DESIGN OF UNIT SIZES OF A WATER TREATMENT PLANT FOR GUWAHATI METROPOLITAN CITY

A thesis submitted towards partial fulfilment of the requirements for the degree of

MASTER OF ENGINEERING

in

Water Resources and Hydraulic Engineering

Submitted by

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Declaration of Originality and Compliance of Academic Ethics

I hereby declare that this thesis contains literature survey and original research work by the undersigned candidate, as part of my **Master of Engineering** in **Water Resources and Hydraulic Engineering** in the Faculty Council of Interdisciplinary Studies, Law & Management, Jadavpur University during academic session 2018-19.

All information in this document have been obtained and presented in accordance with academic rules and ethical conduct.

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Certificate of Recommendation

This is to certify that the thesis entitled "**Design of Unit Sizes of a Water Treatment Plant for Guwahati Metropolitan City**" is a Bonafide work carried out by **Mr. Jaydeb Dey** under our supervision and guidance for partial fulfilment of the requirement for the Post Graduate Degree of Master of Engineering in Water Resources and Hydraulic Engineering during the academic session 2018-19.

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This foregoing thesis is hereby approved as a credible study of an engineering subject carried out and presented in a manner satisfactorily to warranty its acceptance as a prerequisite to the degree for which it has been submitted. It is understood that by this approval the undersigned do not endorse or approve any statement made or opinion expressed or conclusion drawn therein but approve the thesis only for purpose for which it has been submitted.

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ABSTRACT

Guwahati is the largest city in Assam and in the North-eastern region of the Indian subcontinent. The city has a well-developed connectivity with the rest of the country and acts as the gateway to the entire North-eastern India region. Its population in 2001 was approximately 0.89 million which has increased by 25% to about 1.11 million in 2007. It is estimated to further rise to around 2.80 million in 2025, and to 3.23 million in 2040, which is twice and thrice of the current level respectively.

Guwahati is located in Seismic Zone V (As per IS -1893-2002). The City of Guwahati has been divided into four distribution zones for water supply, namely (1) South East, (2) South Central, (3) South West, all located south of the Brahmaputra River and (4) North Guwahati on the northern bank of the Brahmaputra River.

This Guwahati Water Supply Project (GWSP) aims to construct water treatment, conveyance and storage facilities in the South Central and Northern parts of the city to activate a potable water supply system with 100% coverage of the citizens within the above areas and thus leading to upgrading the citizen’s living standard.

Like all large cities even in Guwahati Metropolitan Area there is a problem of space and due to which the site for the construction of WTP had been away from the source of water, but not that far even. Additionally, the city has got undulating topography along the bank of the river and also within the city. The site that was made available for the water treatment plant is on the bank of the river. The area has a steep slope, this slope being over steep presented a problem of dissipation of energy as opposed to the advantage of a gentle slope which is helpful for the design of WTP of this type. The metropolitan area of Guwahati has witnessed an increase in area and as well as in population, the projected demand for water is about 255 MLD in 2025, the current demand is 75% of the future demand. Availability of fund was also a major issue in designing and construction of such plants, considering this entire prospect the following decisions were taken.

01. Design of total plant 255 MLD
02. Construction would be at present 191 MLD.
03. Design and Construction would be modular so that an additional module could be easily build and initially constructed.
04. Design Features
    1. Considering the availability of space, it was decided to go for rectangular flocculator and square type tube settler to economize on space.
    2. The flocculated design was a combination of horizontal flow and vertical flow, a large amount of potential energy that was lost from PST through aerator to flocculator, so that the velocity at outlet of the flocculator entering the tube settler was within acceptable range. This particular feature of the design is not commonly use in the world.

5. Optimum utilization of available space by adopting square and rectangular flocculators.
6. The construction had been of three modules at the present to reduce the capital cost.

The energy dissipation problem arising due to steep slope of the site had been effectively utilized increasing and optimising the efficiency of plant and quality of water.

CONTENT

Chapter 1

1.1 General Requirements

1.1.1 Project Country – India

India is located in the South Asia region bordering the Arabian Sea and the Bay of Bengal. The area of the country is about 3,287,590 sq. km. It has a coast line of about 7,000 km in length. The terrain consists of the upland plain (Deccan Plateau) in the south, a flat to rolling plain along the Ganges to the east, deserts in the west, and the Himalayan Mountains to the north. The climate varies from tropical monsoon in the south to temperate in the north. India is the second largest country in the world in terms of population, second only to China. It is estimated that the population of the country is about 1,050 million. The population density average approximately 320 persons per sq. km.

The principle languages in India are Hindi (official), English (official), Bengali, Gujarati, Kashmiri,

Malayalam, Marathi, Oriya, Punjabi, Tamil, Telugu, Urdu, Kannada, Assamese, Sanskrit, Sindhi (all recognized by the Constitution) and there are 1,652 dialects. English is well understood by the educated classes of India. India is a secular country and all religions find sanctuary here.

India is well connected to the world by approximately 335 airports with major International Airports at New Delhi, Mumbai, Kolkata and Chennai. The major ports and harbors in India are at Chennai, Cochin, Kandola, Kolkata, Mumbai and Vishakhapatnam. The internal transport in the country is through one of the largest rail networks in the world consisting of approximately 63,700 km of railway track (13,800 km electrified). The road network is of 3,320,000 km out of which 1,517,000 km are paved (as of 1996).

1.1.2 Project Background

Guwahati is the largest city in Assam and in the North-eastern region of India. The city has a well-developed connectivity with the rest of the country and acts as the gateway to the entire North-eastern Indian region. Its population in 2001 was approximately 0.89 million and it has increased by 25% to about 1.11 million in 2007. It is estimated to further increase to around 2.80 million in 2025, and to 3.23 million in 2040, which are twice and thrice the current level. Guwahati is located in Seismic Zone V (As per IS 1893-2002). The City of Guwahati has been divided into four distribution zones for water supply, namely (1) South East, (2) South Central, (3) South West, all located south of the Brahmaputra River and (4) North Guwahati on the northern bank of the Brahmaputra River. The total installed capacity of potable water generation under the Guwahati Municipal Corporation (GMC) service area is around 98 million litters per day (MLD) considering capacities of the treatment plant at Panbazar, Patpabhri and Hengrabari, although the total water currently produced is approximately 79 MLD. The current public piped water supply within Guwahati covers only about 30% of the city area, mostly in the South-Central Zone. Even within this area due to the degraded water treatment plants and the high unaccounted-for water (UFW) rate (around 38% in 2008), the provision of water at individual households is limited to 2 to 3 hrs a day. Those citizens without access to a piped water supply rely on ground water, but the water quality is not appropriate for drinking, with high levels of dissolved solids and iron with fluoride contamination. Moreover, the water quality of the public water supply in some areas is contaminated.

At present, there are three agencies which provide water supply in the City of Guwahati, namely the Guwahati Municipal Corporation, Public Health and Engineering Department (PHED), and Assam Urban Water Supply & Sewerage Board (AUWSSB). Of the three agencies the GMC covers about 30% of the population in this city. Most of the water treatment and supply facilities have outlived their lives as a result of a budget deficiency for repair or replacement.

The *Master Plan for the Guwahati Metropolitan Area 2025* sets the target of "100% houses will be supplied with piped filtered water by the year 2025". The currently on-going water supply project for the South West Zone is being taken up under Jawaharlal Nehru National Urban Renewal Mission (JNNURM) funding. The water supply for South East Zone is being planned under the Asian Development Bank's (ADB's) assistance.

The water supply zones under the present Japanese International Cooperation Agency (JICA) funding for this Contract (ID-P 201) are the South Central and North Zones. The South-Central Zone is the centre of the city with the highest population among the four zones. The North Zone is less populated where most of the area is under agricultural use. This Guwahati Water Supply Project (GWSP) aims to construct water treatment, conveyance and storage facilities in the South Central and Northern parts of the city to activate a potable water supply system with 100% coverage of the citizens within the above areas and thus leading to upgrading the citizen's living standard. The existing water supply facilities will be reused or abandoned with a completely new water supply system put in service. This Guwahati Water Supply Project also aims to support the establishment of the Guwahati Jal Board, which is to take over administration of the existing water supply schemes covering the entire city. In this regard The Guwahati Water Act of 2009 has been passed by the Assam Legislative Assembly, making way for the establishment of the Board and the Water Regulatory Authority.

1.1.2.1 Project Objectives

The existing water supply system in Guwahati is now unable to provide sufficient water supply in view of the increasing water demand caused by the growing population. This project intends to improve living conditions in the rapidly growing Guwahati area, by providing new water supply facilities. The purpose of the project is to construct water supply facilities to take water from the **Brahmaputra River** and to supply the **South Central and North Zones.**

Under this project, a variety of measures will be implemented including introducing a water volume management system to control the pressure and quantity of water distributed to each water supply area. By implementing these measures, the project is expected to supply water which is continuous (24 hours x 7 days a week), pressurized, safe, stable and suitable for human consumption. This project will receive a loan assistance of 29,453 million Japanese Yen. The loan will fund civil works for constructing water supply facilities, procurement of machinery and equipment, and consulting services. The main objective of Japanese loan assistance is to support India in establishing physical infrastructure to boost and sustain economic growth. At the same time, Japanese assistance seeks to support India’s efforts to alleviate poverty. In keeping with these goals, the loan package strategically covers this water supply project.

1.1.2.2 Project Components

The current Scope of the project, which may vary based on actual field conditions, is provided in Table 1-2.2.

Table 1.1 Project Components

Components	Description
Intake Structure	1 intake point consisting of intake wells (minimum 2 numbers) with a raw water pump station, a bridge to the shore, and associated piping and electrical service
Water Treatment Plant	1 water treatment plant (WTP) having a nominal capacity of 191 MLD which will be expanded to 255 MLD capacity in the future
Clear Water Pumping Station	1 clear water pumping station within WTP campus.
Office Building of Jal Board	2 storied building (total area 9000 sqm), with metering shop, Inventory room training centre, store yard

1.2 Location of the Project

The service area for this portion of the Guwahati Water Supply Project is on the northern shore of the Brahmaputra River in North Guwahati. The only access by road to North Guwahati from the main city of South Guwahati is via the National Highway (NH) 31.

The entire North Guwahati area is in one water supply zone, as compared to three water supply zones serving South Guwahati.

The Site (map of this project shown in Annex- 01) is to the east of the bridge crossing in the Majh Gaon area. The new water treatment plant will be located approximately 5.5 km east of the north end of the Straight (NH 31) Bridge. The raw water transmission main will convey water from the intake structure in the Brahmaputra River, up the slope at the shoreline, along existing roads to the WTP. The clear water transmission main will convey treated water from the clear water pump station at the water treatment plant southeast within the WTP property approximately 160 meters to the hill top reservoir. The project area is within India Seismic Zone V (as per IS -1893-2002. Design of structures and their components will be dictated by the requirements of Indian Standard (IS) 1983, 2002 criteria.

1.3 Scope of Work

1.3.1 General Scope of Work

The objective of the project was to supply adequate amount of potable quality water to the inhabitants of the northern part of Guwahati. Source of raw water was River Brahmaputra. Prior to the project there was very little treated potable quality water supply to the inhabitants of Guwahati. The project was conceived early in the first decade of 21st century. The capacity of the plant was decided upon considering the likely demand of the population in 2025.

1.3.1.1 The Process of the Treatment of raw water and the Hydraulics of the treatment plant are shown as Annexures at the end of all chapters.

- Process and Instrumentation Diagram (Annex -02)
- Hydraulics Flow Diagram of WTP. (Annex -03)

1.4 Intake Structure and Raw Water Pumping Station

The South Central (SC) intake structure and raw water pumping station was constructed in the Brahmaputra River southern shoreline. These facilities supplying water to the SC Water Treatment Plant that was constructed (the Phase 1 portion). The raw water pumps were replaced and upsized in the Phase 2 projects. The intake was of a jack well (caisson) type structure. There was a provision for the raw water pump station to be housed within this RCC structure. The location of the intake structure and its design were based upon a thorough hydrological study of the past history of the river, its fluctuations of water levels scouring depths, receding characteristics and silt depositions. etc.

The intake was gated to be able to draw off river water at two (2) elevations, near the high and at low seasonal water levels. The intake structure was designed to house vertical turbine pumps for pumping

raw water requirement for Phase 1 and then an additional for Phase 2. The intake structure shall be designed and constructed to meet the requirements of Phase 2.

The Scope of Work for the intake structure with raw water pump station, along with the associated power system, includes the detailed design, construction of structures, manufacture and factory testing of equipment, delivery to the site, unloading, storing, complete erection, setting to work, pre-commissioning tests, trial runs, pre-commissioning and commissioning of all related mechanical, electrical and instrumentation equipment. The scope includes operation and maintenance of these systems in accordance with Subsection 13. The intake structure with raw water pump station layout is indicated in the conceptual drawing.

1.5 Water Treatment Plant including Clear Water Pumping Station

The land available at the South Central WTP (SCWTP) site is approximately 4.6 hectares (ha) to accommodate the water treatment plant, including all process units, the clear water reservoir and pumping station, the administration, chemical and chlorine buildings, ancillary works and road and open space as required to meet the Phase 2 production capacity of 255 MLD fully treated water. The water treatment plant to be constructed was designed for a Phase 1 capacity of producing 191 MLD of treated water output. Some of the unit process components was constructed for the full 255 MLD Phase 2 capacities. Such units included the cascade aerator, flow metering flumes, sludge handling facilities, clear water reservoir and most piping systems. The South Central WTP was capable of treating the raw water from the Brahmaputra River taking in to account the variation in raw water quality and sediment loading throughout the year installation of equipment as following but not limited to:

- Intake Well, Raw Water Pumping Station, Raw Water Pumping Main
- Pre-setting Tank
- Cascade Aerators
- Raw Water Measurement
- Flash Mixers
- Flocculators
- Plate/Tube Settlers
- Rapid Sand Filters and Back Wash System
- Clear water Reservoir and Pump Station
- Chemical Dosing Systems for coagulation and pH correction with Chemical Storage
- Chlorine Building (Pre and Post-Chlorination Systems)
- Water Tank
- Sludge Sump cum Pump Station
- Sludge Thickener and Dehydrators

- Control Room and Laboratory Building
- Electrical Power Supply Substation, Systems and Equipment
- Instrumentation, Automation and Control Systems
- EPABX (Telephone) System
- General Lighting and Ventilation
- Water supply facilities for chemical feeding and other plant operations
- Landscaping of all open areas not occupied by roads
- Boundary Wall, Entrance Gates and Retaining Walls
- Drainage system, sanitary system

1.6 Raw and Clear Water Transmission Mains

The raw water transmission main conveyed water from where the raw water header from the pump station in the Brahmaputra River, westerly approximately 270 meters to the pre-settling unit of water treatment plant.
The clear water transmission main will convey treated water from the clear water pump station at the water treatment plant easterly approximately 2050 meters to the hilltop reservoir on the Rams a Hill. These pipelines will be 1500 mm minimum in diameter and of mild steel (MS). The clear water transmission main be buried and the raw water transmission main may be exposed in some locations and supported on RCC cradles depending upon the presence of rock along its route.

1.6.1 Surge Protection Systems

The surge protection systems shall be designed to

(i) limit the vacuum pressure to 1/3rd atmosphere pressure at any location in the pipeline, and

(ii) To ensure that the maximum residual surge pressure is restricted to 20% of the maximum surge which would have developed without the surge control devices or20% of the normal design operating pressure, whichever is greater. The systems shall be fully automatic and of sound construction with alarm systems tied into the SCADA.

Chapter 2

2.1 Literature Review

Zhu and Simpson (1996) showed that how an expert system based on a combination of forward chaining backward chaining and meta rules has been developed for water treatment plant operations. The expert system was developed by interviewing a number of operators and chemists. Decision tree and fault trees were used to speed up the development of the expert system. The combination strategy of using both backward and forward chaining within the expert's system allows the number of questions asked to an operator to be minimized to prevent the asking of redundant question.

Yan *et al*. (2002) described that Natural organic matter (NOM) is a heterogeneous mixture of complex organic matter and occurs ubiquitously in source water. NOM has a strong implication with water supply. It may not only negatively affect the performance of water treatment processes, but also react with disinfectants such as chlorine to form a variety of harmful disinfection by-products. In addition, NOM may promote undesired microbial growth in water distribution systems. Thus, control and removal of NOM is of particular importance for the water treatment industry. Enhanced coagulation is recommended as an effective method to improve removal of NOM.

Kumar *et al.* (2003) described that the effect of 20 kHz ultrasound on the viability of Cryptosporidium oocysts was investigated. More than 90% of the dispersed Cryptosporidium oocysts could be deactivated in about 1.5 min of continuous sonication. In order to apply this technique to large quantities of contaminated water, quantitative filtration and re dispersion of Cryptosporidium oocysts were investigated and found to be easily achievable. The estimated cost of sonication showed that the ultrasound treatment of Cryptosporidium oocysts contaminated water could be a very effective means of "deactivating" Cryptosporidium oocysts.

Gone *et al.* (2009) evaluate the use of fluorophores A, C and T fluorescence intensities to access the coagulation efficiency for removing dissolved organic carbon (DOC) in the raw water from Agbo reservoir in Ivory Coast. A coagulation–flocculation was conducted with aluminium sulphate as coagulant and DOC residual and fluorescence intensities were acquired. The consistency of fluorescence data was evaluated to ensure that no inner-effect, quenching or enhanced intensities affect the data. Fluorescence-inferred DOC removal was then calculated in percentage terms from the decrease in organic matter fluorescence intensity for each peak between raw and clarified water and correlated with measured DOC removal. The results indicate a high significant correlation between measured DOC removal and fluorescence-inferred DOC removal calculated for peak A (R2 = 0.91), peak C (R2 = 0.89), peak T (R2 = 0.92) indicating a strong linear relationship between DOC removal and fluorescence intensities.

Henderson *et al.* (2009) evaluated A rapid, highly sensitive and selective detector is urgently required to detect contamination events in recycled water systems. This review concludes that the sensitive detection of contamination events in recycled water systems may be achieved by monitoring Peak T and/or Peak C fluorescence. However, in such systems, effluent is treated to a high standard resulting in much lower DOM concentrations and the impact of these advanced treatment processes on Peaks T and C fluorescence is largely unknown and requires investigation. This review has highlighted that further work is also required to determine (a) the stability and distinctiveness of recycled water fluorescence in relation to the treatment processes utilised, (b) the impact of matrix effects, particularly the impact of oxidation, (c) calibration issues for online monitoring, and (d) the advanced data analytical techniques required.

Putraa and Tanakaa (2011) described that the usefulness of the combined electro kinetic (EK) remediation with aluminium drinking water treatment residuals (Al-WTRs) as an entrapping zone (EZ) for removal of lead ion from artificially contaminated soil was demonstrated. Laboratory experiments were performed with variable conditions including (i) type of Al-WTRs materials and the application of Al-WTRs as an EZ system during the EK processing, (ii) pH and (iii) position of EZ in the soil cell. The potential of aluminium leach ability from Al-WTRs as the result of EK process was also discussed. The results show that the lead ions in the contaminated soil were transferred into the EZ by EK process and immobilized by adsorption sites on polymeric aluminium residual in the Al-WTRs. These residual compounds contained lead, which were not dissolved by diluted organic acid (0.1 M acetate buffer), were retained in the EZ and accumulated there. After 72 h of the electro kinetic process, the total amount of lead in the EZ was much higher than the initial lead concentration in the contaminated soil.

Baghoth *et al.* (2011) described that Natural organic matter (NOM) in water samples from a drinking water treatment train was characterized using fluorescence excitation emission matrices (F-EEMs) and parallel factor analysis (PARAFAC). A seven component PARAFAC model was developed and validated using 147 F-EEMs of water samples from two full-scale water treatment plants. It was found that the fluorescent components have spectral features similar to those previously extracted from F-EEMs of dissolved organic matter (DOM) from diverse aquatic environments.

Xing *et al.* (2012) described that in order to understand and improve drinking water treatment process operations Resin fractionation is the most widely used technique to isolate NOM based on its hydrophobicity and hydrophilicity, these can be used to determine the treatability of NOM, however, it is also recognized as a time consuming technique. This paper describes the use of reverse phase high performance liquid chromatography (RPHPLC) as a rapid assessment of the hydrophobicity/hydrophilicity of NOM. The reduction of total RPHPLC peak area correlated well with dissolved organic carbon (DOC) and UV absorbance at 254 nm (UV254) removal efficiency.

Matilainen *et al.* (2011) An **overview on** Natural organic matter (NOM) is found in all surface, ground and soil waters. During recent decades, reports worldwide show a continuing increase in the colour and NOM of the surface water, which has an adverse effect on drinking water purification. Methods used in the characterisation of NOM include resin adsorption, size exclusion chromatography (SEC), nuclear magnetic resonance (NMR) spectroscopy, and fluorescence spectroscopy. The amount of NOM in water has been predicted with parameters including UV–Vis, total organic carbon (TOC), and specific UV-absorbance (SUVA). Recently, methods by which NOM structures can be more precisely determined have been developed; pyrolysis gas chromatography-mass spectrometry (Py-GC–MS), multidimensional NMR techniques, and Fourier transform ion cyclotron resonance mass spectrometry (FTICR-MS). The present review focuses on the methods used for characterisation and quantification of NOM in relation to drinking water treatment.

Zhouet *et al.* (2012) described that drinking water treatment sludge, characterized as accumulated suspended solids and organic and inorganic matter, is produced in large quantities during the coagulation process. Reused sludge at low temperatures is an alternative method to enhance traditional coagulation efficiency. In the present study, the recycling mass of mixed sludge and properties of raw water (such as pH and turbidity) were systematically investigated to optimize coagulation efficiency. They determined that the appropriate dosage of mixed sludge was 60 mL/L, effective initial turbidity ranges were below 45.0 NTU, and optimal pH for DOMs and turbidity removal was 6.5–7.0 and 8.0, respectively.

Zhouet *et al.* (2013) evaluated the physicochemical characteristics of the dissolved organic matter (DOM) in simulated raw water, corresponding filter backwash water (FBWW) and treated water at three recycling ratios of 2, 5, and 8%, including control without FBWW using bulk properties, in addition to advanced characterization by molecular weight distribution (MWD), hydrophobicity, and fluorescence. The DOM characteristics of raw water and FBWW were primarily identified and compared, and it was found that DOM in FBWW was roughly hydrophilic as compared with raw water, and the FBWW was more refractory due to a substantial increment of low-MW (< 3 KDa). Additionally, humic-like fluorophore (Peak A) and protein-like fluorophore (Peak T1), with maxima at the Ex/Em wavelengths of 245.0–265.0 nm/400.0–435.0 nm, 280.0–305.0 nm/305.0–345.0 nm, respectively, were the two main components in raw water and FBWW. Recycling trial results indicated that DOM removal efficiencies were improved with comparison to control.

Jubooriet *et al.* (2015) described that there is a limited work on the use of pulsed ultrasound for water disinfection particularly the case of natural water. Hence, pulsed ultrasound disinfection of natural water was thoroughly investigated in this study along with continuous ultrasound as a standard for comparison. Total coliform measurements were applied to evaluate treatment efficiency.

Das (2015) assessed the power consumption in different units within treatment plant, energy audit. Etc.in connection to operation and maintenance of JHJP water treatment plant. The prime objective of this work was a depth study of the various units of Jai Hind Jal Prakalpa with a view to had an idea about the weakness and inadequacies from which this new plant was suffering at the initial stage. To accomplish this assignment certain fields were chosen like energy audit, turbidity, alum dosing, estimation of production cost of water and hydraulic design calculation. Details study of hydraulic design calculation, detail study of alum dosing and corresponding turbidity of raw water, study of percentage removal of turbidity at different units of treatment plant, percentage of water losses up to treatment process completion.

Yu and Graham (2016) in his paper describes some results of mini-pilot-scale tests concerning the performance of potassium manganite (K_2MnO_4) as a pre-treatment chemical prior to ultra-filtration. Manganite is an intermediate in the commercial preparation of permanganate and in aqueous reactions MnO_4^{2-} can act as both an oxidant and a coagulant/adsorbent arising from the formation of insoluble MnO2. In addition, the combination of ferrous sulphate and manganite (Fe/Mn), offers a potentially cheaper and effective combination of pre-oxidant and coagulant compared to the chemicals used currently in water treatment (e.g. ozone, chlorine, ferric sulphate). Fe/Mn pre-treatment reduced the amounts of both types of fouling material within the cake layer and membrane pores in comparison to conventional pre-treatment with ferrous sulphate, most likely through the formation of solid-phase Fe (III) and MnO2 and by MnO_4^{2}- oxidation, thereby leading to a substantial increase in membrane run time.

Chapter 8

8.1 References

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