

Removal of Triazine by Coagulation and Chlorination Processes

Syafiqah Sunan^{1,a*}, Azmi Aris^{1,b}

¹Faculty of Civil Engineering, Universiti Teknologi Malaysia, Malaysia

^{a*}syafiqah7@live.utm.my, ^bazmi.aris@utm.my

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Abstract: In recent years, concerns over the environmental risks of the so called “New Emerging Pollutants (NEPs)” begin to increase. Advanced treatments which used higher technologies are proven to be effective in removing NEPs. However, higher cost of the treatments lead to difficulties to be applied in developing countries like Malaysia. A study is needed in order to determine the capability of conventional water treatment processes to remove those NEPs. Hence, an investigation on the ability of coagulation and chlorination processes to remove triazine was conducted. Water from Sungai UTM (in front of M46) was used as samples to be treated using coagulation process, while distilled water was used for chlorination process. Triazine of 50 µg/L was spiked to both water samples prior to the treatment. The triazine in the raw and treated water were extracted using Solid Phase Extraction (SPE) and then injected into Gas Chromatography System (GCMS) for the analyses. Based on the GCMS results, coagulation can only removed the triazine up to 29.6%, while chlorination can removed up to 32.1%. The removal was found to be affected by the dosage of the coagulant and chlorine, pH and chlorine contact time.

Introduction

In recent years, there have been increasing concerns over the environmental risks of the so called “*New Emerging Pollutants (NEPs)*”. These concerns are reflected by a rapid increase in the numbers of scientific publications exploring the environmental impacts of NEPs over the past decade. Alongside the monitoring studies, NEPs have indicated to pose a small risk to human and environmental health. Although few studies have been able to detect a very low concentration of these chemicals in the natural and drinking waters, the chemicals may trigger risks towards ecosystem [1]. There are needs for further investigations to remove these pollutants from our water resources. Although advanced treatments such as ozonation and membrane separation have been proven in removing NEPs, they are too expensive to be applied in developing countries like Malaysia.

A study is therefore needed to determine the capability of conventional water treatment processes in removing the NEPs. This study investigated the removal of an NEP, ie. triazine by using coagulation and chlorination treatment processes. The objectives of this study are to determine the optimum dosage of alum and pH of water for coagulation process and to determine the optimum dosage of chlorine, the pH and contact time for chlorination process in removing the triazine.

This study was conducted using lab-scale apparatus. Two different experiments were conducted to test for coagulation and chlorination separately. Water from Sungai UTM (in front of M46) was used as water source in testing coagulation treatment method while distilled water was used for chlorination. The coagulant used was aluminium sulfate while sodium hypochlorite was used as the disinfectant.

Previous Studies

While progress has been made in cleaning up point-source discharges, new research is showing that there are many chemicals in sewage effluent that have, until now, not been extensively studied or regulated. However, the presence of pesticide in surface waters has been regulated by the European Directive 2008/105/EC that established maximum concentration permitted in surface water. The concentration for atrazine is 2 µg/L and 4 µg/L for simazine. In fact, atrazine and

simazine have been listed as “priority hazardous substances” in Decision 2455/2001/EC. US Environmental Protection Agency has considered Atrazine, ametryn, prometryn, terbutryn, simazine and propazine as a group to be endocrine-disrupting chemicals [2].

New Emerging Pollutants

The term “New Emerging Pollutants” (NEP) would probably lead us to think of something new that just exist. However, these pollutants are not necessarily new chemicals, as these substances actually have long been present in the environment but their existence and significance are only now being recognized when many new detection methods have been developed. New Emerging Pollutants may arise from various sources that are in a wide scale, which can commonly derived from municipal, agricultural and industrial wastewater [1]. Many university research laboratories, federal agencies such as the Environmental Protection Agency (EPA) and also public drinking water branches have done some researches and screening processes to evaluate each category of these pollutants regarding the emerging pollutants issue. Specifically, these categories include various product types such as disinfection by products (DBPs), pharmaceuticals and personal care products (PPCPs), pesticides and herbicides, cyanotoxins, endocrine disrupting chemicals (EDCs), persistent organic pollutants (POPs) and micro-constituents [3].

The hazards from chemical such as saline intrusion or pollution events will definitely give bad impacts on the health of many organisms including humans [4]. Studies have been conducted in order to explore the impacts of NEPs towards our environmental systems. Based on the data that have been collected on various classes of NEPs, these NEPs indicate risk to ecosystems and human health [1]. Due to the recent advancement in analytical instrumentation and techniques, scientists have been able to detect very low concentrations of many chemicals in natural and drinking waters. Although the emerging pollutants in natural and drinking waters may not give an immediate lethal effect to human, they may promote disastrous impacts on human health in a long term period. Even though no direct adverse effect on human health and ecological systems has been established from consuming drinking water that contains a very low concentration of these emerging pollutants, the potential for their long term accumulative impact on human health has trigger the public to be more concern about this matter [3].

The NEPs can be found in wastewaters, surface waters and also ground waters [5]. There are many ways for these NEPs to permeate into the water. Pesticides are used worldwide, hence will result in runoff, then into the sewers and finally into the WWTPs[6]. Many municipal landfills that discharge directly into the wastewater treatment plants (WWTPs) without treatment will result into environmental spreading of PFCs, polar and persistent emerging compounds [7]. Veterinary medicines and their metabolites will be released either directly or indirectly into soils when manure and slurry from intensive livestock facilities are applied to agricultural land as fertiliser [1].

Triazine is one of the NEPs that exist in the environment. It is classified as a group of pesticides which have a wide range of uses. Most of them are used in selective weed control programs, while others such as prometon have the non-selective properties which make them suitable in industrial sites usage. Triazines may be used alone or by combining with other herbicides active ingredients in order to increase the weed control spectrum because they are inhibitors of electron transport in photosynthesis. Their chemical structures are heterocyclic, which composed of carbon and nitrogen in their rings. Most are symmetrical with their altering carbon and nitrogen atoms, except for metribuzin. Herbicide members of this family include atrazine, hexazinone, metribuzin, prometon, prometryn and simazine [8]. Long term consumption of high levels of atrazine can caused adverse health effects in animals, including tremors, changes in organ weights and damage to the liver and heart [8]. Atrazine is a known endocrine disruptor, which cause dramatic damage to reproductive structures in frogs, fish and other wildlife [9]. Hexazinone is not considered to be acutely toxic, however can cause serious and irreversibly eye damage [8].

Methods in Removing NEPs

Current advanced analytical instrumentation and techniques help in detecting concentration of NEPs in natural and drinking water. This is because these techniques are able to identify and quantify the emerging pollutants, provide more insight to the occurrence, formation, properties and pathways. Thus, development of feasible techniques are needed to remove those NEPs or at least, reduced them below the regulated levels [3]. There are few techniques that are proven for its functional and abilities of the techniques to remove NEPs such as usage of different types of nanomaterials, reverse osmosis (RO), nanofiltration (NF), powdered activated carbon (PAC) and chemical oxidation [10]. However, these techniques are not feasible to be implemented in developing countries due to high costs.

Besides using advanced treatment technologies, conventional water treatment is one of the most common treatment process used for treatment of raw water from a surface source. This type of treatment is the combination of screening, coagulation, sedimentation, filtration and disinfection processes to provide clean, safe drinking water to the public [11]. As the focus of the study will be on coagulation and chlorination, the following sections will discuss the processes in further detail.

Coagulation

Coagulation involves the addition of chemical coagulants in allowing the suspended, colloidal and dissolved matter to undergo flocculation or create the conditions for the purpose of particulate and dissolved matter removal [12]. Most particles after passing through pre-sedimentation are colloidal type. The colloidal turbidity particles are too small, about 1-100 nm, which cannot settle by gravity. They are negatively charged particles and stay in suspension and will cause turbidity. They will be removed with the use of coagulants such as alum that can make them stick together to form large and heavy particles, known as floc and will finally settle [13].

Performance of coagulation process depends on several factors. Coagulant type is one of the main factors because different sources of water require different type of coagulants. Aluminium sulfate, $\text{Al}_2(\text{SO}_4)_3 \cdot 14\text{H}_2\text{O}$ in a powder form, is one of the common coagulants used because it is such a good coagulant for hard water with high alkalinity and pH 5.5-8.0. Besides powder form, it also available in liquid form, Al_2O_3 . Both forms provide Al^{+3} ions in water. For every 5 NTU to 30 NTU turbidity, coagulation normally need 1 mg/L of alum and will increase for 1 mg/L for every 10 NTU [13].

Coagulant aids will help the coagulation as it creates better coagulation conditions such as proper pH, alkalinity and particulate nuclei. There are also some coagulant aids that act as secondary coagulants such as polymers. Polymers are mostly cationic. They attract negatively charged turbidity particles. Anionic or non-ionic polymers may work better for certain water but depend on the quality of water too [13].

The effectiveness of coagulation will also depending on pH. Different water need different coagulants and pH. Optimal pH varies depending on the coagulant used. Normally, water with colour will coagulate better at low pH (4.4-6) when using alum as the coagulant [13].

Dosage of coagulant used will also affect coagulation process. The relationship between the concentration of colloidal materials to be removed and the coagulant dose required has an inverse relationship. It means that water with high colloid concentrations, the colloid particles act as nuclei on to which the coagulant precipitates while water with low colloid concentrations will require more precipitated coagulant in order to entrap the colloid particles. However, overdosing of coagulant can lead to charge reversal and re-suspension of the colloidal material and affect to poorer filtered water quality if the coagulation process is in neutral charge [14].

Based on some studies, treatment using coagulation-flocculation process was found to be ineffective in removing NEPs. A study was conducted by using a bench-scale simulation water treatment plant model and sample waters were spiked with 30 pharmaceuticals to 80 different EDCs. From the experiment, chemical treatment such as coagulation-flocculation shows ineffective removal either for the PPCPs or EDCs. This finding proved that those compounds were not removed by metal salt coagulants (aluminium sulfate and ferric sulfate) [15]. There is also another

investigation on the process of coagulation-flocculation by using FeCl_3 in pilot plants and drinking water treatment plants to find the removal of NEPs such as carbamazepine, bezafibrate, clofibrac acid and diclofenac. However, coagulation-flocculation process presented a low removal of these micro-pollutants [16].

Chlorination

Chlorine is very useful for disinfecting storage tanks and pipeline, for oxidizing iron, manganese and hydrogen sulphide and also for controlling tastes, odours, algae and slime [11]. Chlorination may involve two main alternatives, which are the use of gaseous chlorine that dissolve in carrier (motive) water before being added to the water that are going to be treated or the use of a solution of hypochlorite, which is normally sodium hypochlorite [17].

There are few factors that affect chlorination process. Temperature of water is one of the factor that will affect the effectiveness of chlorination process. This is because the bacterial kill tend to be slower at lower temperatures. However, in cold water, chlorine is more stable and the residual will remain for a longer period of time, compensating to some extent for the lower rate of disinfection. With all factors considered, chlorination is to be more effective at higher water temperatures [11;17]

The pH of water will influence the action of chlorine as it determines the ratio of HOCl to OCl⁻. It means that either more hypochlorite ion or more hypochlorous acid present is depending on the pH of the water. Hypochlorous acid poorly dissociates at low level of pH. The dominant residual is then HOCl. However, HOCl will dissociate almost completely at high level of pH, then leaving OCl⁻ as the dominant residual. Addition of chlorine gas lowers the pH of water while the use of hypochlorites slightly raises the pH [11].

Chlorine dose is one of the most important factors that will influence chlorination (CBPs formation) and was found to be statistically significant for all the detected compounds [18]. Higher dose of chlorine can give a better treatment of water. Note that dose of chlorine has relationship with contact time. When the chlorine concentration is decreased, the contact time must be increased, in order to ensure the kill will remain the same. Vice versa, when chlorine concentration increases, the contact time needed to kill will be decreases [11].

As discussed before, contact time has the relationship with concentration of chlorine in order to measure the successful of chlorination. Theoretically, the rate of kill should follow Chicks's law (Eq. 1).

$$dN/dt = -kN \quad (1)$$

where N is the number of surviving organisms and k is the rate constant for a particular disinfectant/organism combination.

The rate of kill is proportional to the number of living organisms. By integration, when $kt=1$, there are 43.4% of original organisms will be destroyed. However, the effect of contact time is more complex in practice. As for many organisms, the rate of kill will increases with time. Thus, it is postulated that this is related to the time required for the chlorine to enter and kill the organisms [14].

Chlorine will only be effective if it comes in contact with the organisms to be killed. Turbidity, which caused by tiny particles of dirt and other impurities suspended in the water [11]. The presence of these solids in water may protect the organisms from the chlorine and the concentration of the organisms in water. Thus, chlorination can be ineffective [17]. Thus, disinfection of water with low turbidity is needed by reducing turbidity as much as possible through coagulation, flocculation and filtration [14,11]

It is difficult to remove micro-pollutants, especially pharmaceuticals from water because their concentrations are in range of 10^{-3} to 10^{-6} mg/L, which is much smaller than those conventional macro-pollutants (BOD₅, COD, nitrogen and phosphorus compound). Besides, they include a wide spectrum of compounds with great differences in their main properties which affect their behaviour and fate in water [19]. The removal efficiency may vary significantly among different PPCPs

compounds. Chlorination treatment is to be significantly effective as it manage to degrade sulfamethoxazole almost completely. However, chlorination is not effective in removing carbamazepine [20]. Recently, an investigation on the removal efficiencies of eight pharmaceuticals (caffeine, acetaminophen, carbamazepine, sulfamethoxazole, trimethoprim, erythromycin, lincomycin and codeine) has been conducted. Overall, chlorination was to be highly effective in the elimination of most of these pharmaceuticals [21]. In fact, chlorination also effective for oxidation extracellular cynotoxins as long as the pH is below 8 [3].

Methodology

This section explains on how the study was carried out to obtain the objectives of the study. The experiments were conducted in the Environmental Engineering Laboratory, Faculty of Civil Engineering and Zeolite and Nanostructured Materials Research Laboratory, Faculty of Science, Universiti Teknologi Malaysia.

Sample Preparation

Two different samples were prepared separately for the coagulation and chlorination study. For coagulation, water from Sungai UTM (in front of M46) was taken as the water source. Distilled water was used for chlorination process. Based on previous study [22], 50 µg/L of Triazine was spiked into both samples and stirred thoroughly.

Analytical Method

Turbidity. Turbidity test was carried out by using HI 93703 Portable Logging Turbidity Meter. Short warm-up for the turbidity meter was carried out for 5 minutes. Then, the turbidity meter was calibrated using standard turbidity suspensions. 10 mL of cleared sample from each beaker was taken and poured into the sample tube. The sample tube was wiped thoroughly by using clean cloth before run the turbidity meter. Reading of the turbidity was recorded. The sample was taken into precaution to not introduce air bubbles inside the sample tube. Lastly, turbidity versus dosage of alum and turbidity versus pH of water were plotted to determine the optimum dose of alum and the most effective pH of water respectively.

Triazine. The raw and treated water from coagulation and chlorination tests were analysed for triazine. For coagulation process, which utilise turbid river water, the samples to analyse were filtered through a cellulose membrane filter papers of 47mm and 0.45µm pore size by using vacuum pump filter. The clear water was separated into a separating funnel and underwent the SPE process.

The SPE process consists of a Glass Block Vacuum Manifold with 10 port plugs. SPE cartridges, Chromabond C18 EC were used and attached to the port plugs. In this study, the procedures used were adapted from Bonansea [23].

Before running the sample treatment, each cartridges were sequentially conditioned with the selected solvents; dichloromethane (DCM), acetonitrile (ACN) and ultrapure water (UPW) for the treatment. After introducing the 500 mL samples in each cartridge, the cartridges were washed with ultrapure water and then dried for 30 minutes under vacuum. Finally, elution of analytes was performed by rinsing the cartridge with ACN. During this step, ACN was left to pass through the SPE tubing by gravity force and into small vial. This was to ensure the hydrophobic analytes adsorb better onto the cartridge surface. The vial was kept in the cool box after the elution ends. After all samples were eluted and kept in the cool box, the samples were then brought out from the cool box to be left to dry until the sample volume reached approximately 0.5 to 1.0 mL. The extracted samples were analysed for triazine using GCMS.

The samples were analysed by using Agilent 6890N Network Gas Chromatography System (GCMS). The system used advanced electronic pneumatic control (EPC) modules and high performance temperature control. The full range digital data output able to quantify the smallest and largest peaks in a single run. From these peaks, the type of NEP compounds that were present in the samples could be identified and thus the removal rate of triazine samples could be

determined. To analyse the NEP, the samples were injected into the system. Results were produced in a chromatogram which showed the confirmation of targeted compounds present in the samples.

Procedures

Coagulation

Dosage of Alum. Six beakers containing 500 mL of sample with Triazine were prepared. Prior to pH measurement, the water were initially set for a selected pH value. Using a measuring pipette, different dose of alum was added into each beaker in an increasing amount between 10 and 50 mg/L. By using jar test equipment, the samples were stirred rapidly (60 to 80 rpm) for three minutes. Then the speed was reduced to (10 to 30 rpm) for about 15 minutes. After the stirring period was over, the stirrer was stopped and the flocs were allowed to settle for 10 minutes. Samples were taken for turbidity test. Then, each beaker undergo filtration process and the samples were analysed for NEP.

pH of Water. Six beakers containing 500 mL of sample with Triazine were prepared. For determining optimum pH, the pH were varied between 5.5 and 8.5. The pH adjustment was done by the addition of hydrochloric acid (HCl) to lower the pH and sodium hydroxide (NaOH) to raise the pH. Thermo Scientific Orion Star LogR pH Meter was used to measure the pH value of each water sample. The pH measuring head was emerged into the water to measure the pH. Then, the optimum dosage of alum from previous experiment was added into each beaker using a measuring pipette. By using jar test equipment, the samples were stirred rapidly (60 to 80 rpm) for three minutes. Then, the speed was reduced to (10 to 30 rpm) for about 15 minutes. After the stirring period was over, the stirrer was stopped and the flocs were allowed to settle for 10 minutes. Samples were taken for turbidity test. Then, each beaker undergo filtration process and the samples were analysed for NEP.

Chlorination

Dosage of Chlorine. Six beakers containing 500 mL of sample with Triazine were prepared. Prior to pH measurement, the water were initially set for a selected pH value. Using a measuring pipette, different dose of chlorine was added into each beaker in an increasing amount between 15 and 30 mg/L. The samples were stirred rapidly (60 to 80 rpm) for three minutes. Then the speed was reduced to (10 to 30 rpm) for about 15 minutes. After the stirring period was over, the stirrer was stopped and reactions were allowed to occur for 60 minutes. Then, each beaker undergo SPE process before being analysed for its Triazine concentrations.

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Contact Time

Five beakers containing 500 mL of sample with Triazine were prepared. For determining optimum contact time, different contact time were applied. The samples were set with the optimum pH of water from previous experiment. Then, the optimum dosage of chlorine was added into each

beaker using a measuring pipette. The samples were stirred rapidly (60 to 80 rpm) for three minutes. Then, the speed was reduced to (10 to 30 rpm) for about 15 minutes. After the stirring period was over, the stirrer was stopped and reactions were allowed to occur in an increasing period with 10, 30, 40, 50 and 60 minutes for each beaker respectively. Then, each beaker undergoes SPE process before being analysed for its Triazine concentrations.

Results and Discussion

Coagulation

Turbidity Removal. The results of the coagulation process in removing turbidity are shown in Figures 1 and 2. Figure 1 shows the profile of turbidity with regards to dosage of alum while Figure 2 shows the plot of turbidity with respect to pH of water.

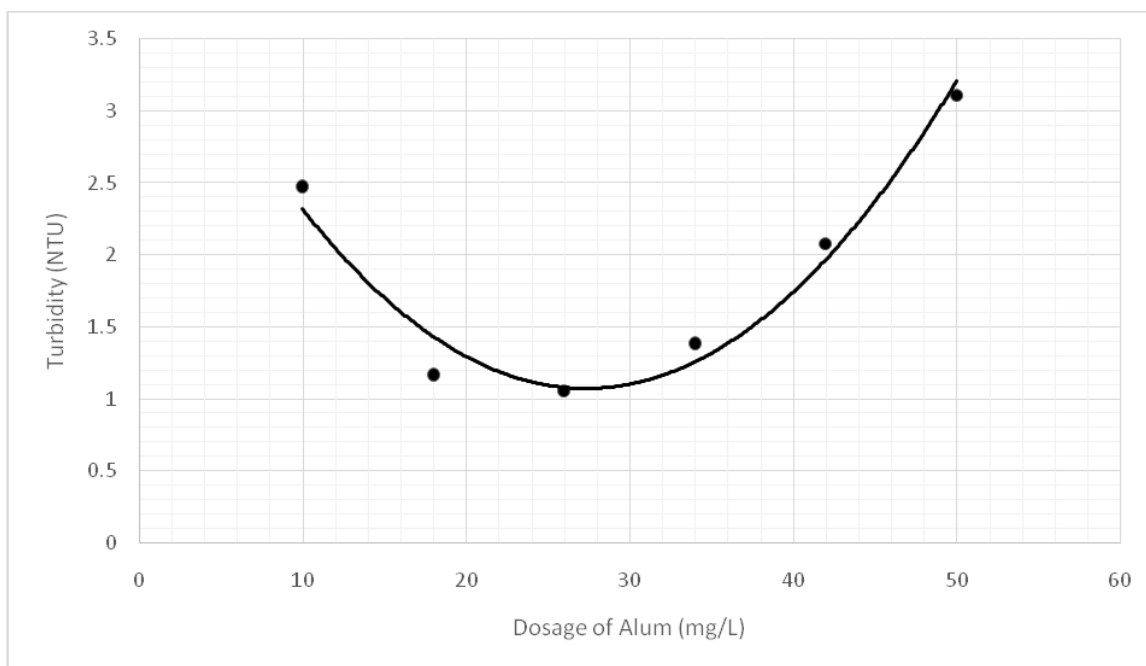


Figure 1: Profile of turbidity of treated water at different dosage of alum (pH = 6.89)

From Figure 1, the turbidity values obtained were in a good trend which a curve profile was able to be plotted. The range of turbidity was from 1.06 to 3.11 NTU. The lowest and highest dose of alum used give the highest value of turbidity, where dosage of 10 mg/L gave the turbidity of 2.48 NTU while 3.11 NTU for 50 mg/L. Dosage of alum with 26 mg/L shows the lowest value of turbidity, which was 1.06 NTU. Thus, the optimum dosage of alum taken was 26 mg/L.

However, the results obtained from experiment on pH of water were inconsequential as shown in Figure 2. The turbidity values were in a range of 7.74 to 26.4 NTU. Lowest and highest turbidity resulted from pH 8.5 and pH 6.1 respectively. The lowest turbidity gave the optimum pH of water in removing of triazine.

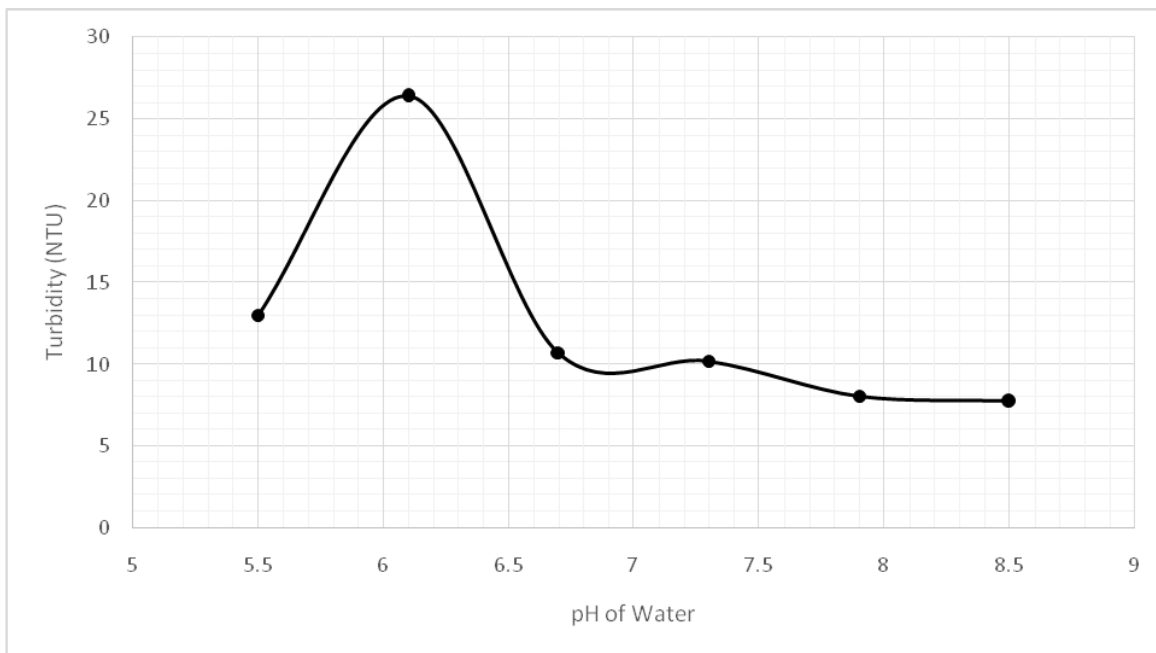


Figure 2: Profile of turbidity of treated water at different pH (Alum dosage = 26 mg/L)

Removal of Triazine. Based on GCMS results, the chromatogram peak for Triazine was detected at the retention time of 24 minutes. Tables 1 and 2 show the removal percentage of triazine according to dosage of alum and pH of water, respectively.

Table 1: Removal percentage of triazine according to different dosage of alum (pH = 6.89)

Sample	Dose of Alum (mg/L)	Removal Percentage (%)
1	10	-2.7
2	18	8.0
3	26	29.6
4	34	24.6
5	42	-4.5
6	50	-3.5

Table 2: Removal percentage of triazine based on different pH of water (Alum dosage = 26 mg/L)

Sample	pH of Water	Removal Percentage (%)
1	5.5	0.1
2	6.1	-3.2
3	6.7	1.2
4	7.3	-2.0
5	7.9	5.6
6	8.5	-7.2

Based on the results obtained from Table 1, the trend of the results were fluctuated and difficult to be observed. Dosage of 10, 42 and 50 mg/L resulted into negative removal percentages. This phenomenon was unexpected to happen. The dosage of alum with 26 mg/L shows the highest removal percentage, which was up to 29.6%. The lowest removal percentage was only 8.0% resulted from 18 mg/L dose of alum. Thus, 26 mg/L was considered to be the optimum dosage of alum in removing triazine.

The same situation happened in the experiment regarding to pH of water as shown in Table 2. pH of 6.1, pH 7.3 and pH 8.5 resulted into negative percentage of triazine removal. This time, the range of removal percentage was from 0.1% to 5.6% only. pH 7.9 shows the highest removal percentage

up to 5.6% and the lowest removal resulted from pH 5.5. Thus, pH 7.9 was taken as the optimum pH of water in the removal of triazine.

Removal of Triazine by Chlorination

Table 3 shows the removal percentage of triazine according to different dosage of chlorine. Table 4 and 5 show the removal percentage of triazine according to pH of water and contact time, respectively.

Table 3: Removal percentage of triazine according to different dosage of chlorine (pH = 6.81, contact time = 60 minutes)

Sample	Dose of Chlorine (mg/L)	Removal Percentage (%)
1	15	1.1
2	18	3.3
3	21	3.7
4	24	3.9
5	27	32.1
6	30	14.0

Table 4: Removal percentage of triazine according to different pH of water (Chlorine dosage = 27 mg/L, contact time = 60 minutes)

Sample	pH of Water	Removal Percentage (%)
1	5.5	23.8
2	6.1	21.3
3	6.7	21.0
4	7.3	25.3
5	7.9	11.8
6	8.5	24.7

Table 5: Removal percentage of triazine according to different contact time (Chlorine dosage = 27 mg/L, pH = 7.3)

Sample	Contact Time (min)	Removal Percentage (%)
1	10	12.5
2	30	16.0
3	40	13.8
4	50	24.2
5	60	27.3

Based on the results obtained from Table 3, an increasing trend of results for the removal percentage can be seen clearly as the dosage of chlorine increases. The range of removal percentage was from 1.1% to 32.1%. The highest percentage of removal was 32.1% with the chlorine dosage of 27 mg/L. The dose 27 mg/L was taken as the optimum dosage of chlorine in removing Triazine.

From Table 4, the removal percentage varies according to the pH of water. In general, the removal was high at low pH, as the pH increases, the removal tend to be lower but start to increase at pH neutral and higher. pH 7.3 was taken as the best pH of water to remove Triazine where the removal percentage was 25.3%. Water with slightly alkaline was the best condition to remove NEP.

As for the effect of contact time, the trend for removal percentage was in increasing manner as the contact time also increased. The removal percentage increased from 12.5% to 27.3% from 10 minutes until 60 minutes. Removal of triazine was the highest during 60 minutes of contact time.

Contact time of 60 minutes was taken as the best contact time for the chlorine to react with water in removing the Triazine.

Discussion

Based on the results for coagulation process, the readings obtained were fluctuated. In fact, the correlation between turbidity test and the GCMS results cannot be seen clearly. As for pH of water, the best pH for turbidity test was pH 8.5 but from GCMS result, the best pH in removing Triazine was pH 7.9. However, the optimum dosage of alum for turbidity test and GCMS show the same dose of alum with 26 mg/L. Thus, the relationship between turbidity and removal of triazine cannot be observed as the results were insignificant. Besides, even though there were few samples that can be used as they showed positive removal rate, the unstable results obtained proved that Triazine cannot be removed by coagulation. The results of this study is supported by another findings reported by Adams [24]. From the study, there was no significant removal of any of the antibiotics via coagulation method.

However, chlorination method showed a better removal trend as compared to coagulation. Even the percentages of removal were not high, but at least chlorination is proven toward its ability in removing Triazine. Based on the same study by Adams [24], chlorination was proven to be effective in removing antibiotics up to 90% of removal.

Conclusion

Based on this study, two major experiments were conducted separately. The objectives of both experiments are to determine the ability of coagulation and chlorination processes in removing selected NEP. In determining the ability of each method, few parameters were evaluated. Thus, the optimum dosage of alum and chlorine, the best pH of water and also effect of contact time were determined. For coagulation process, the optimum dosage of alum was 26 mg/L and the best pH of water was pH 7.9. The results were analysed based on the highest removal percentage of triazine. In chlorination process, 27 mg/L was the optimum dosage of chlorine and also pH 7.3 was taken as the best pH of water to remove triazine. Also, contact time of 60 minutes was able to give the highest removal percentage. In the end of the study, a conclusion can be made where chlorination has a potential to be one of NEPs removal method as this method able to remove triazine. However, coagulation is proven to be ineffective in removing the NEP.

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