Study on Drinking Water Treatment Plant Optimization

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Abstract: Conventional drinking water treatment plant consists of coagulation, flocculation, sedimentation, and filtration and disinfection units. Depending on water quality influent, each unit can be optimized to achieve the desired water quality effluent, both in design and operation stages. A typical water treatment plant has the combination of processes needed to treat the contaminants in the source water treated by the facility. The presence of unbeatable organic or mineral substances causes some problems in obtaining drinking water. Understanding these phenomena requires taking into account the physical and chemical natures of the water to be treated. Optimization of conventional drinking water treatment plant means “to attain the most efficient or effective use” of your water treatment plant regarding some principles, there are: achievement of consistently high quality finished water on a continuous basis and the importance to focus on overall plant performance, instead of focusing too much on individual processes. This paper presents a study on optimization of conventional drinking water treatment plant that eventually proposing a method to maximize process efficiency with less risks. Overall optimization was carried out by dynamic programming to meet drinking water quality standard.

[Paria Amirian, Meisam Asghari, Iman homayoonnezhad. **Study on Drinking Water Treatment Plant Optimization.** *Biomedicine and Nursing* 2018;4(3): 57-64]. ISSN 2379-8211 (print); ISSN 2379-8203 (online). http://www.nbmedicine.org. 7. doi:10.7537/marsbnj040318.07.

Keywords: treatment plant, Dynamic programming, Optimization, Coagulation-flocculation, Sedimentation, Filtration, Disinfection

1. Introduction

Water suppliers use a variety of treatment processes to remove contaminants from raw water. These individual processes may be arranged in a "treatment train" (a series of processes applied in sequence). The most commonly used processes include filtration, flocculation and sedimentation and disinfection for surface water. Some treatment trains also include ion exchange and adsorption. Water utilities select a combination of treatment processes that is the most appropriate to treat the contaminants found in the raw water Optimization of conventional drinking water treatment plant is not only important on its process, but also on its operation. (Reitveld, 2009) & (Backslapper, 2004) reported that although drinking water treatment plants are already functioning for more than a century and in the last decades the operation has become more and more complex. Because of more stringent regulations, the plants have to produce water of a better quality and, therefore, different treatment processes are placed in series to meet the guidelines. Because of frequent job rotation and increased automation, experienced operators who are able to interact with the processes are nowadays scarce. Therefore, it is impossible to compensate for the increased complexity of operation this paper presents a review and discussion of related issues on optimization of conventional drinking water treatment plant. A proposed method or model was developed to maximize treatment objective and minimize risk as the basic principal of optimization.

Optimization of Conventional Drinking Water Treatment Plant: As a “treatment train”, conventional drinking water treatment plant compounds of many series stages and units (coagulation-flocculation, sedimentation, filtration and disinfection), which on each unit should be optimized on its design, process and operation.

(Banff, 2009) defined optimization of conventional drinking water treatment plant means “to attain the most efficient or effective use of” your water treatment plant which consist of some principles, there are; achievement of consistently high quality finished water on a continuous basis; and the importance to focus on overall plant performance, instead of focusing too much on individual processes. Approaches to conventional drinking water treatment plant optimization should be mostly common sense, be organized and get into the facts first.

Systematic gathering of information about plant performance are need, such as: data trending and analysis, check plant design criteria against actual, track chemical dosing versus performance, field measurements and visual observations. The data trending and analysis should remind of the "GIGO"(Garbage In Garbage Out) principles and also correlate to plant operating parameters trends against each other to look for valuable information. (Reitveld, 2009) Reported that in drinking water treatment, it is particular importance to determine the water quality indicators for good operation. In the reported research the objective was to focus on the target water quality parameters and direct indicators for the performance. In the operational practice of drinking water treatment, however, derived indicators are often used. In softening, for example, pH is measured in the effluent as an indicator for performance, while the main purpose of softening is to decrease the calcium concentration. Specific questions and issues to be addressed by the model were linked to the different interest group. Optimization of Coagulation and Flocculation: Water is treated with compounds that make small suspended particles stick together and settle out of the water. Flocculation refers to water treatment processes that combine or coagulate small particles into larger particles, which settle out of the water as sediment. Alum and iron salts or synthetic organic polymers (used alone or in combination with metal salts) are generally used to promote coagulation. Settling or sedimentation are occurs naturally as flocculated particles settle out of the water. (Banff, 2009) also presented that optimization of coagulation and flocculation should be have many considerations, such as: chemical dosing trends, coagulation and flash mixing, colloid stability, selecting and evaluating coagulant, operational and design factors affecting coagulation. Chemical dosing trends optimization consist of; understand how chemical dosing impacts plant performance and look for over-or under-dosing, which it track to relation between; raw water turbidity versus coagulant dose, raw and coagulated water pH and alkalinity versus. Coagulant dose and clarified water turbidity versus coagulant dosage. Coagulation and flash mixing optimization consist of two performance conditions. First, getting the chemistry right, which describe into; coagulation objectives, selecting the right coagulant, appropriate coagulant dosage and matching alkalinity with coagulant dosage. Second, get the right dosing and mixing presented by; coagulation mechanisms, coagulant mixing methods and coagulant pumping. There are some factors that affect coagulation process, especially in term of operational and design. The first factor is uniformity of coagulant flow. This uniformity means the ideally dose in a steady stream. It should be noticed that many utilities are moving to gear pumps in order to avoid pulsation inherent with metering pumps. The second factor is vigor of coagulant mixing. Coagulation reactions take a fraction of a second. Besides, we also have to give attention to critical instantaneous mixing and static mixers which can lose effectiveness at lower flows. The third factor is pH and alkalinity. This means we should consider the need to add alkalinity if coagulant demands are higher. Generally, soda ash is considered as the most effective additive one. We also have to try to ensure 10-20 mg/L as Cacao residual alkalinity after coagulation. In coagulant mixing, rapid mixing is critical where true "Flash" Mixing is desired. Speed of coagulation reactions are very quick and vary from a fraction of a second to 7 seconds while excessive mixing time is wasted. The important thing in coagulant mixing is never pre-dilute coagulant to improve mixing turbulence. Common problems usually occur in coagulation process are under or over-dosing, mixing of insufficient energy, fouling or clogging of injectors or diffusers and side reactions. Under or over dosing can be avoided by using the Jar Testing. Mixing of insufficient energy can cause undesirable coagulation reactions. Fouling or clogging of injectors or diffusers is usually caused either by pre-dilution of coagulant or poor mixing at the point of injection. This circumstance causes high and much localized coagulant concentrations and contributes to significant precipitation around inject. The side reactions are caused by trying to mix too many chemicals at once. Flocculation good practice needs some aspect to be considered. First, tapered flocculation by Gradient Velocity (G = 20-70 s-1) for sedimentation is set to 20-30 min total. Second, perforated intra-cell baffles walls which have objective to minimize short circuiting. Third, higher energy (G = 100 s-1) non-tapered flocculation for insufficient air loading is set 15 min total. Fourth, maximum blade tip must be at speed 2-3 m/s for vertical turbine flocculates to avoid flock damage. Las but not least, we have to include variable speed drives to adjust flocculation energy for optiescmal performance. (Franceschi, 2002) & (Zularisam, 2009) Reported that in some cases, the addition of mineral salts or organic compounds causes the agglomeration of these particles, allowing their elimination by decantation or filtration in most water treatment plants, the minimal coagulant concentration and the residual turbidity of the water are determined by the Jar-Test technique. In their paper a systematic study of the influence of raw water quality and operating conditions on the effectiveness of the coagulation-flocculation process using aluminum sulphate is presented. Parameters studied in the coagulation-flocculation process can be divided into two groups corresponding to two different experimental strategies; parameters relative to raw water quality and parameters relative to the conditions of process.

Results show an antagonistic influence of the important parameters on the studied responses. (Franceschi, 2002) & (Gregor, 1997) Also reported that residual turbidity depends primarily on the quantity and the type of argillaceous colloids, the quantity of organic matter of argillaceous colloids, the quantity of organic matter concentration of humic acid and when humic acid concentration is high, pH is also an important parameter. This parameter had a particularly unfavorable effect for a value of 6.3. In the other research. (Huseyin, 2000) Reported that the main possible applications of ozone are preoxidation, intermediate oxidation and final oxidation. Generally pre-ozonation decreases color, turbidity, tastes and odors. This treatment is generally used to enhance the coagulation. Preozonation and coagulation processes were optimized for total organic carbon removal and bromate control.

Optimization of Sedimentation/Clarifier: Water is passed through a settling basin or clarifier allowing time for mud, sand, metals and other sediment to settle out. This particle conglomerate is removed from the water prior to filtration. (Banff, 2009) presented that optimization of sedimentation/clarifier it should be presented by many conditions, there are; consistently result less than 2 NTU, stable when faced with rapidly changing water quality conditions, produces a sludge of consistent quality, sedimentation: 0.5-1% of Total Solid (TS). Common causes for poor clarifier performance are: density currents due to temperature variation within basins, excessive operating loading rates, entrained air-incidental flotation, poor hydraulics due to uneven inlet flow splitting or flocculation circulatory patterns, sudden changes in raw water conditions, chemical under-or over- dosing, inappropriate sludge removal rates, insufficient air loading or sand concentrations (ActiFlo). It is also important to make sure that clarifier operating at or below design capacity, there are list of conditions which should be monitored; loading Rate-Flow per unit area (m3/m2/hr, or m/hr), typical loading rates, traditional sedimentation (up to 4 m/hr), conventional insufficient air loading (up to 20 m/hr), high rate insufficient air loading (30-45 m/hr), ActiFlo (40-60 m/hr). Loading rate is an average over the entire basin area and localized high velocities can cause major problems. Density currents generally worst in large sedimentation basins due to surface warming and it can cause significant flock carryover. Design and operation of inlet flow also affecting performance of sedimentation. Inlet flow mal-distribution generally caused by poor inlet channel design and sometimes caused by uneven inlet weirs. Poorly designed flocculation basins result in bulk circulation, resulting in high localized entry velocities, better flow distribution usually requires head loss to be introduced, mitigation can be difficult, without causing flock damage. For rectifying mal-distribution we should switch to flow meters and valves, but often there is insufficient head and modify the inlet channel to provide tapering and equalize velocities. Design and operation of inlet flow also affecting performance of sedimentation. Inlet flow mal-distribution generally caused by poor inlet channel design and sometimes caused by uneven inlet weirs. Poorly designed flocculation basins result in bulk circulation, resulting in high localized entry velocities, better flow distribution usually requires head loss to be introduced, mitigation can be difficult, without causing flock damage. For rectifying mal-distribution we should switch to flow meters and valves, but often there is insufficient head and modify the inlet channel to provide tapering and equalize velocities.

Optimization of Filtration:

Water is passed through a dual media (sand and anthracite) filter, which removes many remaining pollutants. Many water treatment facilities use filtration to remove all particles from the water. Those particles include clays and silts, natural organic matter, precipitates from other treatment processes in the facility, iron and manganese and microorganisms. Filtration clarifies water and enhances the effectiveness of disinfection. (Banff, 2009) presented that a “good” filter performance should be presented by many conditions, such as; consistently less than 0.3 NTU, particle counts < 50 particles/mL, long and predictable filter runs (24+hours), minimal premature particle breakthrough. Poor performance can be difficult to rectify, but many issues can be resolved with simple fixes. He also presented that “good” filter design should be presented by many conditions, most efficient media design has largest media at the top and the finest at the bottom, however, backwashing immediately re-classifies bed to place the finest grains at the surface, therefore use multi-media to mimic this effect, with coarse grains in the top layer to trap solids and finer layer below for polishing. “Conventional” filter design covered of some criteria, i.e.: typical Loading Rates 6-9 m/hr, higher possible with pilot testing, total media depth =1 m with composition; anthracite (Effective Size /ES 0.8-1.2 mm and Uniform Coeffisien /UC 1.4-1.65); and sand (ES 0.45-0.55 mm, UC 1.4-1.65). “Deep Bed” Filter Designs covered some criteria, i.e.: typical loading rates much higher, relying on chemical dosing to a greater extent, total media depth 2-3 m with composition; Anthracite (ES 0.8-1.2 mm, UC 1.4-1.65), Sand (ES 0.45-0.55 mm, UC 1.4-1.65). The important thing to remember is that all media should be selected to share a common fluidization velocity; this minimizes intermixing of media layers. Severe intermixing causes short filter runs by reducing void volume in upper layer of filter. Media characteristics can change over time by encrustations, deposition and physical degradation of media grains (wear). (Banff, 2009) Also presented that filter indices by; Unit Filter Run Volume (UFRV) = Filtration Rate (m/hr) x

Filter Run (hr), it means a measure of net filter production per unit filter area per filter run. UFRV of 300-500 m3/m2 is desirable. L/d Ratio (Ratio of Filter Bed Depth to Media Nominal Diameter), in theory filters with the same L/d should perform equally under similar conditions. L/d ratio > 1,000 for conventional filters, > 1,200 if using filter aid. Filter Efficiency-Similar to UFRV, but accounts for losses as waste. Filters should typically produce 2-4% as waste. Filter auxiliary cleaning criteria design are: Air Scour, air flow (0.9-1.5 m3/min/m), air scour provides a vigorous cleaning action, due to "collapse pulse" action; Surface Wash, generally falling out of favour, but common in older filters. Typical Flows; Fixed nozzles (5 m3/m2/hr), Rotating Arms (1.2 m3/m2/hr). Premature particle breakthrough may occur by increases in filtered water particle concentrations are common near the end of a filter run-well before turbidity breakthrough, passage of pathogens may occur before a turbid meter "notices", particle counting may be a more appropriate trigger for backwashing turbidity measurements. There is such a thing as over-washing a filter. Backwash waste characterization can help assess the "right" duration, perform timed sampling of backwash waste to determine solids content. Use data to asses when to terminate washing may allow reduction in water wastage and residuals volumes. Discussion about filter evaluation techniques, (Banff, 2009) Presented that it consist of; Visual Inspection, Filter Surveying, Filter Core Sampling, Backwash Waste Characterization, Floc Retention Profiling and Backwash Trough Level Check. Many questions as scope of visual inspections are: "cracking" at media surface, sand separation at filter walls, visible algae growth, filter media in troughs, has scaling or fouling changed the backwash characteristics of the media, depth uniformity of media, level of are the wash water troughs, freeboard-top of media to underside of trough, effectiveness surface wash reach the corners. There are many important issues of filter evaluation safety; never walk directly on filter media, ensure filter is fully drained before entering filter box, beware of filter appurtenances, use a safety harness where applicable, particularly during bed fluidization testing. For anticipating poor filter performance, there are many possible solutions: optimization of filter backwashing, addition to Filter-to-Waste, use of filter aid polymers, addition of coagulant or other chemicals to backwash water. In the other research (James, 2005) reported that the increased passage of particles and microorganisms through granular media filters immediately following backwashing is a common problem known to the water treatment community as filter ''ripening'' or maturation. While several strategies have been developed over the years to reduce the impact of this vulnerable period of the filtration cycle on finished water quality, this research involves a recently developed filter backwashing strategy called the Extended Terminal Sub fluidization Wash (ETSW). Their research concludes that optimality of the coagulation process was also shown to influence the magnitude of filter ripening particle passage. Extended Terminal Sub fluidization Wash on filtration is a method of terminating the backwash cycle with a sub fluidization wash for a period of time sufficient to pass one theoretical filter-volume of water upward through the filter. Extended Terminal Sub fluidization Wash was shown to remove significantly greater quantities of backwash remnant particles thereby reducing the magnitude of filter ripening turbidity and particle count spikes. Optimum Extended

Terminal Sub fluidization Wash flow rates were determined for deep-bed anthracite and granular activated carbon filters herein by monitoring filter effluent turbidities and particle counts during the filter ripening period. Optimality of the coagulation process was also shown to influence the magnitude of filter ripening particle passage. Extended Terminal Sub fluidization Wash was found to be equally effective for biological and conventional deep-bed anthracite filters. Theoretical approach to Extended Terminal Sub fluidization Wash optimization is intended to remove backwash remnant particles from the filter (both within and above the media) after a fluidized bed backwash while simultaneously minimizing the production of further remnant particles. It seems plausible to optimize the Extended Terminal Sub fluidization Wash rate by minimizing detachment of new remnant particles by decreasing the shear forces at the surface of the media grains via lower wash water flow rates, while also maintaining efficient removal of particles previously dislodged from the filter media.

Optimization of Disinfection: Chlorine is added to the water to kill and/or inactivate any remaining pathogens. Fluoride is added to prevent tooth decay and a rust inhibitor is added to preserve the pipes that deliver the water to homes and businesses. Water is often disinfected before it enters the distribution system to ensure that potentially dangerous microbes are killed. Chlorine, chloramines, or chlorine dioxide are most often used because they are very effective disinfectants, not only at the treatment plant but also in the pipes that distribute water to our homes and businesses. Ozone is a powerful disinfectant and ultraviolet radiation is an effective disinfectant and treatment for relatively clean source waters, but neither of these is effective in controlling biological contaminants in the distribution pipes. (Nikolaous, 2005) reported that occurrence of disinfection by-products (DBPs) in drinking water has been an issue of major concern due to their adverse health effects. Application of disinfection processes during water treatment leads to the formation of disinfection by-products. The development and optimization of analytical methods for the determination of Disinfection by Products in water are key points in order to estimate human exposure after water treatment. The optimized analytical methods were applied for the determination of the formation potential of the Disinfection by Products studied in samples from different place of water resources for supplying drinking water treatment plants. The advantages of the optimized methods are the lower amounts of reagents used and the shorter sample analysis time. Application of the methods to water samples from two places of resources was performed in order to determine the formation potential of the Disinfection By Products studied during chlorination. In the other research (Huseyin, 2000) reported that the purpose of intermediate oxidation is to degrade toxic micro pollutants and to remove chlorinated by-product precursors. Thereafter, final ozonation is applied for the elimination of all possible remaining microorganisms. The formation of chlorinated and brominated by-products is the unwanted side of ozone application in drinking water treatment.

Remarks for Optimization of Water Treatment Plant: Based on many articles which discuss about optimization of water treatment plant, their researches have given us the basic scientific information. From (Franceschi, 2002), we could conclude on coagulation-flocculation process that; optimization of the residual turbidity needs to retain only a few parameters as opposed to the optimization of minimally added Aluminum Sulfate concentration.; there is an antagonistic influence of the different parameters on the two studied responses turbidity and aluminum sulfate so it is impossible to simultaneously optimize both of them. We also could conclude from (Huseyin, 2000) that after pre-ozonation, alum coagulation was applied and it was found that pre-ozonation enhanced the efficiency of alum coagulation, however Bromate removal was insignificant at the optimum alum concentration. (James, 2005) found that Extended Terminal Sub fluidization Wash (ETSW) on filtration was shown to remove significantly greater quantities of backwash remnant particles thereby reducing the magnitude of filter ripening turbidity and particle count spikes. Optimum Extended Terminal Sub fluidization Wash flow rates were determined for deep-bed anthracite and granular activated carbon filters herein by monitoring filter effluent turbidities and particle counts during the filter ripening period. Extended Terminal Sub fluidization Wash was found to be equally effective for biological and conventional deep-bed anthracite filters. Their research also concludes that optimality of the coagulation process was also shown to influence the magnitude of filter ripening particle passage. Based on the disinfection process research of (Nikolaous, 2005), although the water quality of both water resources studied was similar and the total concentration of all disinfection by products (DBPs) comparable, differences were observed in the formation of some species of disinfection by products, possibly due to differences in organic precursors of the waters. Results indicate that aluminum sulfate coagulation after pre-ozonation is not applicable for bromate removal. (Chaiket, 2002) Concluded that much attention should be paid to organic removal before disinfection to control disinfection by products formation and preserve biostability and they also reports the range of efficiency of each unit process to calculate the total efficiency of different process combinations in order to help choose the appropriate water treatment process. However, for all stages or units of water treatment plant (Banff, 2009) developed and determined many indicators and criteria condition that should be fulfill on optimization which have objective for maximizing the quality of treated water to meet the standard.

Approach and Model of Optimization: Water supply companies are gradually changing to a centralized, fully automated operation. The drivers for this change are the increase in efficiency and a better and more stable water quality. Fully automated treatment plants will require more sophisticated operator care than manually operated plants, so operation supervisors should periodically train in a drinking water treatment plant simulator. The successful first time setup of such a simulator is addressed in the paper which reported by (Chaiket, 2002). Environmental decision-support systems (EDSSs) were used as a blueprint for this simulator because the integration of different models is common in EDSSs. Models are an essential part of the simulators since they represent the behavior of the treatment plant's processes. Four models run simultaneously in the simulator: a water quality model, a hydraulic model, a process control model and a field object model. Discussion about decision support systems, (James, 2005) Reported that Dynamic Programming is an approach developed to solve sequential, or multi-stage, decision problems; hence the name "Dynamic programming". But, as we shall see, this approach is equally applicable for decision problems where sequential property is induced solely for computational convenience.

Basically what Dynamic programming approach does is that it solves a multivariable problem by solving a series of single variable problems. Dynamic Programming like branch and bound approach is a way of decomposing certain hard to solve problems into equivalent formats that are more amenable to solution. This is achieved by tandem projection onto the space of each of the variables. In other words, we project first onto subset of these and so on. Dynamic Programming is a technique for computing recurrence relations efficiently by sorting partial results, for solving a problems exhibiting the properties of overlapping sub problems and optimal substructure that takes much less time than naive methods (optimal substructure means that optimal solutions of sub problems can be used to find the optimal solution of the overall problem). (Gregor, 1997) Reported that the number of deficits (the number of months that released flow from reservoir is less than required water for downstream of dam.) was calculated by a simulation program. Simulation program made used of dynamic programming in this research. Several scenarios were considered for yield model and simulation program. A number of researchers applied programming for simulation and optimization of reservoir. Researchers applied linear programming (LP), nonlinear programming (NLP) and dynamic programming (DP) for solution of problems in water resource management. Two researchers made used of combination of linear programming and dynamic programming for optimization of volume of parallel multi objective reservoirs. Two engineers applied dynamic programming method for determination of the value of required water in future. Recently researchers developed folded dynamic programming (FDP) method. This method is applied for optimization of multi reservoirs systems. This method does not need to primary path for finding of global optimum. Therefore this method does not converge to local optimums. Also the number of iteration of this method is less than the number of iteration of dynamic programming for reaching to global optimum. In the other research, (Banff, 2009) reported that the problem of minimizing water shortages while maximizing hydropower generation through a multi objective optimization problem. Optimizing water management strategies is complex, as some impact relations are nonlinear and interdependent. A basic problem of multi objective optimization is that the various objectives may be conflicting and incommensurable, or may affect different groups of people or interests. In multi objective optimization there is no single optimal solution. Instead, the interaction of multiple objectives yields a set of efficient or non-dominated solutions, known as Pareto-optimal solutions, which give a decision maker more flexibility in the selection of a suitable alternative. Based on the other paper, (Reitveld, 2009) & (Backslapper, 2004) reported that modeling and control will lead to better water quality, cost reduction and to a more stable performance of a plant and a better understanding of the processes. The purpose of the modeling was to optimize the operation of drinking water treatment, without taking design changes into account. The models can then be used for off-line decision support to technologists. Ultimately, the models can be considered for incorporation in advanced control strategies to be implemented in the treatment plant. Good modeling practice increases the credibility and impact of the information and insight that modeling aims to generate. It is known to be crucial for model acceptance and it is a necessity to amass a long-term, systematic thorough knowledge base for both science and decision making. Their research shows how ten steps in model development and evaluation can also be applied to numerical modeling of drinking water treatment, using models of drinking water treatment processes of the treatment plant. (chaochen,2002) Also reported the range of efficiency of each unit process to calculate the total efficiency of different process combinations in order to help choose the appropriate water treatment process.

Remarks for Optimization Approach and Model: Based on many articles which discuss on optimization approach and model, the papers have given us the basic scientific information. conclude that for the different processes models were developed that were used for operational improvements. The modeling resulted in new insights and knowledge about the treatment processes and improved operation of the processes. Although implementation of models in daily operation is not part of the ten-step method it was the justification of the reported modeling effort. It has therefore been decided to continuously verify the measured data of the full-scale plant with the model and to improve user-friendliness of the model to give operators and technologists the opportunity to work with the model. The modeling itself resulted in new knowledge about the treatment processes and proposals for improved operation. It can be concluded that, in general, the ten steps in model development and evaluation could be used for operational improvement of drinking water treatment. It was felt to be useful to explicitly indicate the steps to be made. In contrast to other environmental modeling efforts in drinking water treatment it is possible to quantitatively verify, evaluate and test the models. Frequently pilot plants are available for calibration and validation of the models and in full-scale plants the models can be tested and used for improvement of operation. (Chaiket, 2002) Concluded that the interface between the simulator engine and the water quality model and also demonstrated that a generic simulator has been developed for drinking water treatment plants. As a consequence of the generic setup and standard interfaces, the application of the simulator at a future drinking water treatment plant will only require models to be set up and validated. More effort must be put into the development of the process control model. We also could conclude from (James, 2005) that Dynamic Programming is a very useful technique for making a sequence of interrelated decisions. It requires formulating an appropriate recursive relationship for each individual problem. However, it provides a great computational savings over using exhaustive enumeration to find the best combination of decisions, especially for large and/or complicated problems. Therefore conventional drinking water treatment plant as like a “treatment train” which has many stages and need optimization approach for each stage/unit, then exhaustive enumeration must consider up to combinations, whereas dynamic programming need make no more than calculations.

2. Discussions

Optimization of conventional drinking water treatment plant is not only important on its process, but also on its operation and design. Many indicators and criteria's condition for each stage or unit of conventional drinking water treatment plant should be fulfill on optimization which have objective for maximizing quality of its effluent/treated water. Optimization on the earlier unit/stage of conventional drinking water treatment plant may lead to a better result hence the loading factor of the following unit/stage will be reduced. To choose the priority unit of conventional drinking water treatment plant which will be optimized, is depend on the characteristic of raw water quality, but it can be formulated by approach and modeling. The total result of optimization of all /units of conventional drinking water treatment plant should be considered which it will lead to the best performance of final effluent, hence would be met with the standard quality of drinking water. Therefore follow up research on optimization by Dynamic Programming model approach should be perform for reaching to global optimum.

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9/25/2018