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# Aeration, Coagulation and Flocculation Processes in Water Treatment plant: Case Study Water Treatment Plant around Maiduguri, Borno State Nigeria.

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***Abstract:*** *The paper identify and explain three of the most commonly use processes of enhancing the quality and purity of water treatment namely aeration which is the process that provides oxygen from the atmosphere to effect beneficial changes in the raw water such as taste, odor and colour, coagulation that is the addition of chemical substances to water in order to aid settlement of the dissolved particles, by forming large floc and flocculation which is use of gentle stirring in water, which floc has formed to induce the particles to coalesce and grow into bigger and denser floc particles, for quicker increase of the rate of settlement.*

## I. INTRODUCTION

Absolutely pure water is rarely found in existence in nature, and man cannot exist without water, so there has always been a demand for pure portable water. (3) Most waters have to be purified before they can be used for portable purposes. Raw water is so infinitely variable in quality, that there is no fixed starting point to the treatment process, and within much narrower limits, there is any rigidly fixed finishing point either. There is virtually no water that is impossible to purify into potable standards. To slake man's thirst, drinking water must be whole some and palatable. Accordingly it may be free from disease-producing organisms and poisonous or physiological undesirable substances[1].

The source of raw water determines its inherent quality, the quality of which is difficult to foresee, hence there is the need to collect samples of the raw water for a certain period of time and carry out some tests to ascertain the characteristic purities of the raw water and the relative quantity of each impurity. Naturally occurring water can generally be classified as; groundwater, or surface water. Each has its own characteristic, but in general, ground water is the purest form of water available, and may not require much treatment compared to its counterpart (surface water). The associated impurities of surface and ground waters can be classified as shown in table 1.

It is worthwhile to look into, what processes actually take place in these stages, and the components required for the processes. The processes, which take place, are governed by certain scientific theories relating to the behavior of the liquid particles, and the impurities associated, with them in the various purification stages.

This can generally be outlined as; screening; raw-water storage; pre-chlorination; aeration; algal control; straining; preliminary setting; mixing; coagulations; flocculation; settlement, filtration and sterilization. In this presentation we shall only look at aeration, coagulations and flocculation processes.

## II. AERATION

This treatment process provides oxygen from the atmosphere to effect beneficial changes in the raw water. At the same time it may liberate undesirable gases such as carbon dioxide, hydrogen. The principle behind this is that of mixing the raw water with normal air from the atmosphere to replenish or add to the raw water quality. This trend generally improves the water taste, odor, and colour and may also affect the killing of some pathogens. This is usually done by splashing the water over trays to break up the stream into countless droplets or by reversing the effect and blowing air bubbles through the water.

Gases are absorbed or liberated front water until equilibrium is reached between the natural content of each gas in there and its content in the water [1].

Aerators are commonly found to be necessary if any of the following conditions are present in the raw water.

(a) Hydrogen sulphide (tests, odor etc.);
(b) Carbon dioxide (corrosive tendencies);
(c) Test due to algal growth (caused by volatile oils release);
(d) Iron and Manganese in solution;
(e) De-aeration
(f) Above increase oxygen content, while (a) – (b) liberate excess gas.

Types of Aeration

1. Fixed – Spray Aerators: - This are specially designed nozzles which direct thin jets of water against metal plates to produce a spray which exposes countless droplets of the water to the atmosphere. Some of the factors considered in the design of this aerator include; orifice or nozzle behavior, including ballistic principles: wind-age or wind effects, shared with spray cooling and pipe friction associated with multiple tank inlets and filter under drains. The resistance offered by calm air can usually be neglected. The time of exposure also governs the distance droplet are carried by the wind [2]. The areas where the sprays are working are often sheltered by louvers set in a surrounding wall.
2. Mechanical Aerators: - There are many kinds of mechanical aerators, but the most commonly used is those which employ the use of submerged paddies that circulate water in aerator chamber and renew its air water interface.
   Surface paddles or brushes that dip lightly into aeration chambers, but far enough to circulate their water release air bubbles and throw spray of droplets onto their water surfaces.
   Propeller blades that whirl at the bottom of a central down draft tube in an aeration chamber and aspirate air into the water.
   Turbine blades that cap a central up draft tube in aeration chamber and spray droplets over its water surface (3).
3. Cascade Aerators:- This depend on the turbulence created in a thin stream of water flowing swiftly down an incline and impinging fixed obstacles the surface area of liquid exposed is rather limited and there is a loss of efficient (1). 25-50% of carbon dioxide may be removed (2)
4. Gravity Aerators: - In this design water is allowed to fall on sheet over one or more concrete steps. Overman (1968) single arrangement with 400mm supply can de-aerate meters per day with 50% - 60% carbon dioxide removal (2).
5. Tray type Aerators: -This consists of about five perforated trays, increasing in size from top to bottom. Then waterfalls from tray through a total depth of 2-3m and splashes on through and off the trays 5-6 times. The total area of the trays in relation to the flow is generally about 0.2m$^2$ per m$^3$/h. This type of aerator is apt to freeze in cold weather and to encourage the growth of algae and other life in warmer climates. However it is a simple and cheap method used much more widely than any of the others.
   The trays may be filled with layers of coke or gravel and this loss found to improve its carbon dioxide removal to 30%- 60%.

## III. COAGULATION

Coagulation can be said to be the addition of chemical substances to water in order to aid settlement of the dissolved particles, by forming large floc. (Gelatinous precipitates). There are many substances which react suitably with water to produce such an effect and these are known collectively as coagulants, examples of these are A12 (SO4)3.18 H2O, known as alum (Aluminum sulphate), ferrous sulphate or FeSO4.7H2O sodium Aluminates etc. [l]. Use of additional chemicals, which while not themselves true coagulants, intensify and improve floc formation otherwise called coagulant aids. Coagulants should be added immediately downstream of any re-setting basin which may have been considered necessary. Their primary purpose is to assist in the removal of the more finely divided sediment and colloids. Most of the larger and heavier particles settle unaided in the pre-settling basin thus permitting the coagulants to work more efficiently on the finer particles [1].

Where floc formation is poor, or for reasons of overall economy, coagulant aids may be added. By producing a heavier faster-setting floc, this allows small basins to be used, and smaller doses of the main coagulants may also be possible. The choice of the best coagulant for any particular water is determined by experiment [1].

Immediately coagulants are introduced into the water, rapid mixing is essential. Floc starts to form and immediately after this, the water is stirred very gently for the fine particles adhere to each other and grow into settle-able floc. This gentle stirring action occurs to some degree naturally in all basins but can be greatly accentuated by methods designed to encourage the rolling action required. [1]

Certain designs of basins are multi-chambered and therefore flocculation does not infact proceed more separately than might appear to be the case at first glance. The pH of water is very vital in coagulation because, it indicates the right type of coagulant and dosage required to form the heaviest floc at the waters characteristic pH value, which can also be determined using the jar test. Acid waters i.e. those having a pH of 5-6.5 are often difficult to clarify, due to the high dosage of coagulants and alkalis required. Waters of pH between 6.2 - 7 with a reasonable degree of alkalinity reacts well with aluminum sulphate. Alkaline waters with PH values of 7 - 7.8 may again be difficult and absorb high doses of alum. [1]

Coagulants can be added to the water either as a solution, which is the commonest way or in powder or slurry form. As treatment is a continuous process, dosing must also proceed in continuous and controlled fashion. The types of feed of coagulants can generally be classified as solution feeds and dry feeders. The two essential parts of solution feed system comprise a tank in which a solution of the correct strength may be stored and closing rate or flow controller. The tank should hold 24 hours supply and be duplicated so that one tank may be in service while the other is being replenished. There should be some sort of continues stirring mechanism to reduce the risk of settlement after initial preparation. Many coagulants (particularly ferric chloride and alum) are corrosive and the tanks should be lined with acid resisting material, commonly rubber, glass or special cement.

The dosing mechanism should be capable of being controlled manually. There are two kinds of dosers: gravity-feed, and displacement pumps or tippers. The rate of flow can be altered in the former by altering the length of piston stroke of the specially made plunger pumps. The speed at which tippers operate can also be regulated. In big works of sophisticated design, dosing is automatically controlled. A dry feeder incorporates a hopper which contains the feeds measuring device; this often takes the form of a revolving table from which a scraper of adjustable length deflects a greater or lesser amount of powder into the raw water. If the powder is not very soluble it may be mixed with water and fed as slurry. In humid/tropical conditions, trouble by caking is sometimes experienced on dry feeders and for this reason solution feeders are preferred. Most mixers lend themselves to automation, with the rate of flow of coagulate dependent on the rate of flow of water through the works on a small or unsophisticated works where the rate of flow tends to be constant, the simplicity of manual regulation is much to be preferred [1]. The design considerations for coagulation are basically that of knowing the right amount or dosage of chemicals to be added and the time taken for such a treatment.

## IV. FLOCCULATION

Flocculation as a means of further improvement in the water is a relatively new invention, which emerged in about the 19thcentury. This is the process whereby the water purification stage of coagulation is further enhanced by the rotating members to form large floc which become heavy and easy to settle in the bottom of the tank [5]. The use of gentle stirring in water, which floc has formed to induce the particles to coalesce and grow is known as flocculation. The bigger and denser the floc particles, the quicker are the rate of settlement. The source of power for flocculating devices are mechanical and pneumatically. Generally speaking, seldom used in large plants, even though they possess quite useful features ([2].

When the dosed water carrying floc finally passes into the flocculator through the inlet port, a certain rolling motion is inevitable, which can be accentuated by baffles in Horizontal flow basin or in an upward flow basin by the sludge blanket [1].

However in many basins there is ample evidence that better results can be obtained if mixing and flocculation can be intensified. In recent years much research has been done on both and sound theoretical rules have been laid down. There are methods of theoretical approach, the mixing and flocculation can be carried out either by mechanical means in specially built chambers or in suitable baffled channel or interconnected chambers. The latter methods requires no mechanical equipment but lacks flexibility, because the system can be designed for maximum efficiency only at one rate of flow and at one temperature, where-as the speed of mechanical paddles can be adjusted to suit the variations of flow, temperature and silt conditions. However, the cost added to the complexity of mechanical equipment introduces additional complications to be avoided in a developing country, and in practice a sinuous inlet channel preceded by violent mixing generally provides a reasonable effective solution [1]. If the pipe or channel through which the incoming water enters the basin is so dimensioned as to ensure a velocity greater than 1m/s, and if the channel or directed at an end wall so that the flow is forced to reverse abruptly through 180o, any coagulant introduced into the water before that sudden reversal will be adequately mixed and flock will form almost instantaneously.

Unlike the absolute necessity for thorough mixing, the need for flocculation as a separate process may or may not be essential much depends on the nature of the suspended solids. For rivers carrying coarse and heavy sediment the main problem is to prevent the silt settling and blocking the inlet channels before it reaches the basin [1].

Shallow depth settling may present operational difficulties in developing countries, so separate flocculators are mostly found before conventional horizontal flow basins where colloids are a problem and the complication of additional machinery may be avoided by having the flocculating action imparted to the water by the gently rolling motion resulting from passing water along a sinuous channel. In practice a channel providing a velocity of flow of about 0.3m/s with cross-walls ensuring 12-20 changes of direction though 180o (with well rounded corners), has often proved to be very effective. The emphasis must be placed on the comparative smoothness of flow required. Under no circumstances should velocity or turbulence be such as to break up the floc this can be seen in fig. 1 below. Similarly table: 1 show the recommended GT values for flocculation.

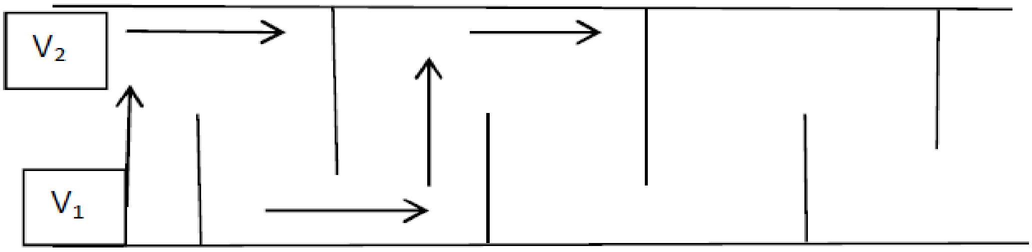


Fig: 1 Sinous Flow Channel

TABLE 1: RECOMMENDED GT VALUES FOR FLOCCULATION [1]

| Type | Velocity Gradient $G, s^{-1}$ | GT |
|---|---|---|
| Turbidity or colour removal (without solids recirculation | 20-100 | 20,000-150,000 |
| Turbidity or colour removal (with solids recirculation) | 75-75 | 25,000-200,000 |
| Softeners (solid contact reactors) | 30-200 | 200,000-250,000 |
| Softener (ultra-high solid) | 250-300 | 300,000-400,000 |

## V. CONCLUSION

The need for pure water for human use and consumption cannot be overemphasis. Different method and processes for water treatment to meet up with the world health organization standard (WHO) for a portable drinking water are available both in the literature and practical applications. However in this presentation three of the most widely used and the most cost effective have been identify particularly within a villages and small communities with surface water sources. That is aeration which explain the principle of pass air into the water under certain condition with a view to liberate undesirable gases such as carbon dioxide, hydrogen and also improves the water taste, odor, and colour and may also affect the killing of some pathogens. While coagulation involve the addition of chemicals such as alum to water in order to aid settlement of the dissolved particles, by forming large floc. This is followed by gentle stirring by rotating members to form large floc which become heavy and easy to settle in the bottom of the tank referred to as flocculation.

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