

Resource Optimization for Wastewater Management in Paint Manufacturing Plants: Case Study

Victor Msimango¹, *Paul A. Ozor^{1,2} and Charles Mbohwa¹

1. Department of Quality and Operations Management, Faculty of Engineering and the Built
Environment, University of Johannesburg, South Africa

victormsimango@gmail.com, pozor@uj.ac.za and cmbohwa@uj.ac.za

2. Department of Mechanical Engineering, Faculty of Engineering, University of Nigeria Nsukka

***Corresponding Author**

Abstract

Wastewater from paint manufacturing concerns can be very harmful to the ecosystem if not effectively managed. Discharge of such water into the environment can pose danger to plants and animals. In an attempt to combat the problem, an intensive study has been conducted in this paper to optimize the effectiveness of wastewater management, through exploration of alternative treatment resources. Data was sourced from an existing wastewater treatment plant of a Paint manufacturing Company at the Mpumalanga Province, East of South Africa. The plant is currently using lime as a coagulant and an electrolyte as a flocculent. Use of new Chemical reagents- Ferric chloride and Aluminum Chlorohydrate were investigated in the laboratory. Both of the reagents explored gave better results than what obtains with lime. While the existing and newly introduced reagents proved to be useful in controlling the wastewater, the Ammonium Chlorohydrate demonstrated stronger reduction capabilities in most of the wastewater indices tested.

Keywords: Wastewater, Management, Paint manufacturing, Resource Optimization, Effectiveness

1. Introduction

The study, investigate methodologies to conduct an optimization in the operations of existing wastewater treatment facilities in a paint manufacturing industry. Municipal Quality officers have several times discovered components of paint that has been discharged in municipal drains. This trend threatens human health and the entire ecosystem. The discharge of such wastewater into the environment impedes light penetration in water; which reduces Photosynthesis to aquatic vegetation. Contaminated water can generally be toxic to aquatic life and to the entire food chain of organisms. Humans can become victims while drinking or using unhealthy water in the attempt to accommodate the changing environment (Debnath, et al. 2006). The traces of mismanaged Paint wastewater detection in the ecosystem is an evidence that the existing technology still need to be reviewed and improved to the most optimum level as much as possible. Scientific methodologies had long been suggested in the wastewater treatment Industry. A number of paint production companies have inefficient wastewater treatment plants with a percentage of untreated effluent discharged in municipal drains. Blends of all the little percentages of the poisonous substances that are being discharged in rivers can result in bioaccumulation and splendid proportion of the entire water impurities (Dipark, 2017). The eventual consequence of the trend can be an outbreak of diseases, and Some Animal species becoming extinct in the ecosystem. Some of the diseases can be both strange, untraceable and chronic. The manufacturing sector has begun advancing prevailing processes by introducing substitute material that can replaced previous ones with a view to optimizing product quality. Activities of that nature is not out of place if properly applied to advancement of wastewater treatment techniques. Certainly, new products come with new problems, hence requires continuous improvement. Some processes in the manufacturing sector, especially pollutant discharges constitute threats to the ecosystem. As an interim response, the ISO 14001 and 2015 has to be obeyed by all manufacturing Industries, while research into the achievement of zero pollutant continues.

Studies on the strength of contamination that can result from Paint wastewater when discharged to parts of the environment, nearby water bodies in particular is available (Chidozie and Nwakamma, 2017). Wastewater can be characterized by various parameters, some of which include level of sulphates, suspended solids, Chemical Oxygen demand (COD), Biochemical Oxygen demand (BOD) and Phosphates. Paints are typically made of ingredients ranging from organic and inorganic pigments, extenders, thickeners, latexes, emulsifying agents, anti-foaming agents to preservatives, solvents and coalescing agents (Tesfalem and Hassen, 2017). Constitutive reagents applied in paint pigments manufacturing includes but not limited to heavy metals such as Lead, Zinc, Cadmium and Chromium (Ogilo, et al. 2017). This causes the wastewater from paint manufacturing plants to have high concentration of heavy metals such as copper, cadmium, lead, silver and chromium. Concentrations of these heavy metals differs per colour of the paint that is being manufactured. These heavy metals are toxic in nature, and can be serious triggers of environmental health challenges and diseases such as myocardium (heart disease), gastrointestinal symptoms, gauzier, Vomiting etc. The adverse effects to plants cannot be overstressed. Irrigation activities can be hampered by effluents from paint. There is also the possibility of wastewater hazardous substances being absorbed by plants and transferred to animals and humans alike, as they eat the plants as part of food source. Unwholesome wastewater can equally run into safe drinking and usable water resources in the environment causing further health threats to end users (humans, plants and aquatic animals). This chain of infection from one organism to the other along the food chain is called bio-magnification. The bio-magnification will, result in health problems to human beings, since they are on top of the food chain. The discharge of such wastewater into rivers may also impede light penetration in water; which reduces Photosynthesis to aquatic vegetation and may also contaminate the land. This study investigates methodologies for Quality improvement of the paint wastewater, with particular emphasis on the paint factory located at Mpumalanga Province.

2. Instruments and Importance

The following instruments were used in the study. The PH meter was employed to quantity the amount of alkalinity and Acidity of the wastewater upon harvesting with a special container. The container was carefully washed and dried to ensure that the contents does not interfere with the results of the PH meter. PH scale ranges between zero and fourteen (0-14). While zero to six represents decreasing order of acidity, eight to fourteen shows increasing order of alkalinity. Seven means neutral. Figure 1 shows a typical PH Scale. The make and Model used was PC 700 and Eutech instruments respectively. It has two Probes; one measure PH, the other probe measures conductivity in Micro Siemens and total dissolved solvents in the same SI Units.

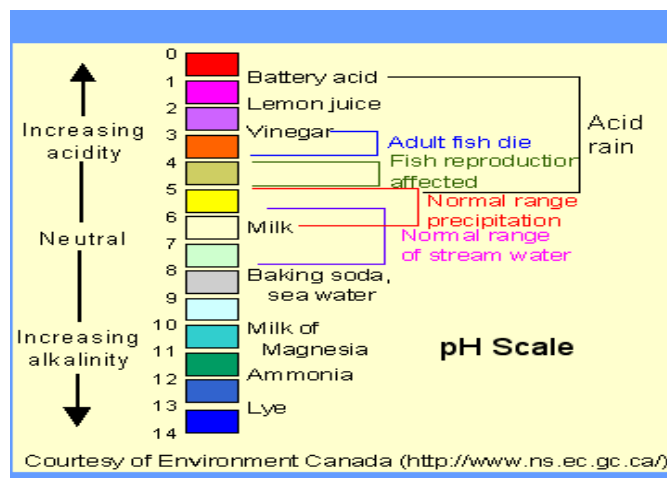


Figure 1. PH Meter

The device used to test for appropriate Flocculants and coagulants during the laboratory analysis of the wastewater is called fluctuation tester. In the procedure, flocculants and coagulants are allowed to interact with water sample. It has six stirrer blades that can agitate six samples in six Glass beakers at a time. The particular type made by Velp Scientifica with model JLT6 was used for the study. The device has back lights that shine through the sample from behind the sample. This allows tiny flocs that form in the water sample to be viewed seamlessly. The blades can rotate up to the speed of three hundred revolutions per minute (300rpm). Turbidity was one of the indices measured in the

collected wastewater. For the purpose of identifying appropriate levels of Turbidity, a 2100P Turbidity meter model manufactured by Hatch was used. The apparatus measure the definite degrees of water cloudiness and clarity. It uses the principles of refraction of light ray. Different clarities and colours of water have different refracted angles and wavelengths. The instrument interprets the combination in Nephelometric turbidity units (NTU). Turbidity is inversely proportional to water clarity. When turbidity value becomes higher it means that water is dirtier.

There is also the COD and BOD reactor used to digest samples for the purpose of reading COD in the spectrophotometer. It can digest samples at 150⁰ Celsius in approximately two hours. Some COD reagent test tubes are normally fitted into the small slots in the periphery of the reactor. Once switched on, it has an option to select either COD or BOD, depending on which quantity is being tested. Any of these parameters once selected the Reactor will heat at the required temperature for the required time. The model used for this study is HACH DRB 200. The magnetic Stirrer is a Laboratory device that can agitate and heat liquids within desired scale. It has a potentiometer that can run up to 8 speed. It also has an analogue temperature controller to raise or drop temperature according to the liquids requirement. The device is used to achieve uniform distribution of reagents during the experiment such that the readings obtained at any stream is a true representative of the entire mixture. Some Chemical substances can be trapped in samples within or outside the regime of what usually obtain for paints. A spectrophotometer was employed to detect any presence and also to measure concentration of Chemical substances in the samples. The device compares wavelengths of different lights. It uses chemical reagents that turn to predetermined colour, as soon as they react with the chemical substance that is being tested in a sample. In particular, it measures concentration of Chemical substances in water by an intensity of output light rays resulting from colour change of solution. Good spectrometers can provide data over a range of visible wavelengths and allow the absorbance of a solution at a particular frequency of visible light. When it passes light through the sample, the sample colour will have an effect on the light intensity and wave length. The device then interpret the output light in concentration of the chemical substance in part per millions. A HACH DR 3900 Spectrophotometer model was used during the analysis of the paint factory wastewater. It is accompanied by small reagents sachets that result colour change of solution as they react with different substances that are being tested in the water sample.

3. Methodology

Three sets of wastewater samples were randomly sampled three times a day from the case study waste water treatment plant. The factory is located at Middleburg, Mpumalanga, East of South Africa. Five liters of sample were sampled per time in a five liter Container and decanted into a 25 Liter container to make up an overall composite sample of fifteen liters a day, for both inlet and outlet sample. The samples were continuously collected for a week. The sampling technique adopted, was a virtual reality of the overall population in the waste water treatment plant at any given time of a day. The samples collected were then taken to a laboratory for analysis. A Qualitative analysis was carried out by mixing the sample in a magnetic stirrer until a homogenous mixture is obtained. The samples were then transferred into six glass beakers of 500 mL Volume. PH, conductivity and TSS were tested using PH and Conductivity meters. The six samples were put into a flocculation tester. Solutions of 1 mg/L concentrations were prepared for Aluminum Chlorohydrate, Ferric Chloride and Poly Amide Polymer. 0.5mL of each of the three reagents was taken using a Syringe and was added in 500mL containers. The beakers were then filled with water to a 500mL mark of each container. Magnets were then immersed into each of the mixtures and placed on a magnetic stirrer and stirred until completely mixed. Every 0.5mL of this solution made up a 1mg/L concentration when added into the 500mL wastewater sample.

3.1 Chemical Flocculation and Coagulation

The Chemicals ; Aluminum Chlorohydrate, Ferric Chloride, and the Poly Amide Polymer that had been prepared according to the above mentioned procedure were then dosed into the waste water in the Six 500mL glass beakers in the Flocc tester according to the following; 0.5 mL of the prepared Aluminum Chlorohydrate solution was added in a waste water sample. Every 0.5mL of the 0.1% solution makes up 1mg/L when added in the sample. Concentration was increased in the next beaker to 2mg/L, and 3mg/L to the next beaker. The Concentrations of the coagulant was increased until Floccs were formed. Aluminum Chlorohydrate started forming Floccs at 5mg/liter. Concentrations were then increased in multiples of five (5). Accordingly, 5mg/L of Poly Amide Polymer was added to grow the floccs bigger, once they had formed. The Floccs were allowed to settle at the bottom of each sample. The wastewater sample

became clearer as the coagulant concentration increased. The same procedure is repeated with Ferric Chloride. Although, it was observed that Ferric Chloride needed higher concentrations for flocs to start forming.

3.2 Nitrate and Phosphates Test

A 10ml sample vial made of glass was filled with the effluent sample. Nitraver 5 was added in the sample vial and shook vigorously. Another 10 ml sample was added in another sample vial, but no Chemical reagent was added in the second vial. This was used as a blank sample to zero the spectrophotometer. A nitraver reagent is made of Cadmium and Gentisc Acid. The sample colour changed into yellowish brown. The chemical reaction was allowed to take place for three minutes as instructed by the manufacturer's operating manual. As stated earlier, the model used was Spectrophotometer DR3900. A nitrate program was selected. The instrument was zeroed with the Blank sample. The 10ml sample with Nitraver 5 was put in the sample slot of the instrument, and was run. A reading was displayed on the screen in part per millions (ppm). Phosphates were tested in the same procedure as the Nitrates. For the starting, 10ml sample was added in a sample vial of 10ml volume. A phosphosver 3 reagent was added in the water sample and mixture was vigorously shaken to dissolve the reagent. Phosphosver 3 is made of Potassium molybdate, and Potassium pyrophosphate. The sample colour changed upon addition of the reagent. The Chemical reaction was allowed to take place for four minutes. A phosphate program was selected on the spectrophotometer. The instrument was zeroed with a Blank sample, then the Sample with the Phosphover 3 reagent was inserted in the sample slot and the instrument put in a run mode. A reading was displayed on the screen in part per millions (ppm).

3.4 Sulphates

A 10ml sample vial made of glass was filled with the effluent sample. Sulfaver 5 was added in the sample vial and shook vigorously. Another 10 ml sample was added in another sample vial, but no Chemical reagent was added in the second vial. This was used as a Blank sample to zero the spectrophotometer. The sample turned slightly milky. The chemical reaction was allowed to take place for four minutes as instructed by the manufacturer's operating manual. A Spectrophotometer; DR3900 was used as an analysis instrument. A sulphate program was selected. The instrument was zeroed with the Blank sample. The 10ml sample with Sulfaver 5 was added in the sample slot of the instrument, and was run. Readings was displayed on the screen in part per millions (ppm)

3.4 Total Suspended Solids and COD

Suspended solids were analysed using the spectrophotometer model DR3900. A 10ml sample of deionized water was prepared. The instrument was blanked in line with the earlier mentioned blanking procedure on the Phosphates-Section 3.2. Subsequently, 10ml of waste water sample was then added in another 10ml vial. A suspended solids program was selected. The blank sample was put in the sample slot of the device. The device was zeroed, then as sample was slot in the device and the device was set in to run mode. The suspended solids readings were displayed on the screen in ppm. In the COD analysis, 2ml de-ionised water was added in the high range COD reagents using a 2ml pipet and vigorously shook. This was to be used as a blank. Later, a 2ml sample of the wastewater was added in another COD reagent and vigorously shook. It was observed that the sample turned green at this stage. The result meant that further dilution was required. The sample was diluted into a ratio of one is to ten to obtain a better result. The COD reagents are made of Sulphuric Acid. The mixture was then digested in a COD reactor at 150⁰Celcius for two hours. The samples were taken off the reactor after two hours and allowed to cool to room temperature. COD was finally analysed using a spectrophotometer DR3900.

4. Results and Discussion

The Chemicals; Aluminum Chloro hydrate and Ferric Chloride were used as Coagulants in the study and Poly amide polymer was used as a Flocculent. The two Chemical reagents gave two positive results but in two different criteria. This is an indication that both Chemical reagents can be used in two different applications. That is; the reagents can be applied in two different water treatment techniques. Table 1 and Table 2 present the various components of the raw and Outlet effluent sample while what obtains in the treated samples using different reagents in the Laboratory is shown in Table 3 and Table 4.

Table 1: Raw and Outlet Effluent constituents

Effluent	Raw	Outlet
Turbidity (NTU)	2070	754
Phosphates (ppm)	94.11	41.09
COD (ppm)	3844	1303
TSS (ppm)	1464	592

Table 2: Raw and Outlet Effluent constituents

Effluent	Raw	Outlet
PH	7.81	6.89
Turbidity (NTU)	2070	40
Phosphates (ppm)	95.05	82.69
Nitrates	286.3	971
COD (ppm)	1826	111.2
TSS (ppm)	3020	2934
PH	946.096	971

Table 3: Effluent interactions with Aluminum Chlorohydrate

Aluminum Chlorohydrate (ppm)	Turbidity (NTU)	Phosphates (ppm)	COD (ppm)	TSS (ppm)
Raw	2070	94.11	3844	1464
5	234	23.97	613	182
10	18.8	5.64	270	2
15	9.52	4.01	300	0
20	7.13	1.94	254	0
25	24.8	2.47	238	5

Table 4: Effluent interactions with Ferric Chloride during Laboratory Test

Ferric Chloride (ppm)	PH	Turbidity (NTU)	Phosphates (ppm)	Nitrates (ppm)	COD (ppm)	TSS (ppm)
40	7.31	620	65.74	149.4	1319	391
50	7.24	344	23.75	57.9	821	236
60	7.18	243	15.74	55.2	844	227
70	6.88	385	1.85	7.1	268	23
80	6.8	32.8	1.67	5.4	248	18
90	6.63	6.77	1.51	3.6	230	5
100	6.79	9.96	1.76	4.6	244	0
110	6.19	4.95	1.32	3.2	216	0
120	5.95	6.64	1.32	3.7	251	3

4.1. Phosphates

The amount of Phosphates decreased with increasing concentration of coagulants. Both Aluminum Chlorohydrate and Ferric Chloride proved to be effective in the Phosphate removal. Phosphates are dissolved in water and can be removed by precipitation reaction. It takes place in a form of exchange reaction, where the phosphates react with the metal in coagulant forming metal phosphate, irrespective of whether it is Aluminum or Iron (Nur et al, 2014).



Li et al (2005) had noted that the same reaction can occur in the same manner with Ferric Chloride. The metal part of the coagulant reacts with the phosphate to form Iron phosphate, though other useful paint coating agents can precipitate. In the case of this study, the phosphates came in a form of Manganese Phosphate, zinc phosphate, and Iron Phosphate which are active ingredients for Base and Corrosion resistant Coating. In Fresh water, Phosphate usually derive from soil erosion and rock weathering in streams and lakes. When the concentration becomes significant in such natural water resources (rivers and lakes), it can lead to Eutrophication (Carpenter et al, 2005). Humans are not immune to the adverse effects of Phosphates, as it is a key factor when considering the causes of Cardio vascular diseases and kidney failure (Kendrick, et al., 2011). When the Phosphates in Paint wastewater are not brought to needed management and control, there can be a possibility of Bone and Liver diseases, if it is eventually picked up by humans using any of the processes already discussed (Das et al., 2015). The revelation that the two reagents tested in this study can reduce Phosphates to the barest minimum is both interesting and significant to the Managers of Paint manufacturing Industries. Figure 2 presents the interaction between Ammonium Chlorohydrate coagulant and Phosphate removal, while that of Ferric Chloride coagulant and Phosphate is displayed in figure 3.

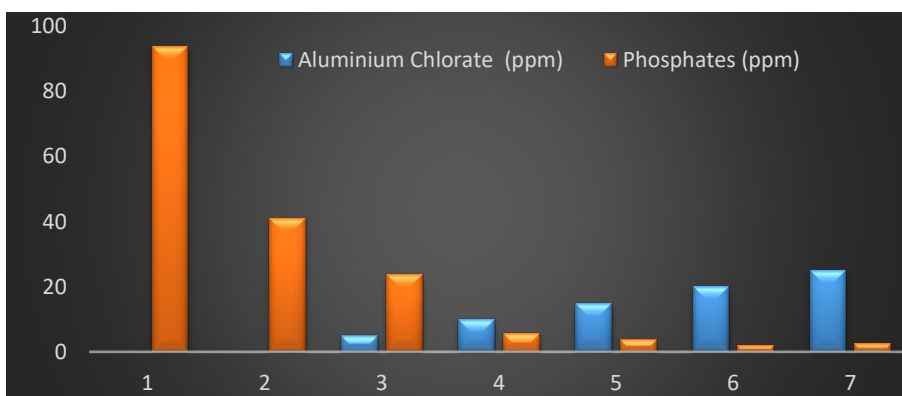


Figure 2. Phosphates versus Aluminum Chlorohydrate coagulant

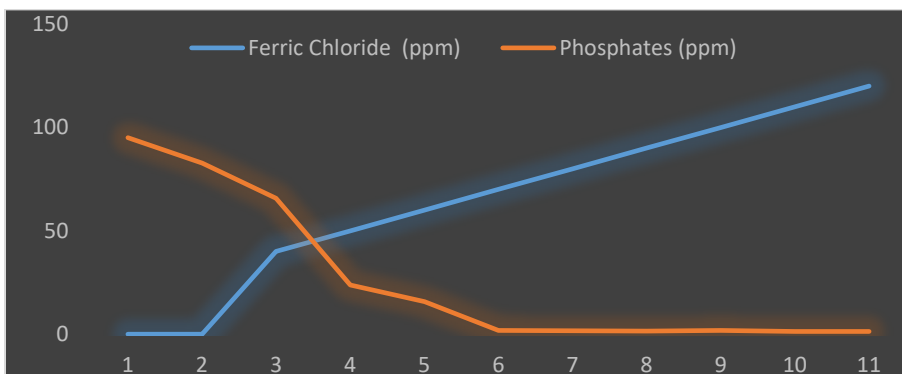
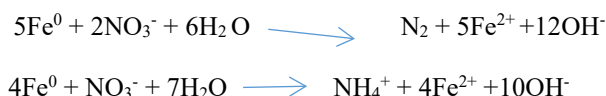


Figure 3. Phosphates versus Ferric Chloride coagulant

4.2 Nitrates

The In-si-tu wastewater treatment apparatus of the Paint plant removed only about 20.95% of Nitrates. That is; Nitrates concentrates decreased from 286.3ppm to 226.3ppm after the treatment provided by the Plant wastewater treatment resources. It was this 226.3ppm Nitrates wastewater that was harvested for this study for experimental treatment in the laboratory. The application of the tested reagents was found to reduce Nitrates concentration drastically. The 226.3ppm Nitrates wastewater reduced to Nitrates concentration of 3.2ppm in the Laboratory. The basic observation was that the Nitrates Concentration needed an increased coagulants concentration to decrease. The Ferric Chloride, and the new process proved to be more effective in Nitrates removal than the subsisting coagulant used in wastewater treatment by the Plant Management. A similar behaviour as in the case of phosphates is evident. It is good to recall that both phosphates and Nitrates present almost the same shape of graphs. The de-nitrification procedure can actually be implemented in two basic steps according to the following chemical dependence (Shahid et al 2014):



Past researcher (Carpenter, 2005) has identified the need for zero Nitrates concentration in the ecosystem. The author maintains that Nitrates can deplete blood Oxygen concentration with a possibility of raising infant mortality and birth defects (Fewtrell et al., 2004). The presentations report that Adults can equally contact discomforting disease like hypertension, diabetes, respiratory tract infections, and changes to the immune system through Nitrates contamination. Figure 4 shows the Nitrates removal capabilities of the Ferric Chloride Coagulant while that of the relationship with Turbidity is shown in Figure 5.

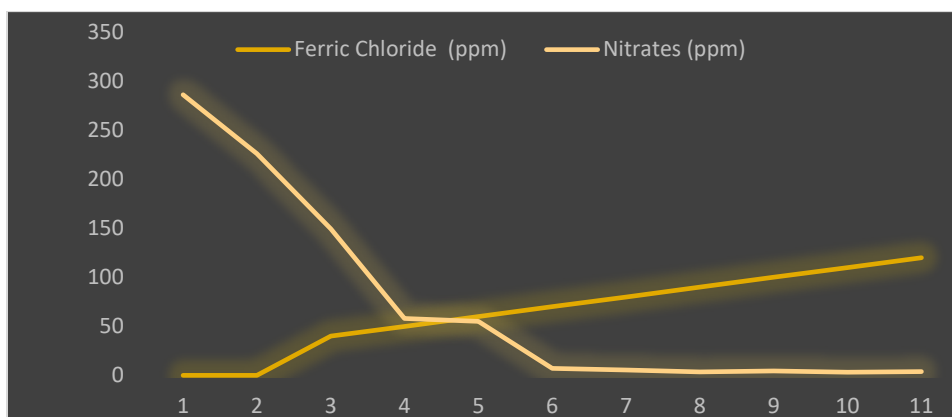


Figure 4. Nitrates versus Ferric Chloride coagulant

4.3 Turbidity

Turbidity is the measure of the degree of clarity of wastewater. High turbidity indicate a high degree of cloudiness of water or fluid. It is caused by suspended solids and colloidal particles in the water. Turbidity curves are partly similar to suspended solid curves, partly because the later are part of turbidity. This has been witnessed by Hydrological methodologies invented by hydrologists to monitor soil erosion. The downstream turbidity is usually monitored, so as to quantify the amount of soil that is being eroded (Kinyua et al., 2015). When the forces of attraction between the particles of an aggregate is destabilized, the rate of agglomeration can be decreased. This is what obtains in the process of removal of colloidal particles by means of flocculation. Figure 5 and Figure 6 clearly delineates that Ferric Chloride and Ammonium Chlorohydrate are good reagents for destabilizing the conglomeration of wastewater particles. In the case of Ferric Chloride, slightly increasing the coagulant lead to rapid decrease in turbidity. It should however be noted that the extent to which this results holds true must be carefully determined. The excessive input of reagent can be a costly exercise when the decrement in turbidity is no longer justified as in the case of Figure 5. Also, the addition of Ammonium Chlorohydrate can be unwarranted whenever the decrement in turbidity is no longer significant. It is represented by the region when the reagent-turbidity lines becomes asymptotic to each other in Figure 6. Not observing this trend can lead to loss of save-able expenses to the Management.

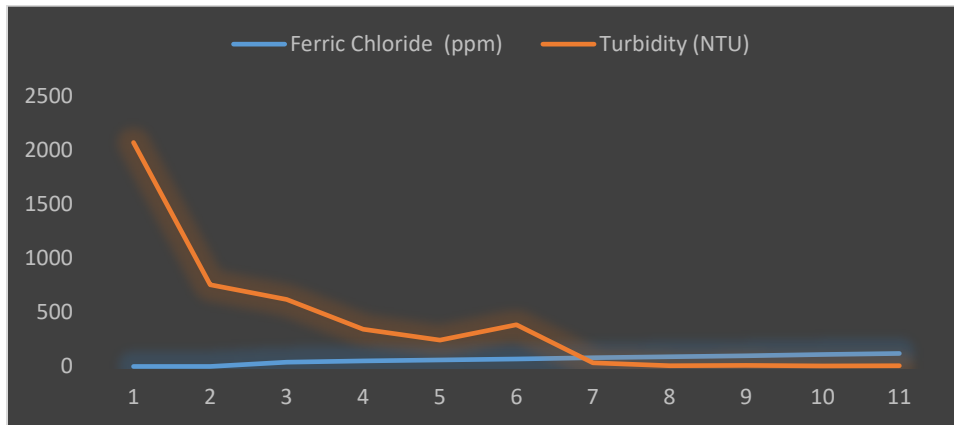


Figure 5. Turbidity versus Ferric Chloride coagulant

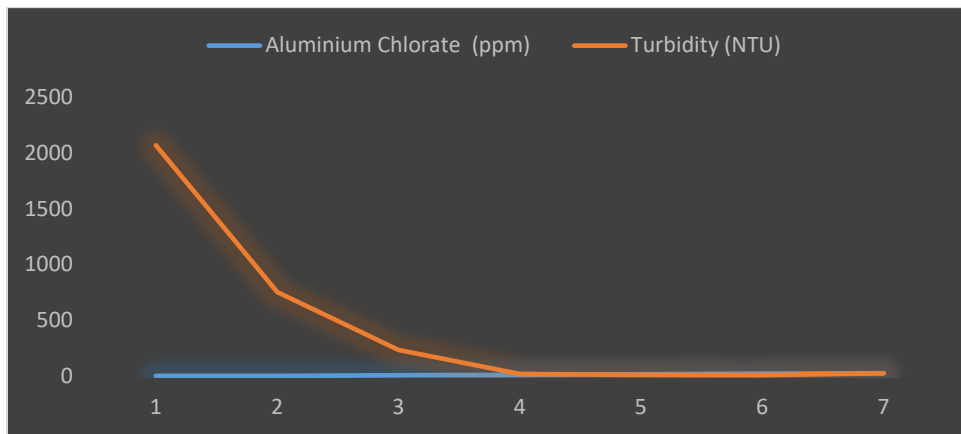


Figure 6. Turbidity versus Aluminum Chlorohydrate coagulant

4.4 Total Suspended Solids

The waste water treatment facilities of the paint manufacturing company was able to decrease the total suspended solids in a virgin sample from 1464ppm to 592ppm. The 592ppm of wastewater was then taken to a laboratory and further treated with Aluminum chlorohydrate and Ferric Chloride in turn. The experimental investigations was able to reduce the TSS to 5ppm. This implies that the treatment capacity has been optimised. Total suspended solids are the major cause for turbidity. They displace the water clarity by obstruction of light rays in the water. Water clarity improves as the suspended solids decreases in the water sample. The relationship between TSS and turbidity is directly proportional. Shapes of the graphs are similar, this proves that they occur at similar trends. The lowest TSS of Zero gave the lowest turbidity of 4.95 for ferric chloride and 7.13 for Aluminum chlorohydrate. TSS has serious negative impact in the ecosystem and must be reduced as much as possible. Suspended solids have a tendency to clog in fish gills, resulting into death or serious health problems. The evident health issues include low growth rate, respiration problems and delayed egg hatching in poultry (Capper, 2006). The process of Photosynthesis in plants which is very essential for the production of Oxygen needed by animals (humans inclusive) can be hindered to a considerable extent by suspended solid deposits. Increased suspended solids in water can hinder normal processes in aquatic flora. Figures 7 and 8 present the relationship of TSS with Ammonium Chlorohydrate and Ferric Nitrate respectively.

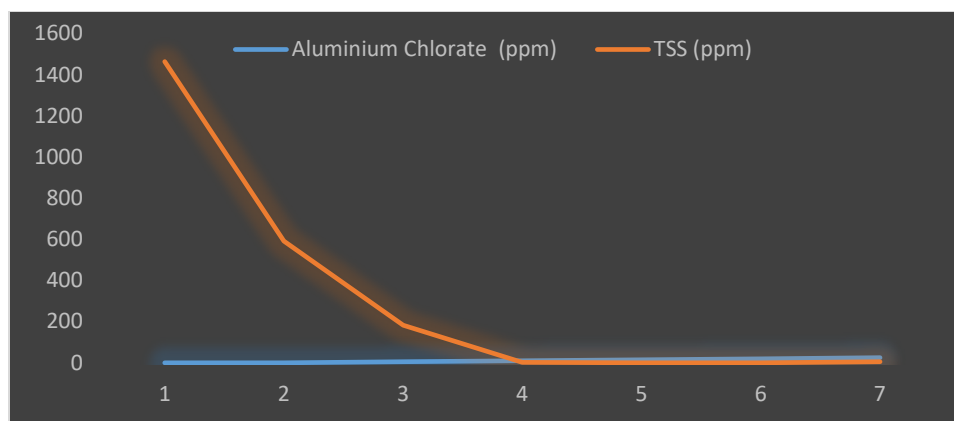


Figure 7. TSS versus Aluminum Chlorohydrate coagulant

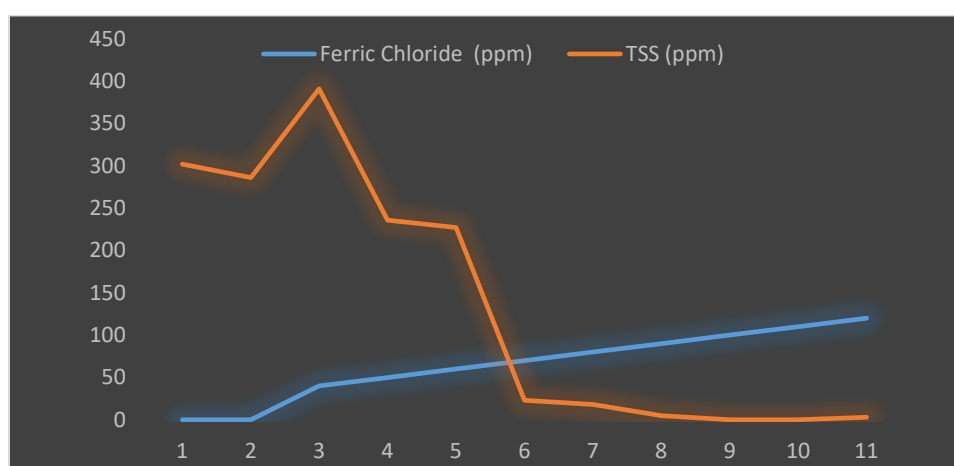


Figure 8. TSS versus Ferric Chloride coagulant

4.5 Chemical Oxygen Demand

As displayed in figure 9, the COD decreases as the Ammonium Chlorohydrate is increases. COD maintained a constant decrease until it is almost completely removed from the mixture. This is close to the trend obtained for TSS, probably due to the existence of somewhat relationship between the two. In particular, the COD depends on the suspended solids and other substances dissolved in wastewater. Thus, removal of suspended solids to some degree, decreases the COD index. The COD is inversely proportional to the coagulant concentration. COD decreases as flocc concentration increases in the water until the saturation point. The coagulants and flocculants become pollutants when they exceed the required levels. The coagulant and the waste water should not exceed the stoichiometric balance in order to achieve the lowest COD. With the Ferric Chloride, the decrease in COD is maintained. However, this is achieved by adding considerable amount of the coagulant. See Figure 9. It is evident that no amount of the coagulant can completely remove the entire COD. It is therefore better to use Ammonium Chlorohydrate for COD removal, in line with the results of the study.

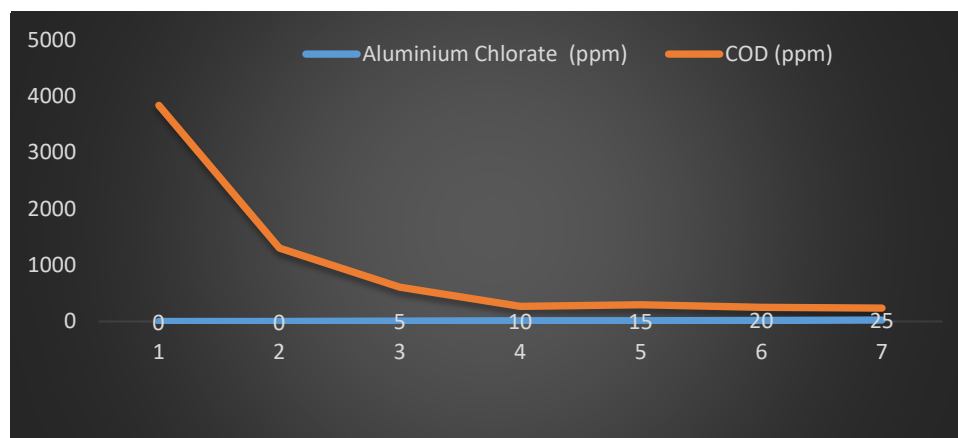


Figure 8. Refractive index versus Aluminum Chlorohydrate coagulant

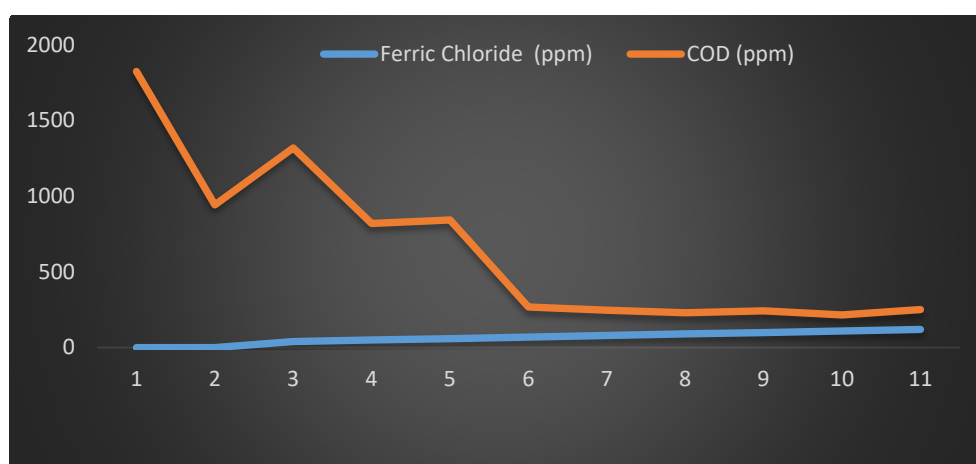


Figure 9. COD versus Ferric Chloride coagulant

Conclusion

This study has satisfied the cleavage of presenting possible resource optimization for wastewater management in paint manufacturing plants. An illustrative example case of a Paint manufacturing Plant located at Mpumalanga Province, East of South Africa have been set. The results of experimental investigation were displayed in clear figures to remove any form of ambiguity. The Aluminum chloride dosage was 25ppm, and the Ferric Chloride dosage was 120ppm. Ferric Chloride can work efficiently on a Batch process and may require two settling tanks because its flocs settle a bit slower than the Aluminum Chlorohydrate, while Aluminum Chlorohydrate can work in a continuous process and may require one settling tank because it generate flocs settle very fast. The overall quality of wastewater from the treatment plant can be optimised using the procedure described in this paper. The methodologies followed during the research can be implemented in wastewater treatment facilities of other spheres. However, we recommend that a settling tank can be installed for evacuation of the resulting flocs.

Acknowledgement

The material and financial assistance of the NRF-TWAS fellowship: Award number PD-TWAS160531166951; UID: 105554, towards this research are hereby acknowledged. However, opinions expressed and conclusions arrived at, are those of the authors and are not necessarily to be attributed to the NRF-TWAS.

References

- Capper, N. (2006) The Effects of Suspended Sediment on the Aquatic Organisms *Daphnia magna* and *Pimephales Promelas*; All Theses, Paper 2, Clemson University, Clemson, USA, Tiger Prints
- Carpenter, S.R. (2005), Eutrophication of Aquatic Ecosystems: Bistability and Soil Phosphorus, *Proceedings of National Academy of Science, U S A.*, Jul 19, 102 (29), pp. 10002-5
- Chidozie K, Nwakanma, C. (2017) Assessment of Saclux Paint Industrial Effluents on Nkoho River in Abia State, Nigeria, *Journal of Ecosystem and Ecography*, 7, (2), Available online, Doi:10.4172/2157-7625.1000240
- Das, R.N., Mukherjee, S. and Sharma, I. (2015), Liver Enzymes and Bone Mineral Density in the General Population, *The Journal of Clinical Endocrinology and Metabolism*, 100, pp. 3832–3840
- Debnath NC and Vaidya, S. A. (2006) Application of X-ray diffraction technique for characterization of pigments and control of paints quality, *Progress Organic Coatings*, 52 (2-3), pp 159-168
- Dipak, P. (2017), Research on heavy metal pollution of river Ganga, *Annals of Agrarian Science*, 15, pp. 278-286
- Fewtrell, L. (2004), Drinking-Water Nitrate, Methemoglobinemia and Global Burden of Disease, *Environmental Health Perspective*, 112, (14), pp. 1371 – 1374
- Gippel, C. J. (1996), Potential of turbidity monitoring for measuring the transport of suspended solids in streams, *Hydrological Processes*, 9, pp. 83 - 97
- Kendrick, J., Kestenbaum, B. and Chonchol, M. (2011), Phosphate and Cardiovascular Disease, *Advances in Chronic Kidney Diseases*, 18, (2), pp. 113 - 119
- Kinyua, E.M., Mwangi, I.W., Wanjau, R.N. and Ngila, J.C. (2015), Clarification of Colloidal and Suspended Material in Water Using Triethanolamine Modified Maize Tassels, *Environmental Science and Pollution Research*, Available online, DOI 10.1007/s11356-015-5766-y
- Li G.Y., Lian J.S., Niu L.Y., and Jiang Z.H. (2005), A Zinc and Manganese Coating on Automobile Iron Castings; China: ISIJ International, 45, (9), pp. 1326 - 1330
- Mohsenipour, M, Shahid, S, Ebrahimi .K (2014), Removal Techniques of Nitrates from Water, *Asian Journal of Chemistry*, 26, (23), 7881-7886
- Nur, T., Johir, A. H., Loganathan, P. Nguyen, T. Vigneswaran, S. and Kandasamy J. (2014) Phosphate Removal from Water Using an Iron Oxide Impregnated Strong Base Anion Exchange Resin, *Journal of Industrial and Engineering Chemistry*, 20, (4), pp.1301-1307
- Ogilo J.K., Onditi A.O., Salim, A.M and Yusuf, A.O. (2017), Assessment of Levels of Heavy Metals in Paints from Interior Walls and Indoor Dust from Residential Houses in Nairobi City County, Kenya, *Chemical Science International Journal*, 21, (1), pp. 1-7
- Tesfalem, B. W. and Hassen, A.S. (2017), Toxicity Study of Heavy Metals Pollutants and Physico-Chemical Characterization of Effluents Collected from Different Paint Industries in Addis Ababa Ethiopia, *Journal of Forensic Sciences and Criminal investigation*, 5, (5), pp. 001-006

Biographies

Victor Msimango is currently a postgraduate student with the Department of Quality and Operations Department of University of Johannesburg, South Africa. He holds a Bachelor of Technology in Quality Management and practices with a Wastewater management Company.

Dr Paul A. Ozor obtained a bachelor's degree (B.Engr) in Mechanical/Production Engineering at Enugu State University of Science and Technology, Nigeria. He worked as project manager with an Engineering Company before proceeding to Department of Mechanical Engineering, University of Nigeria Nsukka (UNN) for higher studies, and specialized in Industrial Engineering and Operations Management. He obtained both Masters and PhD degrees in 2008 and 2015 respectively from UNN. He has been a teaching and research staff of UNN for over a decade. He is a Professional Member of Nigeria Society of Engineers. Dr Ozor is currently a TWAS-NRF research fellow to University of Johannesburg, South Africa, and had been awarded the Association of Common Wealth Universities' (ACU) early career scholarship in 2014. His research interests include Industrial Operations modelling, Quality management, Systems Analysis, Reliability Engineering, with special emphasis on System Sustainability, Failure mode effects and criticality analysis (FMECA), Safety and Risk assessment (SRA) as well as Environmental influence modelling, including Waste Management, Water and Energy nexus.

Professor Charles Mbohwa is the Ag, Executive Dean of Faculty of Engineering and the Built Environment, University of Johannesburg. He obtained B. Sc. Honours in Mechanical Engineering in 1986 from Department of Mechanical Engineering, University of Zimbabwe, Harare, Zimbabwe. He later bagged M. Sc. in Operations Management and Manufacturing Systems in 1992, with a distinction from Department of Manufacturing Systems Engineering, University of Nottingham, UK. He obtained PhD in Engineering (Production Systems focusing on Energy and life cycle assessment) from Tokyo Metropolitan Institute of Technology, Tokyo, Japan in 2004. Professor Mbohwa is an NRF-rated established researcher. In January 2012 he was confirmed as an established researcher making significant contribution to the developing fields of sustainability and life cycle assessment. In addition, he has produced high quality body of research work on Southern Africa. He is an active member of the United Nations Environment Programme/Society of Environmental and Toxicology and Chemistry Life Cycle Initiative, where he has served on many taskforce teams.