe, potable water supply usage of population. Domestic consumption of treated water requires aesthetical convenience -lack of eminent turbidity, color, odor and objectionable taste [18]. Conventional surface water treatment plants are built based on three crucial assumptions. Firstly, the source water inflow arriving at the treatment plant merely contains naturally developed biological and chemical pollutants (for instance, total dissolved solids, turbidity, and some bacterial species). Secondly, they are observed in source waters (typically a reservoir, lake or a river) mainly due to (1) surface water runoffs, (2) existing local conditions in the source waters and (3) cross contamination due to the disposal of untreated sewerage. Thirdly, the contaminants present in source water would be totally removed through simple treatment practices following an order of phases such as coagulation-flocculation, filtration and disinfection [31].

Evaluation of the treatment plant site is based primarily on the distance from the intake, the layout of the treatment processes units, the environmental impact of the treatment plant and method of the water distribution. The following items must be included in evaluation of this site: (i) geographical location, (ii) information obtained from the geological study, (iii) availability of electric power and utilities, (iv) accessibility to major highways, (v) history of flooding or presence of earthquake faults, (vi) construction costs, (vii) site maintenance costs, (viii) operator safety, (ix) provisions for future plant expansion, and (x) environmental impact study [20].

Water supply approaches, factors affecting the choice of process, selection of appropriate processes for water treatment should be considered for choosing of water treatment processes.

5.1. Water supply approaches

Utilization of the best source water quality that can be achieved economically is an idea that has been supported by public health authorities. The principal idea of obtaining the top-quality source water that is financially plausible is a critical factor in making choices on source selection and treatment method [30].

Water utilities and their engineers need to take utilization of optional sources into consideration when another treatment facility or a noteworthy capacity expansion to a current facility is being assessed, or when an alternative and more expensive means to deal with treatment is under investigation. In case of very high level of treatment costs, improvement of a water source of higher quality might be financially appealing. The options are as follows [30]:

- Alternative surface water or groundwater source
- Groundwater as an alternative to surface water
- Riverbank infiltration as an alternative to direct surface water withdrawal

Well supplies usually yield cool, unpolluted water with the uniform quality for municipal use. If necessary, groundwater may require processing to remove toxic contaminants or to improve aesthetic quality. On the other hand, river supplies regularly require the broadest treatment plants with most prominent operational adaptability to deal with the day-to-day varieties of raw water quality [18].

At the point when distribution systems have high rates of water loss, a program of leak detection and repair may bring about expanding the measure of water accessible to customers without an expansion underway. Examination of other options for treatment may in numerous cases disclose the nonexistence of any practical or lucrative options regarding treatment of a currently utilized or new water source. In such conditions, modified, expanded, or new water treatment plants would be crucial [30].

5.2. Factors influencing process selection

All engineering, economic, energy and environmental factors will be taken into consideration by preliminary feasibility workouts in determining the design of treatment plants.

Contaminant removal is the ultimate objective of treatment for many source waters, especially surface waters. The quality of treated water must be in compliance with the requirements of effectual drinking water regulations [32]. Much is known in general about the capabilities of various water treatment processes for removing both regulated contaminants and contaminants conducting to aesthetic problems [30].

Comparison of **source water quality** and the desired/finished water quality is fundamental for the choice of the treatment process. With the knowledge of the adjustments in water quality that must be achieved, the engineer can define at least one or more treatment processes that would fit for accomplishing the improvement of quality [30]. The source of raw water can be an attractive target for an adversary. Whether it is a lake, river, or well field, many sources are remote can offer an attacker numerous opportunities to attempt contamination or physical attack [33].

Process reliability is a critical notion and at times could be a primary viewpoint in choosing the procedure. Disinfection of surface water is obligatory, so this is an example of a treatment process that must be basically safeguarded [30].

Existing conditions - The selection of processes to join into treatment train might be impacted firmly by the current procedures when a treatment facility is assessed for redesign/upgrading or expansion. Site constrains might be essential in choosing the process, particularly in pre-treatment when optional clarification methods are accessible, some of which require just a little portion of the space needed for a conventional settling basin [30].

Process flexibility - The capacity of a water treatment facility to oblige changes in future laws or amendments in source water quality is very imperative. Source water quality ought to be entrenched when a treatment facility is arranged, with the objective that good decisions on treatment procedures can be made. Most treatment facilities are established to endure for a very long time, and changes can happen in the quality of source waters with the progression of time [30].

Utility capabilities - Following the choice and outline of treatment procedures, the water utility must have the capacity to conduct them effectively to achieve the desired water quality. Accessibility to maintenance and repair of equipment includes contemplations of time and distance to service representatives, and this might be doubtful for some small-sized, exceptionally remote water utilities [30].

Cost considerations are mostly the main factor in process choice. Assessment of expenses for optional process trains utilizing standards of engineering economics may at first appear to be direct, yet this may not be the situation [30]. The cost of water treatment is dependent on three factors: (1) quality of the raw water, with costs increasing as raw water quality deteriorates, (2) the degree of treatment required, so that the purer the finished water required, the more it will cost to produce it, and finally (3) the volume of water required and hence the size of the treatment plant, with the cost of water per unit volume decreasing as the capacity of the treatment facilities [34].

Environmental compatibility issues involve a broad range of concerns that include residual waste management, the fraction of source water wasted in treatment processes, and energy requirements for treatment. The impacts of water treatment surpass the treatment facility. The advantages of procuring safe drinking water are extremely noteworthy, however certain level of caution must be taken when it comes to choose water treatment methods that would not result in severe environmental issues [30].

Distribution system water quality - The impact of treatment processes on desired water-quality in the distribution system is a factor to be taken into consideration in process assessment, and it includes the following [30]: (i) Chemical and microbiological stability of water outflowing from the treatment facility**,** (ii) elimination of internal corrosion and deposition, (iii) microbiological control in the distribution system, (iv) congruity of the quality of water from alternative sources and (v) minimization of formation of disinfection by-products in the distribution system.

Issues of process scale - Feasibility to scale procedures up to vast sizes or to scale them down to little sizes can be vital at times. Complicated treatment processes, e.g., coagulation, and filtration of surface water or precipitative lime softening, can be downsized physically. However, the expenses of hardware and the requirement for a profoundly prepared administrator may make the downsizing process unrealistic [30].

5.3. Source dependent treatment process selection

The basis for selecting treatment process alternatives is established by the properties of the raw water and finished water quality goals. Consideration must be given to the future implementation of more stringent drinking water quality standards and possible changes and variability in the raw water quality [20]. Engineers with expertise in water treatment facility design are expected to decide the best treatment system for a specific circumstance, and their recommendation ought to be considered in preliminary phases of project planning [35]. Raw water characteristics vary widely, the major differences being between surface and groundwater, hard and soft water, and river water compared to reservoir water. Therefore, groundwater systems are more prevalent than surface water, but more people drink water from surface water systems [16]. If groundwater is selected as the source of the process water, the same considerations associated with surface water apply [20].

Surface water treatment can be performed by a variety of process trains (Fig. 2), contingent upon source water quality. Since all surface waters require disinfection, process train must involve disinfection regardless of the selected treatment method. Disinfection is a part of the conventional treatment process, with the point or points of addition of disinfectant transmuting at different treatment facilities [30].

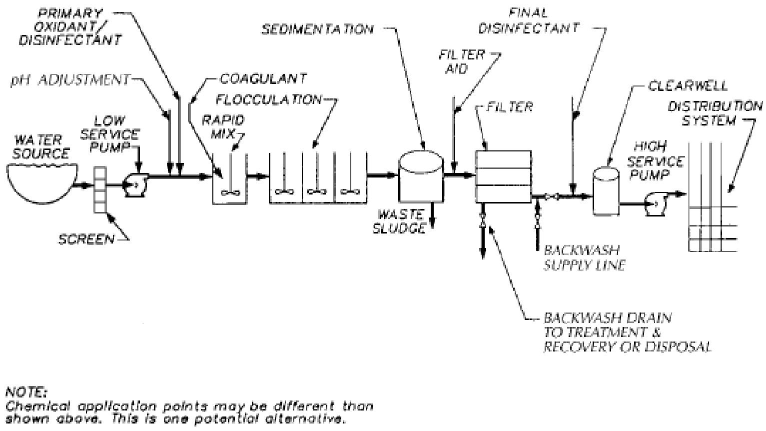


Fig 2. Conventional treatment, surface water [30]

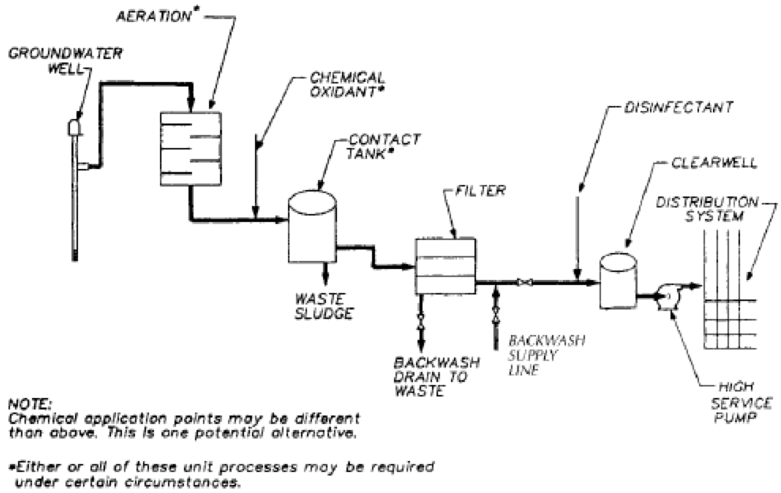


Fig 3. Iron and manganese treatment, groundwater [30]

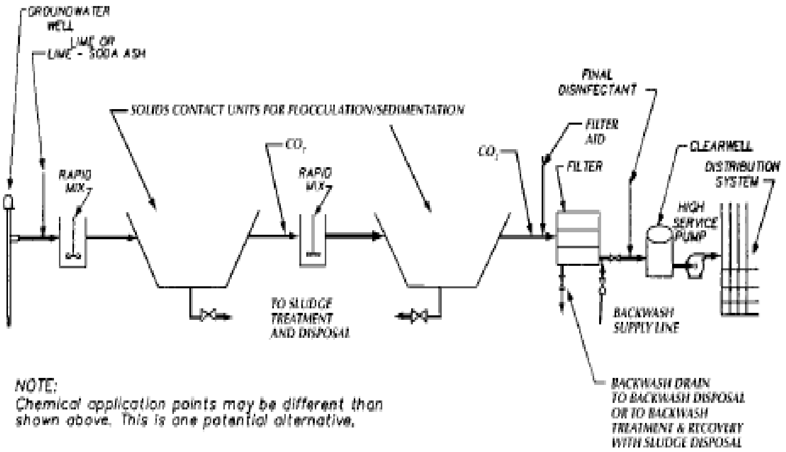
Groundwater treatment - Many groundwaters provided from deep wells have high quality with respect to turbidity and microbiological contaminants. They may be convenient for consumption as soon as disinfection process is completed unless they have mineral components that would require extra treatment. The extra treatment process is mostly required due to the minerals in the aquifer incorporate iron or manganese. For removal of iron and manganese (Fig. 3), oxidation, precipitation, and filtration are normally utilized [30].

Hard water contains calcium and magnesium in excess concentration. Both ground and surface water can be processed by precipitative lime softening to remove hardness. The most common ion exchange softening resin is a sodium cation exchange (zeolite) resin that exchanges sodium for divalent ions, including calcium, magnesium, and radium (Fig. 4) [30].

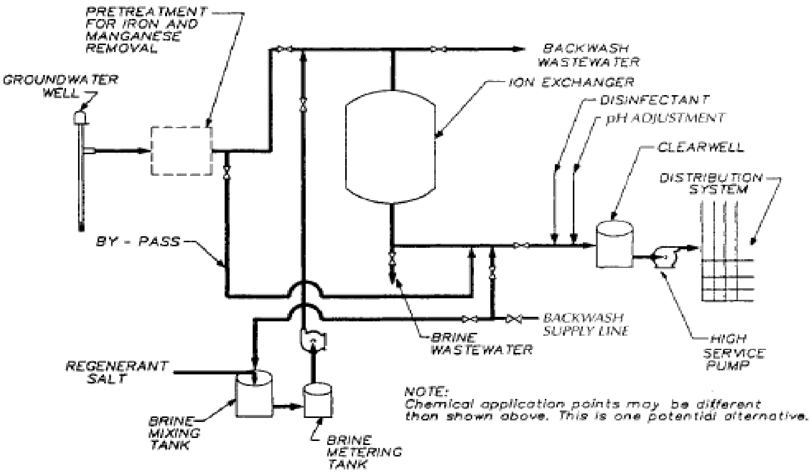
5.4. Selection of appropriate processes for water treatment

The main function in determining the water treatment technology relies on the source of water and water quality required by the consumers. There are several types of water resources for supplying drinking water treatment plant as surface water, groundwater, and seawater. Each sort of water resources has variable characteristics depending on surrounding conditions playing a big role in selecting water production systems [36]. The problem is that numerous treatment processes are unsuitable for their usage and/or their vicinity. The spare parts, maintenance, and power consumption required by all treatment procedures render them impractical alternatives. The objective of the treatment process must be determined [12]. There may be a necessity to prioritize the issues.

Treatment procedure should be chosen to improve water stability. The basis for selecting treatment process alternatives is established by the properties of the raw water and finished water quality goals. Surface and groundwater treatment can be achieved by a variety of process trains, depending on source water quality. For analysis purposes, the problems to be addressed into the "SHTEFIE (Social, Health, Technological, Economic, Financial, Institutional and Environmental)" criteria can be grouped as an instrument to help with analysis of development programmes [12].



(a)



(b)

Fig 4. Two-stage excess lime softening treatment (a), ion exchange softening (b), groundwater [30]

6. RESULTS AND CONCLUSION

As the main part of the PURE-H2O Project that intends to amend the situation (a) supporting the exchange of good practices and promoting green competencies for sustainable engineering and water management (from cleaner production and technical procedures), (b) providing training materials in the attractive and practically enriched model, (c) providing new jobs for young population in the drinking water supply sector, (d) exploring water business sector and its opportunities for young entrepreneurs in the partner countries, which is comprised of Turkey, Bulgaria, and the Netherlands, this study focuses on the selection of the water source, unit operations for drinking water and choosing water treatment processes.

Many treatment processes (sometimes called unit processes/operations) are linked together to form a treatment plant for producing water of the desired quality. To achieve this goal, a variety of treatment procedures are used employing a variety of physical and chemical phenomena to remove or reduce the undesirable constituents from the water. Surface and groundwater treatment can be achieved by a variety of process trains, based on source water quality. The essential concept of attaining the high-quality of source water, which is economically feasible, is an important factor in making decisions on source selection and treatment. Selecting the suitable treatment process is a primary step in procuring safe, reliable, top-quality drinking water at a cost-effective price. The sources of raw water can be an attractive target for an adversary. Whether it is a lake, river, or well field, many sources are remote can offer an attacker numerous opportunities to attempt contamination or physical attack. Process reliability is crucial contemplation and in most cases could be a primary notion in deciding which process to choose. Site constraints may be crucial in a choice of process, especially in pre-treatment when optional clarification processes are accessible, some of which require merely a insignificant portion of the space needed for a conventional settling basin. Source water quality should be well established when a treatment facility is designed so that good decisions on treatment processes would be made. After treatment processes are chosen, designed, and on-line, the water utility must be able to operate them fruitfully to acquire the desired water quality. Cost considerations usually one of the key factors in process selection.

Treatment procedures should be chosen to enhance water stability. The basis for selecting treatment process alternatives is established by the properties of the raw water and finished water quality goals. Surface and groundwater treatment can be attained by a variety of process trains, based on source water quality. Environmental compatibility issues for drinking water involve a broader range of concerns that include residual waste management, the fraction of source water wasted in treatment processes, and energy requirements for treatment. "SHTEFIE (Social, Health, Technological, Economic, Financial, Institutional and Environmental)" criteria can be grouped as a tool to help development programmes for pure water. New approaches to siting and designing critical system components, including water treatment plants, are evolving to reduce its vulnerability.

The PURE-H2O partnership among many institutions and national authorities contributes to the process of regulation, transparency, and recognition of qualifications at the national and European level. By applying the PURE-H2O, the regional development benefits from (i) standardized user-centered VET learning paths, (ii) qualifications descriptions in the field of PURE-H2O to be introduced into the educational and industrial sectors in Bulgaria, the Netherlands and Turkey and (iii) cluster activity with identical initiative for further conduct of the PURE-H2O model.

In the fields of chemistry and eco-engineering, environmental protection, biotechnology, health and food industry, there is a need for a qualified staffs emerging in the PURE-H2O Project. This study is a theory and practice guide of drinking water and focuses on this unique Project that provides a tool encouraging environmental planning and training in the development of sustainable practices in the operation of drinking water treatment plants. Due to absence of mutual recognition of qualification, which is frequently weakened by national limitations, by applying EUROPASS, EQF and ECVET instruments through the PURE-H2O will (i) provide guidance through these qualifying instruments for not only to partner countries but also EU-wide and (ii) assist Turkey in the Adaption of Acquis and carrying out the Development Plan as part of Turkey's accession process.

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