Drinking Water - Treatment

An Online Continuing Education Course for Engineers

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I. INTRODUCTION

Evidence of man's desire to improve the quality of water is found in the earliest recordings of knowledge. In the earliest days of man's existence, water was used as found. It might be pure and abundant, plentiful and muddy, scarce but pure, or both scarce and pure. To get more or better water, ancient man either found other sources or devised methods to improve the quality of the available water. Man's earliest standards of quality were few: freedom from gross turbidity, taste, and odor. While his criteria of purity have become more complex and certainly more quantitative, the principles, methods, and materials for purifying water have remained remarkably similar from the earliest recorded date of about 2000 B.C. down to the present time.

When, after many centuries, watertight household vessels became available, man observed that water could be more or less clarified by storage in containers or by filtration through porous receptacles or sand layers, leaving the objectionable sediment behind. After a lapse of many more centuries, he discovered that sedimentation could be aided by adding a precipitant or coagulant. The recognition that coagulation aided both sedimentation and filtration and the use of great variety of organic and inorganic materials mark the beginning of the treatment of water. The first known treatment plant to serve an entire city was completed in 1804 at Paisley, Scotland. The first water purification plant for an American city was built in 1832 for Richmond Virginia. The half century beginning in 1913 has been described as one distinguished for its consolidation and expansion of existing water treatment knowledge. During that span, the number of water treatment plants on public water supplies in the United States increased from several hundred to more than 10,000.

In the design of water treatment plants, the provision of safe water is the prime goal. Water treatment plants have demonstrated the ability to produce safe water under adverse conditions. Through the years, those concerned with water supply have established standards. The first standards were established in 1914, with subsequent revisions in 1925, 1942, 1946, and 1962. After the 1962 standards, minor changes have been introduced. These standards establish parameters for physical, chemical, biological and radiological requirements. Treatment plant operators must collect samples at periodic intervals from different locations in the treatment plant and distribution system for analysis of the various parameters. The analysis is made following the procedures shown in *Standard Methods of Water Analysis.*

In addition, the treatment of water also includes producing water which is appealing to the consumer. Ideally, appealing water is one that is clear and colorless, pleasant to the taste, and cool. It is non-staining, and is neither corrosive nor scale-forming. The consumer is principally interested in the quality of water delivered to the tap in his home or place of business, as opposed to the quality at the treatment plant. Therefore, water utility operations should be such that quality is not impaired as water flows from the treatment plant through the distribution system to the consumer.

Another objective of water treatment is to build facilities that are reasonable with respect to capital and operating costs. To accomplish this, various alternatives must be investigated, including performance and cost studies, and an optimum design is evolved based upon sound engineering principles and in full consideration of the abilities of operating and maintenance personnel.

Typical water sources for municipal supplies are deep wells, shallow wells, rivers, natural lakes, and impounding reservoirs. Water treatment processes selected must consider the raw water quality. Deep well source satisfies the municipal water quality factors such as safety, temperature, appearance, taste and odor, and chemical balance. It has relatively uniform quality of water and hence the treatment processes employed are the simplest. Excessive concentrations of iron, manganese, hardness, hydrogen sulfide, chlorides, sulfates, and carbonates exist in well waters. Quantity of the well water depends upon aquifer permeability, well spacing and depth, seasonal changes in river flow, and pumping rates. About $1/4^{th}$ of the nation's population is served by well water source.

Larger cities are dependent on surface supplies. Water quality in rivers depends on the character of the water shed; pollution caused by municipalities, industries, and agricultural practices; river development such as dams; the season of the year; and climatic conditions. A river water treatment plant must be capable of handling day-to-day variations in quality and the anticipated quality changes likely to occur within its useful life. The quality of water in a lake or reservoir depends on the physical, chemical, and biological characteristics. Size, depth, climate, watershed, and degree of eutrophication, influence the nature of an impoundment.

Treatment process used depends on the raw water source and the quality of finished water desired. Many chemicals are employed in the treatment. The specific chemicals selected for treatment are based on their effectiveness to perform the desired reaction and cost. The most important consideration in designing water treatment plant is to provide flexibility.

Chemical residues from water treatment, (mainly sludge from the settling basins following chemical coagulation, or precipitation softening, and wash water from backwashing filters) are wastes and require to be processed. These wastes are relatively non-putrescible and high in mineral content.

Natural water polluted either by human activity or by nature, is likely to contain dissolved organic and inorganic substances; biological forms, such as bacteria and plankton; and suspended inorganic material. The principal water treatment unit processes employed to remove these substances are as follows:

- Rapid mix,
- Coagulation and flocculation,
- Sedimentation,
- Filtration,
- Disinfection,
- Softening,
- Ion exchange.
- Adsorption,
- Reverse osmosis,
- Aeration,
- Chemical feeding and handling, and
- Sludge handling.

A schematic flow diagram of a typical treatment process is shown in Figure I.1 and the various process units shown above are described below in Section II.

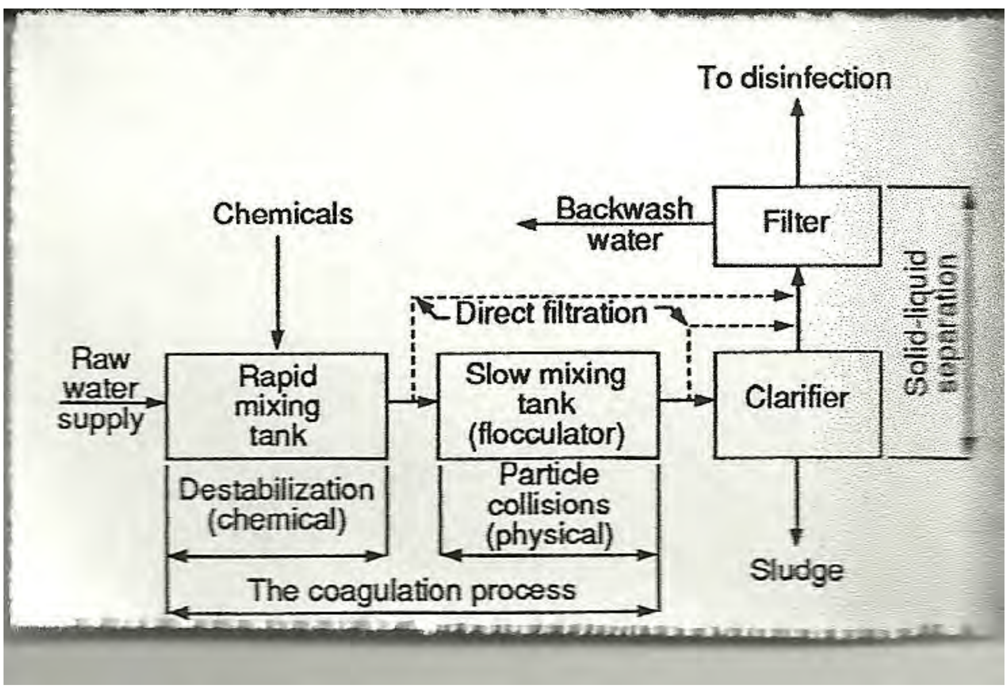

Figure I.1 Schematic Diagram of Coagulation Process

II. RAPID MIX, COAGULATION AND FLOCCULATION

II.1. Rapid Mix – Rapid mix, or flash mix or quick mix is the process by which a coagulant is rapidly and uniformly dispersed through the mass of the water. Rapid mixing is important to obtain uniform dispersion of the chemical and to increase the opportunity for particle-to-particle contact. The process usually occurs in a small basin immediately preceding or at the head end of the 'coagulation basin'. This process is used to generate a homogeneous mixture of raw water and coagulants which result in the destabilization of the colloidal particles in the raw water to enable coagulation. Mixing is provided by pumps, venturi flumes, air jets or rotating impellers (paddles, turbines, or propellers). Where possible, the rapid mix should be a two-compartment unit. Design parameters for rapid mix are as follows:

Mixing intensity……………………………700 – 1000 s^{-1}
Detention time………………………………10 – 30 sec
Power……………………………………….0.25 – 1.0 hp/MGD
Basin dimensions……………………………3 – 10 ft

Three arrangements for rapid mixing are shown in Figure II.1 below.

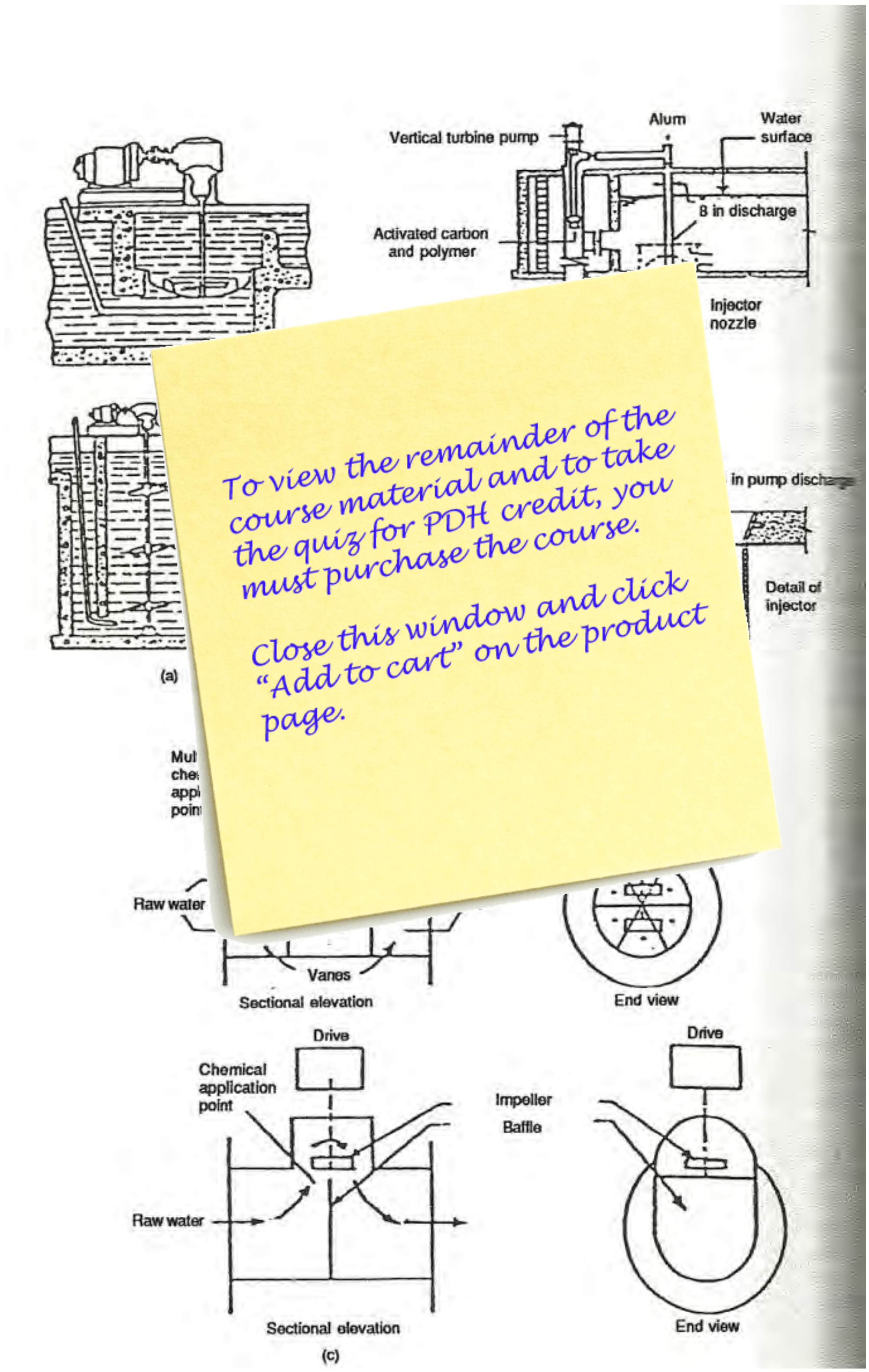

Figure II.1 Rapid Mixers: (a) Mechanical, (b) Injection, (c) In-line Blender