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Unit Operations in Pilot Wastewater Treatment Plant Used for Textile Wet Processing - A Review

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Abstract- Textile processes use abundant water for processing of fabric. Their unit operations need water of desired quality which will give good finish to fabric. Drawdown of ground water level, diminishing water sources forced this industry to search for alternative sources of water. Municipal wastewater after treatment is disposed to environment. This plentiful water is wasted which can be recycled in to the industry with required amount of treatment. In this research pilot treatment plant was constructed to recycle municipal treated wastewater in cotton textile wet processing after a necessary treatment. This review paper comprises of assimilation of research work carried out by researchers in wastewater treatment.

Index Terms- Wastewater treatment, oil and grease removal unit, slow sand filter, activated carbon filter, chlorination, ion exchange

1. INTRODUCTION

Pilot treatment plant was prepared and treatment was given to treated municipal wastewater. Units in Pilot treatment plant are described below.

1. Municipal treated water storage tank: To store the treated wastewater for further treatments. Also acts as a sedimentation tank.
2. Oil & Grease removal unit: Oil & Grease can be removed with this unit.
3. Slow Sand filter (SSF): Slow sand filter is provided with various layers of sand of different particle size.
4. Granular Activated Carbon filter (GAC): Through this the color and odor from the wastewater is removed.
5. Chlorination unit: This is carried out to disinfect the treated municipal effluent. For this sodium hypochlorite solution with various dosages was used.
6. Cationic Exchange Resin (SAC): Here cations like Na^+, Mg^{++}, Ca^{++} etc. was exchanged with H^+ ions. The cationic exchange resin used was strong acid type
7. Anionic Exchange Resin (SBA): Here anions like $S0_4^{--}$, CO_3^{--}, Cl^- etc. was exchanged with OH^- ions. The anionic exchange rein used was strong base type. It is a strong base anion exchange resin based on polystyrene matrix, containing quaternary Ammonium group.

Wastewater treatment comprises of required treatment processes so that water can be treated to desired extent. Here literature review has been carried out to study the work done by renowned researchers in wastewater treatment.

2. LITERATURE REVIEW

Salvato J.A. *et al. (*2003) give details of septic type oil and grease traps which are used in practice. He gives details of oil and grease trap which of septic tank type style. A grease trap, interceptor or separator is a unit designed to remove grease and fat from kitchen wastewater. Liquid wastes leaving properly designed and maintained units should not cause clogging of pipes or have a harmful effect on the bacterial and settling action in a septic tank. There is also a natural tendency, if mixing is not too rapid, for the warmer liquid to rise and the cooler liquid, from which grease has been separated.

Picrova T. *et al.* (2009) include a sedimentation tank and oil and grease removal unit before placing a portable dual purposes water filter system. They use five layered filter after oil and grease trap. Researchers experimented on five layered laboratory scale filter by incorporating oil and grease trap before filter.

Rhee C. H. *et al.* (2008) summarises available technologies to remove oil and grease and should assist oil and grease dischargers in complying with their effluent limits. They discuss on various control technologies of oil and grease removal. The control techno1ogy for oil and grease removal varies in complexity, although the basic processes involve the collection and recovery of valuable oils and the removal of undesirable pollutants before discharge to a receiving system. The wastewater treatment systems operated in the oil processing wastewaters are often much larger and more complex than those found in other industries. These systems generally include gathering lines, junction boxes, collection basins and channels which transport wastewater from processing units to oil-water separators

Kommalapatti R.R. and Johnson R. (2001) take a review on evaluation of modern grease traps and high strength wastes. They study parameters used in the design of modern grease traps especially for onsite sewage facility of restaurants. While carrying out study they quote that oils and greases influence wastewater treatment systems if present in excessive amounts. They may interfere with aerobic and anerobic biological processes and lead to decreased wastewater treatment efficiency. When discharged in wastewater or treated effluents, they may cause surface films and shoreline deposits leading to environmental degradation.

Salvato J.A. *et al.* (2003) explains that filters are of the slow sand, rapid sand, or other granular media (including multimedia) and pressure (or vacuum) type. Each has application under various conditions. The primary purpose of filters is to remove suspended materials, although microbiological organisms and colour are also reduced. Of the filters mentioned, the slow sand filter is recommended for use at small communities, in developing areas, and in rural places, where adaptable. The sand should have an effective size of 0.25 to 0.35 mm.

Kikkawa I. (2007) carried out study on modification of a biosand filter in the northern region of Ghana. He gives stress on to test and evaluate an experimental modification of the LPD BSF for treatment of highly turbid water. Two unmodified local plastic design (LPD) BSFs and two modified LPD BSFs were constructed and operated in northern region, Ghana. The treatment efficacy of the modified and unmodified LPD BSFs was evaluated in the research.

Nancy A.B. *et al.* (2014) carry out their study aimed at the evaluation of the effect of sand bed depth on SSF performance by comparing data from sewage effluent filtered through sand beds of varying depths (0.5, 0.7 and 1.0) m. They conclude that sand bed depth had a significant effect on removal of physicochemical parameters but did not influence the removal of bacteria in filtered effluents significantly. Physicochemical parameters such as pH, B.O.D.$_5$, NO_3^-, NO_2^-, conductivity and T.S.S. are decreased significantly when sand bed depth is increased. However, reduction of PO_4^{-3} in filtered effluents is not significantly affected by sand bed depth.

Converse M.M. and Converse J.C. (2007) in their study describe the sand filters were found to reduce the concentration of T.S.S., B.O.D., and total nitrogen by 96%, 98%, and 37% from the septic tank based on the median values. The fecal coliforms showed a 4 - log reduction from the septic tank, with 76% of the samples having a fecal count of 200 col. /100 ml or less. The sand quality used for the sand filter was meeting or exceeding the recommended effective diameter 59% percent of the time. Twenty five percent of the time the sand fell within the recommended gradation with an additional 49% that were slightly coarser than the recommended gradation curve. There was not a significant difference in effluent quality between the coarse and the fine sand for this study. Since the average age of the systems was 14 months there are still some concerns about sites with finer sands producing a biomat and failing.

Collin C. (2009) carried out study on biosand filtration of high turbidity water which is modified filter design and safe filtrate storage. Recontamination of treated water is also a major concern and it is recommended that the biosand filter be used only as required and filtrate collected in a dedicated container with tight fitting lid and tap dispenser. Based on the results of the field and laboratory testing, recommendations for design of a biosand filter suitable for use with highly turbid water source and using materials locally available in Tamale were proposed. Safe storage methods for the filtrate have also been identified.

Kubare M. and Haarhoff J. (2010) in their study describes biosand filtration (BSF) unit is an intermittently operated slow sand filter designed for household use. Their work reviews the practical application of BSF, identifies the important design considerations and proposes a systematic design procedure. Guideline values for the filtration rate and the ratio of the pore volume to the water dosage volume are established and used as design checks. It is noted that the filtration rate is determined solely by the properties of the water temperature and the media-customary constraints posed by the bed area and the bed depth had been eliminated. Therefore the heart of BSF design lies in the careful and appropriate selection of the filter media.

Tansel B. (2008) studies new technologies for water and wastewater treatment: a survey of recent patents. In his study he takes overview of hybrid filtration systems and filtration cartridges. The recent patents applicable for water and wastewater treatment address improvements for ease of operation, reliability, cost, size, maintainability, improved water quality, and analytical methods. There are also patents that show applications of nano technology especially in the areas of disinfection, ion exchange, and detection methods.

With the increasing demand for drinking water and requirements for improved quality, more strict regulations for effluent discharge limits, and environmental awareness for water quality impacts, the research and development in water and wastewater technologies will increase in the coming years.

Campos L.C. (2002) carried out study on modelling and simulation of the biological and physical processes of slow sand filter. The model prepared provides operational behavior of slow sand filter. He prepared model which was calibrated and verified using data from full and pilot plant scale SSF. The model provides fundamental nature of SSF processes and could form the basis of an operational management system to optimise SSF.

Amini F. *et al.* (1994) carried out an experimental study of the optimal thickness of a sand layer in a sand filter water quality structure. Sand filter can be used to remove fine particles in water. While the water moves through the filter media, the fine particles in the water are trapped in the voids of the filter media. This process continues until the size of the voids has been reduced considerably. The water ceases to flow when all the porous spaces have been completely filled. When the flow rate reduces to a certain limit, the filter media needs to be replaced or the deposited particles needs to be removed from the filter media. Sediment particles trapped in sand filters may be cleaned by back-washing with clean water. For a sand filter in the field, back-washing is impractical because clean water is hardly accessible. As a result, the filter media of a sand filter needs to be replaced when the flow rate reaches its lower limit.

Clayton S. (2010) studied the impact of design and operating parameters on small scale slow sand filtration performance for household water treatment in developing countries. The filter built for this project was extremely successful at removing turbidity from the influent water at a variety of filtration rates. They did this with relatively little variation in terms of percentage removal, even when the filter media was reduced to half the original depth.

Way C. and Thomas T. (1994) in their research describes the findings and also examines how slow sand filtration could actually be incorporated in rainwater tank design. The very positive laboratory results certainly warrant further work into physical representation of the filter and system design. Indeed this is fundamental to making these very positive experimental results useful in a wider context. Filter size, construction and cost will all be crucial factors in making in tank slow sand filtration (SSF) a viable option for improving domestic rainwater quality. Work could also be done into filter material possibilities where graded sand is not an option. Investigation into other filter materials would include materials such as un-graded sand, rice husks or crushed coral which are known to be used as filter material around the world where graded sand is not available.

Shrivastav S.K. (1993) carried out pilot scale studies on colour removal from coloured ground water which is to be used for textile units. He studies the behavior of activated carbon filter for colour removal. Textile wet processing is hindered by coloured water. In his study he used sand filter and GAC column. He reports removal of colour at the outlet of GAC column unit.

Barakat M.A. (2010) carried out research on adsorption and photodegradation of procion yellow-EXL dyes in textile wastewater over TiO_2 suspension. The dyes removal percentage is inversely proportional to its concentration, the lower the dyes concentration, the higher the efficiency of dyes removal. The efficiency values of both adsorption and photocatalytic degradation processes reached maximum values of 46.4 and 100 %, respectively, with dyes concentration of 10 mg/l. The photocatalytic degradation of the investigated dyes exhibited pseudo first-order kinetics according to the Langmuir-Hinshelwood's heterogeneous catalytic model.

Ridder D.J. *et al.* (2009) studied development of a predictive model to determine micropollutant removal using granular activated carbon. Removal of negatively charged solutes by preloaded activated carbon was reduced while the removal of positively charged solutes was increased, compared with freshly regenerated activated carbon. Differences in charged solute removal by freshly regenerated activated carbon were small, indicating that charge interactions are an important mechanism in adsorption onto preloaded carbon. The predicted solute removal was within 20 removal- percentage deviation of experimentally measured values for most solutes.

Chen D.Z. *et al.* (2010) studied adsorption of methyl tert-butyl ether using granular activated carbon: Equilibrium and kinetic analysis. Results illustrate that granular activated carbon is an effective adsorbent for methyl tert-butyl ether (MTBE) and also provide specific guidance into adsorption of methyl tert-butyl ether on granular activated carbon in contaminated groundwater. The adsorption equilibrium and kinetics of MTBE onto GAC have been studied in the present work. The equilibrium data could be fitted by both the Langmuir isotherm model and the Freundlich isotherm model which reflect that GAC has good capacity adsorbing MTBE. The adsorption kinetic data have been respectively analysed by the Lagergren first-order model, the pseudo-second order model and the intraparticle diffusion model. The results indicate that the adsorption of MTBE onto GAC could be best described by the pseudo second- order model.

Sivakumar P. and Palanisamy P.N. (2008) carried out research on low-cost non-conventional activated carbon for the removal of reactive red 4 with kinetic and isotherm studies. The Langmuir adsorption capacity increases from 222.22 mg/g to 227.27 mg/g with increasing the temperature from 30 to 50°C. Langmuir model is more appropriate to explain the nature of adsorption with high correlation coefficient. The positive ΔH° value suggests that the adsorption is endothermic in nature.

Haarhoff, J. and Olivier J. (2006) studied GAC performance at three southern African water treatment plants. From their meta-analysis, a clear picture emerged of which water quality parameters were significantly improved by GAC, and to what extent. In his one of the finding they mention that the data obtained from the small pilot filters of 50 mm diameter at Rietvlei appeared to have produced data comparable with much larger pilot filters, indicating that smaller filters may be used with good effect if larger systems are beyond the reach of a specific location.

Van der Aa L.T.J. *et al.* (2004) carried out research on modelling biological activated carbon filtration: determination adsorption isotherms of organic compounds. Four DOC and UV254 isotherms were determined for natural water, ozonated water, biologically treated water and ozonated and biologically treated water. Ozonation resulted in a decrease of DOC adsorption capacity between 0 and 20%. Biodegradation resulted in a decrease of DOC adsorption capacity between 0 and 50%. The combination of ozonation and biodegradation resulted in a decrease of DOC adsorption capacity up to 30%. Biodegradation of the ozonated water resulted in 20% removal of organic matter. For the combination of ozonation and biodegradation the total effect of the reduction of adsorption capacity and removal of biodegradable organic matter was 44% reduction of solid phase concentration of organic matter on the activated carbon.

Pala A. and Tokat E. (2003) conducted experimentation on activated carbon addition to an activated sludge model reactor for colour removal from a cotton textile processing wastewater. Colour removal from cotton textile processing wastewater by addition of powdered activated carbon PAC into a lab scale activated sludge system was examined.

McDougall G.J. (1991) gives details of the physical nature and manufacture of activated carbon. In his conclusion he states that the main objective in the manufacture of granular activated carbon is the development of an optimum pore structure associated with a high surface area-with minimum loss of the carbon content through carbonisation and oxidation- and of a product with sufficient structural strength to withstand normal usage without excessive attrition of the particles. The manufacture of high quality activated carbon products is significantly more complex than has been outlined here because of the number of variables involved in the manufacturing process, and the complex interrelationship between those variables. When unsophisticated methods of manufacture are employed, each raw material tends to produce its own characteristic type of pore structure. Nevertheless, this natural tendency can be altered considerably by special treatment requiring considerable effort and know-how.

Marmagne, O. and Coste, C. (1996) studied colour removal from textile plant effluents. They found high rate of colour removal above 90% for cationic, mordant and acid dyes. In their study researchers discuss about powdered activated carbon and its colour removing action.

Fiore J. V. and Babineau R.A.(1977) are carried out study on effect of an activated carbon filter on the microbial quality of water. This study was conducted to investigate the effect of carbon filters on the microbial content of water. Results indicated that the microbial content of filtered and unfiltered water increased to about the same level on overnight standing and, in both cases, was reduced by flushing the next day. In addition, the use of activated carbon for the filtration of contaminated well water over a period of 11 weeks had no effect on the total or coliform count. Under use conditions, activated carbon filters were found to have no significant effect on the number of bacteria present in the water.

Rhys O.G. (1978) carried out research on adsorption on activated carbon as a solution on dye waste problem. Rhys discusses some advantages and limitations of carbon treatment. He quotes that GAC requires less space and can be reactivated without causing secondary pollution.

Sheng L. et al. (2009) in their work give details of an innovative treatment concept for future drinking water production as fluidized ion exchange-ultrafiltration-nanofiltration- granular activated carbon filtration. In research he states the combination of NF and GAC removed most of the micro-pollutants successfully, except for the very polar substances with a molecular weight lower than 100 Daltons.

McKay G. *et al.* (1980) experimented on kinetics of colour removal from effluent using activated carbon. He concludes that the rate of adsorption of disperse blue 7 on activated carbon has been found to vary with agitation, initial dye concentration, carbon particle size range and temperature of the dye solution.

Paul J. (2008) carried out research on removal of C.O.D. and colour from textile wastewater using limestone and activated carbon. The experimental data agreed with the pseudo-second-order kinetic model ($R2 > 0.96$). In upflow column, the experimental data showed that higher flowrate resulted in shorter column saturation time. Column studies conducted using mixture of limestone and activated carbon of 35:5 indicated over 80% removals of the C.O.D. and colour as proven in the batch studies. Lower flow rate resulted higher saturation time. The limestone and activated carbon mixture provides alternative medium for removing C.O.D. and colour at a much lower cost as compared with activated carbon.

Allen S. J. and Koumanova B. (2005) carried out review on decolourisation of water and wastewater using adsorption. In his review he states that adsorption processes are modeled using a variety of isotherm models, kinetic models and diffusion models.

Hambsch B. *et al.* (2007) conducted research to study incidence of faecal contaminations in chlorinated and non-chlorinated distribution systems of neighbouring European countries. If the water companies strive for high distribution system integrity, i.e. low water losses to reduce the danger of pressure losses and good quality management for repair work to reduce contamination during works in the distribution system, non-disinfected supply zones can be as safe as disinfected supply zones. This is especially an advantage if chlorine-resistant pathogens can be present in the respective raw waters.

Galal-Gorchev H. (1996) gives detailed information on chlorine in water disinfection. Chlorine, as well as other disinfectants, produces a variety of chemical by-products. The risk from the presence of microbial pathogens in drinking-water is estimated to be several orders of magnitude greater than the risk from chlorination by-products. Any efforts to control these by-products must not compromise the microbiological quality of drinking water.

Suslow T.V. (2001) in his study expressed water disinfection as a practical approach to calculating dose values for preharvest and postharvest applications. In his study he uses chlorine and hypochlorite (bleach) treatment. He describes ease of use and relative low cost make hypochlorite (usually liquid sodium hypochlorite) a very common water disinfectant in the produce industry. The antimicrobial activity of chlorine compounds depends largely on the amount of hypochlorous acid (HOCl) present in the water after the treatment is applied.

Le Chevallier M.W. and Kwok-Keung A. (2004) carried out study on water treatment and pathogen control process efficiency in achieving safe drinking water. In the executive summary of the report they state that for control of microbes within the distribution system, disinfectants must interact with bacteria growing in pipeline biofilms or contaminating the system. The mechanism of disinfection within the distribution system differs from that of primary treatment. Factors important in secondary disinfection include disinfectant stability and transport into biofilms, disinfectant type and residual, pipe material, corrosion and other engineering and operational parameters.

Pant A. and Mittal A. K. (2007) carried out research on disinfection of wastewater with comparative evaluation of chlorination and DHS-biotower. To achieve good disinfection, the contact time and dose are extremely important. A longer contact time is required for complete disinfection to occur. As per Lindsay (2004), a contact time of 30 minutes is a minimum, and if the dose remains constant, the contact time may necessitated to be increased at low temperatures or higher pH to obtain the same level of disinfection. Typical chlorine doses for municipal wastewater disinfection are about 5-20 mg/1 with a contact time of 30 to 60 min.

Ross W.R. (1976) conducted research on disinfection and chemical oxidation with ozone and chlorine in water reclamation. According to Ross the laboratory studies showed that there was little difference in the efficiency of chlorine and ozone for the disinfection of chlorine demand free water.

Raghu S. and Basha C.A. (2007) carried out study on chemical or electrochemical techniques, followed by ion exchange, for recycle of textile dye wastewater. Researchers have indicated that chemical or electrocoagulation treatment followed by ion-exchange methods were very effective and were capable of elevating quality of the treated wastewater effluent to the reuse standard of the textile industry.

Gaikwad R.W. (2010) discusses the methodology used to determine the optimal ion-exchange column size to process all separate batches of feeds from acid mine drainage wastewater. The optimal design ensures the best utilisation of resin material and therefore results in a minimum amount of spent resins. Ion exchanger materials have been studied for removing heavy metals from a metal bearing wastes. For the current treatment, a facility has been designed for the removal of heavy metals from the acid mine drainage (AMD) waste by the ion exchange technology. Both exchange columns used in study are of 50 mm diameter and 1000 mm height.

Cotrino C.R. *et al.* (2007) carried out research on removal of hydrogen sulfide from groundwater using packed-bed anion exchange technology. The major conclusion from his project is that packed bed anion exchange technology is effective for removing hydrogen sulfide from groundwater sources. Resin capacity is related to the concentration of exchangeable anions. Supplemental benefits of anion exchange include removal of TOC and sulfate and the reduction of chlorine demand. Other benefits of using packed bed anion exchange for hydrogen sulfide control include its ability to process groundwater without supplemental pumping or exposure to air and its amenability for use at wellhead treatment sites that are constrained by space limitations or encroachment of residential neighborhoods.

Meena R.C. *et al.* (2009) experimented on degradation of textile dyes ponceau-s and sudan iv using recently developed photocatalyst, immobilized resin Dowex-11. This study focused on the evaluation of Ponceau S, (S-IV)) removal by means of a novel photocatalytic reactor with thin-film of methylene blue immobilized resin dowex-11 prepared.

Pandya K. (1997) carried out study on ion exchange demineralisers for big problems with small solutions. Ion-exchange demineralisers are time tested proven tools to produce high quality water; however the demineraliser performance can deteriorate due to improper application of ion exchange resins, seasonal changes in the raw water analysis, extreme variation of flow rates, and wrong regeneration techniques.

Kirkiridis A. P. (1992) works on two stage decolourisation of refinery liquors by ion exchange resin. The second stage has now been operational for four years. Colour removals of around 70% are being obtained. He concludes that the second stage has now been operational for four years. Colour removals of around 70% are being obtained. This has allowed the refinery to meet consistently the EEC2 specification as intended.

Bahowick S. (1993) conducted research on ion exchange resin for removing hexavalent chromium from ground water at treatment facility with study on data on removal capacity, regeneration efficiency and operation. In his study he explains the treatment to influent ground water at 60 gpm with concentrations of hexavalent chromium averaging 30 ppb. The ion exchange system removes the hexavalent chromium to below its limit of detection (2 ppb). The resin used is a strongly basic type-I quaternary ammonium anion exchange resin with a styrene-divinylbenzene copolymer gel matrix.

Brown C.J *et al.* (2002) carried out research on a new ion exchange process for softening high T.D.S. produced water. In their study they explain the rationale for the process using ion exchange equilibrium calculations and then show pilot plant and field data. He concludes that use of a novel ion exchange process called Recoflo has made it possible to utilize either strong or weak acid cation resin to soften produced waters at T.D.S. levels up to 7000 mg/l to levels of residual hardness below 0.1 mg/l.

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