Occurrence of Surface Water Contaminations: An Overview

M M Shahabudin[1], S Musa[2]

[1] Post Graduated, Department of Water Engineering and Environment, Faculty of Civil and Environmental Engineering, Universiti of Tun Hussein Onn Malaysia
[2] Senior Lecturer, Department of Water Engineering and Environment, Faculty of Civil and Environmental Engineering, Universiti of Tun Hussein Onn Malaysia

Corresponding e-mail: m.muzzammil6852@gmail.com[1]

Abstract. Water is a part of our life and needed by all organisms. As time goes by, the needs by human increased transforming water quality into bad conditions. Surface water contaminated in various ways which is pointed sources and non-pointed sources. Pointed sources means the source are distinguished from the source such from drains or factory but the non-pointed always occurred in mixed of elements of pollutants. This paper is reviewing the occurrence of the contaminations with effects that occurred around us. Pollutant factors from natural or anthropology factors such nutrients, pathogens, and chemical elements contributed to contaminations. Most of the effects from contaminated surface water contributed to the public health effects also to the environments.

1. Introduction

Water is needed by all organisms in their life and without water everything are impossible to live. As time goes by with the increment of the needs has turn the water quality into worst condition as pollutant are becoming as a major problem. Greatest posed of the problem to the surface water is pointed sources of contamination rather than non-pointed sources [1].

The pointed sources are mainly from the human activities why the surface water becoming polluted with the pollutants such nutrients, pathogens, and chemical elements which turn into different of environmental effects [2]. As contamination happened has turned the quality of the water into worst conditions thus created health problem to the public [3]. Together with high technologies invented each day plus with public effort, all arise questions can be answered and solved effectively.

Oceans, seas, ice, saline water and atmospheric water which comprises over than 99 percent of water quantity around the world are not suitable to be used by human [4] and Figure 1 shows the fraction of the water in pie charts. Only 1 percent is usable for human being. This figure shows that how important the water in our life from past till now in terms of water usage. Water is precious gift from god to human as water is needed by all. Main focus of this paper is to identify the characteristics of raw surface water that contributes to water quality problems that occurred today for different effects.

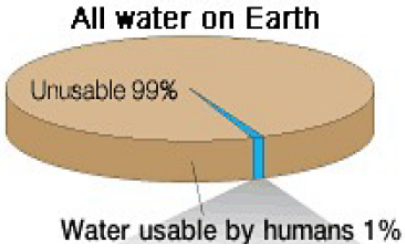

Figure 1: Usable Water by Human (USGS, 1998) [4]

2. Surface Water Contaminant

Definition of pollution to the water can be described as a presence of the other substances to the water until they cannot be used for a specific purpose [5].Qualities of water decrease due to change of the human surroundings through several of human factor such as urbanizations result a serious threat to both human population and earth [6]. Thus, Latiff [7] stated that polluted water is not suits for drinking from domestic outlets and once the ecosystem was threatened the others will get the same problem while waste most often directly discharged into water bodies.

Pollutants are coming from various ways of sources and once the source of water is polluted, It can be transported along the stream line till to the public users [2] and can be categorized in two sections which are: a) pointed sources b) non-pointed sources.

2.1 Pointed Sources

Latiff [7] stated that pointed sources means pollution that entered the water bodies which can be traced. Pointed are such from industrial and domestics' wastewater. Major causes of the sources are coming from pointed sources as they can be identified through their activity such from industrial waste, domestics waste, excessive use of the pesticides and fertilizers and etc. are notable man-made pollutants [8]. Chaudry et al. [1] also stated that the pointed sources of pollutants are entering directly to water bodies. In India, situated at the river of Narmada was polluted of water bodies with pointed sources of pollutants. The river was contaminated directly from the waste of the factory and domestics waste [9].

Others incidents of source by pointed method pollutants also in India where many rivers in Marahastra showed that BOD contents with number between 20 mg/l and 180 mg/l. Pollutants are coming from the waste of industrial such chemical, heavy metal and food processing. Also due to the location of the water bodies in the dense populated area [8].

The point sources have caused a lot of health effect due to the pollution such chronic mercurialism, arsenism, also microcystines and cancers [9]. Figure 2 showed the point sources of the pollution that entering the water bodies. This condition may concern to more than 80% of the pollution will be contributes to surface water polluted for only one source.

Figure 2: Point sources of pollution [10]

2.2 Non-Point Source

In non-pointed source are stated as an unknown of pollution or pollution that occurred due to the various point of elements [1]. This source still gives the same result like pointed sources because all elements such as nutrients (e.g; phosphorous), pathogens, and chemical are still polluting the water bodies.

Mixed of pollutants such as agricultural run-offs containing pesticides and fertilizers has turn the quality into other conditions where the nutritional contents are getting higher which turns the algae to proliferate. Routine of activity in land for agricultural cause leaching where the waste are seeping through the soil and contaminating the water bodies [11]. The waters from the run-offs always mixed with different pollutants like atrazine, benomyl, linuron etc, maybe founded in the agricultural area as the chemical are used to kill the insects at the agricultural area [12]. As the occurrence of the pollution due to the mixed of waste has turned the cleaning action to the river into a big problem.

Pollution on surface water can be affected by the activities of surface and subsurface runoff that come from croplands and urban areas where they are varies depending on climate variability and seasonal time. The conditions of the sources can be worsened as the change of natural factor such as precipitation differences, surface runoff, interflow and groundwater flow [13]. Figure 3 shows the example of interaction of pollutant those becoming non-point sources.

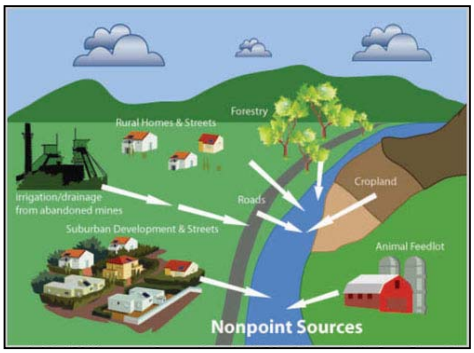

Figure 3: Non-point sources [14]

This path may differ from one to other places as pollutant may differ. This non point's source occurs as the rainfall comes and brings all the waste into to surface water bodies which resulting mixing all kinds of waste thus polluting the water sources directly [7].

3. Investigation Records

In this review paper are focusing on identifying characteristics of surface water quality where are causes by any of pollution in terms of two categories which are point and non-point sources of the causes with certain cases that happened around the world with assess of interaction between the water bodies and the occurrence of the pollution. Also assess some of the effects off the surface water pollution to the public.

3.1 Types of Water Pollution

Latiff (2011) [7] stated that water pollutant comes in many forms and terms of pollutants which are biological, chemical, sedimentation, eutrophication, and groundwater pollution. Studies by Awang et al., [15] of Sembrong River, pollutants are coming from the organic matter, decaying timber, tree roots, high in soil loss contents. Acidic condition of Sembrong River comes from high total coliforms and concentrations of hydrogen ion (H^+).

Previous report from National Report Malaysia (2003) where pollutants are mainly cause from palm oil, raw natural rubber, rubber product, food and beverages, textile and leather, paper and chemical. From all factors above, pollutants has contributed to the total pollution of public people in 79.56 percent [16].

Supported by Kroeze et al. [2] proved that the cause of water pollution comes in various ways all around the world as action from human. A cause of the pollution comes in forms of nutrients, pathogens, chemicals, and plastics waste.

In biological perspective of pollutants, it may come in terms of pathogens such waste from sewerage, feces of animal, latrines, bacteria, virus, and other organisms which spread into the water bodies [8]. As nutrients in the water are increasing, water pollutants may contains fertilizer and pesticides which gives adverse impact. Increasing of the nutrients in the water has boost up the organism to growth fast. Due to increase of organism in the water, it may slow the flow of the streams and increased the proliferation of organism [11].

Forming of hazardous algal blooms in the water due to nutrients enrichments from the waste, may pose a threat to surroundings as the organisms releasing the toxin [17]. Cases in Sabah state n fisheries field sources as resulting from nutrients enrichments in the water causing the discoloration of water and killing the fish as impacts from Cochlodinium polykrikoides microalgae [18]. Impacts from dead fish, waste from decaying fish has pollute the water sources thus increased the hazard. High in concentrations of certain elements such NO3–N and PO4–P in water also have caused the harmful algal blooms [19].

Causes in Malaysia culture mainly comes from effluent waste from industries also domestic's zone especially rubbish [20]. Impacts from the pollutions has brings another matters to the surroundings in physical, chemical and biological where the sources of contaminations are in pointed and non-pointed sources [21].

In physical scopes, impact on water bodies due rapid growth of algae has blocked the nutrient to reach the bottom of the water bodies and caused death on organisms [22]. Waste from chemicals is different where special care needed on treating the waste and can be in various forms of solid, liquid or gaseous [1].

Surface runoff may also carry the waste materials such pesticides and hazardous material thus polluting the ecosystems [1]. Sedimentation also contributing to the pollution as effects from soil erosions and can be greater than 100 times if a human activity is persist [8].

At Baltic Sea, rapid growth of algae effect from sedimentation process that contained organic matters turn into eutrophication problem [23]. The causes of the eutrophication are mainly from fish farming and agriculture. Eutrophication also poses a threat to human in drinking water resources, natural ecological and economic development [24].

Lake Kenyir in Terengganu are known as a tourism places facing eutrophication around the lake as the result of waste of nutrient are coming from the fish farmings and sport-fishing [25].

3.2 Treatment Method

The study at Sembrong River conducted based on on site data collection with assessment in water quality also taken into account in degree of pollution classification.

Treatment method on conventional water treatment for water can be grouped into 12 types by Minnesota Water Quality Association [26] which is carbon filtration, distillation, ion-exchange, demineralization, ion-exchange softening, iron or oxidizing filtration, neutralizing filtration, ozone, pot feeders or chemical feed pumps, reverse osmosis, sand filtration, sediment filtration, ultra-violet, and sterilization

Highlighted by Rodriguez-Narvaez et al, [27], treatment has turn into 3 categories where the treatment goes to phase changing technologies, biological process and advanced oxidation process of water. Each of the group can be distinguished through the action done to the water.

Table 1: Comparison of biological process [29]

Type of biological process	System	EC	Removal efficiency, %	Notes
Aerobic and anaerobic	Activated sludge	Benzotriazole 5-Methylbenzotriazole 5-ChloroBenzotriazole	36-46 61-100 52-71	WWTP in Australia
Anaerobic	Activated sludge	Estrone 17β-Estradiol Estriol 17β-Ethinyl estradiol	0-36 0-8 0-1.67 0-4.2	WWTP in Paris and Southern France
Aerobic and anaerobic	Activated sludge	Didofenac Bisoprolol Naproxen	0-26 28-46 97-100	WWTP in Finland
Anaerobic	Activated sludge	Ibuprofen Ketoprofen	90 92	Wastewater from agricultural industry in Malaysia
Anaerobic	Activated sludge	Bezafibrate Carbamazepine Naproxen Ibuprofen Didofenac Diaztrizoic acid	>90 0 >90 >90 >90 0	WWTP in Germany

Phase changing technologies can be determined as turning the material from one phase into another phase such as water into solid condition aid by technology apparatus (Rodriguez-Narvaez et al, [26]. Phase changing have been studied by Moussa et al. [28] using method of electrocoagulation in water treatment. Method is used to remove stubborn pollutants such organic and inorganic contaminants in wastewater.

Biological process treatment by Rodriguez-Narvaez et al, [27] stated that certain process is suits with activated sludge system in treatment used because of its effectiveness. Table 1 show that biological process is divided into two parts which is aerobic and anaerobic process. Each of aerobic and anaerobic gives different result of removal in emerging contaminants (EC). In Malaysia, activated sludge treated with aerobic process turning the results up to 90 percent of cleaning to the wastewater from agricultural industry [29].

Table 2: Removal of contaminants using AOP [27]

System	EC	Removal Efficiency, %	Notes
UV	Estrone	90	$[C]_0$ = 5 mgL^{-1} pH = 6.5; 13W low pressure Hg lamp (254 mm; 18mW cm^{-2}) T = 20°C; 30 min
UV/H_2O_2	Doxycydine	100	pH = 3; $[Dox]_o$ = 10 mgL^{-1}; $[H_2O_2]_0$ = 100 $\mu molL^{-1}$ UV-C radiation; 5.03 x 10^{-5} Es^{-1}; 20 min
UV/Ozone	Caffeine	>95	$[C]_O$ =40 mgL^{-1};pH = 7; UV 32W; 22.5 min
	Esradiol (E2)	>99	$[O_3]_{0\ E2}$=2.4 mol L^{-1}; 1s
Ozone	Ethynilestradiol (EE2)	80	$[O_3]_{0\ EE2}$=3.7 mol L^{-1}; 3s
	Naproxen (NPX)	80	$[O_3]_{0\ NPX}$=4.75 mol L^{-1}; 30s
	Ibuprofen (IBP)	90	$[O_3]_{0\ IBP}$=100μ mol L^{-1}; 2500s
$Ozone/H_2O_2$	Ketoprofen	90-996	Lab water; T=24°C; $[O_3]$=2.4 mg L^{-1}
	Naproxen	96-98	H_2O_2/O_3 ratio = 0.5; 1; 2 min; $[C]_0$= 1 mgL^{-1}
	Piroxicam	96-98	
$Ozone/H_2O_2/UV$	Estrone	>99	$[C]_0$ = 5 mgL^{-1}; pH = 6.5; low pressure Hg lamp (254 mm; 18mW cm^{-2}); T=20°C; 30 min
Fenton Process	Doxycydine	100	$[C]_0$ = 100 mgL^{-1}; $[Fe^{+2}]_0$ = 25 mgL^{-1}; $[H_2O_2]_0$= 611 mgL^{-1}; T=35°C
Photo-Fenton	Acetamiprid	70-90 90-100 100-100	[Fe] = 1,2,3 mgL^{-1}; H_2O_2/Fe ratio: 2:1; 4:1; pH = 2.8 Synthetic secondary effluent; 15 min; low pressure UV lamp (30Wm^{-2}; 254 nm)
Sono chemical	didoxacillin	>99	pH = 5.5; 600 kHz; $[C]_0$ = 0.21 mM; 180 min

Sui et al., [30] reported that each treatment in biological process only easily biodegradable can be removed but others need special action. Advanced oxidation process (AOP) associated with concentration of hydroxyl radicals where their ability to remove the pollutant higher than conventional water treatment process [27]. Table 1 below shows the system of advanced oxidation process in removal the pollutant.

Table 2 providing data on previous of action advanced oxidation process in water treatment. The system are using different kind of oxidation process which is UV rays, combine UV/H202, combine UV/Ozone, combine Ozone/ H202, combine Ozone/ H202/ UV, Fenton process, Photo-Fenton, and Sono chemical. Range of removal was in high range from 80 to 100 percentages of results.

4. Conclusion

Surface water pollution is polluted by many factors around us either by the pointed or non-pointed sources All sources of pollutions mainly came from human activities such industrial, domestic waste and agricultural. Other than that is the change of climate and seasonal time where they can influences the rate of the pollution to be transported from one sources to another places.

Polluted water can harm and cause health effects to the public also to the country. In terms of public health they can polluted people who are consuming the polluted water and to the country where large effort are needed to clean the water bodies when they are polluted. Due to the pollution that occur the whole ecosystem are actually disturbed.

Several fatalities reported also to public people due to consuming of polluted fisheries sources. The adverse of pollution not to the environments and ecosystems also people are involved.

Other than fatalities to the peoples, the polluted area will becoming a dangerous area as nutrient in water that comes from dead organisms cause other problem such bas smell and discoloration of water resources.

As urbanization and industrialization are rapidly growth and suitable action taken to overcome the pollution, the problem of water scarcity and pollution will be a never ending story and nightmare to us.

Not well treated of wastewater in certain cases has turn the story of pollution becoming a nightmare. As human needs everyday are getting higher, the rate of pollution also getting bigger.

Day to day with concern on getting of the fresh water in good condition to people, treatment method for water also changes. From basic method or normal practices, now it turns into more complex and high technologies of treatment that meet and suits the needs of providing the clean water to public.

As mention above, basic practices are still around but only focusing more on cleaning of the already treated water. Different with treating the water sources that have been polluted where special action are taken in providing the water are safe to the public.

Phase changing technologies, biological process and advanced oxidation process outline by the researchers showed that the need of special action for wastewater is important.

Each part gives their play their role where providing the different result after the process. Effectiveness of treatment also differ shows that pollutant can be removed are based on substances that exist in the wastewater.

Removal process also is like treatment process where the previous condition or quality of the water is getting back to its natural conditions.

Remain and getting back the natural condition of water is important things as both human and our surroundings are depending on water as one of our needs.

References

[1] Chaudhry., FN., and Malik., MF., (2017) Factors Affecting Water Pollution: A Review, Department of Zoology, University of Gujrat, Hafiz Hayat Campus, Gujrat, Pakistan, J EcosystEcography, an open access journal, Volume 7 (1).

[2] Kroeze., C., Gabbert., S., Hofstra., N., Koelmans., A., A., Li., A., Löhr., A., Ludwig., F., Strokal., M., Verburg., C., Vermeulen., L., Vliet., v., TH., M., Vries., d., W., Wang., M., and Wijnen., v., J., (2016) Global modeling of surface water quality: a multi-pollutant approach, Wageningen University, The Netherlands and Faculty of Management, Science and Technology, Open University, The Netherlands, Current Opinion in Environmental Sustainability 2016

[3] Alaguraja.P, Yuvaraj.D, Sekar.M Muthuveerran. P Manivel .M, (2010) Remote Sensing and GIS Approach for the Water Pollution and Management In Tiruchirappli Taluk, Tamil Nadu, India, Department of Geology, Bharathidasan University, Tiruchirappli, International Journal of Environmental Sciences, Volime 1, No1, r2010.

[4] U.S. Geological Survey (1998), http://ga.water.usgs.gov/edu/earthwherewater.ht ml [Accessed on: 01 October 2017], U.S. Department of the Interior

[5] Owa. W. F., (2014) Water pollution: sources, effects, control and management. Department of Integrated Science, Federal College of Education, Okene, Kogi State, Nigeria. ISSN 2300-9675. International Letters of Natural Sciences 3 (2014) 1-6.

[6] Halder. N. J. and Islam. N. M., (2015) Water Pollution and its Impact on the Human Health. 1Department of Environmental Engineering, Sangji University, Wonju, Kangwon-do, Republic of Korea. Journal of Environment and Human, p.p 2373-8324 (Online): 2373-8332.

[7] Latiff, A., A., A., (2011) Water Pollution : the never ending story, Syarahan Perdana 2011, Penerbit UTHM

[8] Bagul., V., R., Shinde., D., N., Chavan., R., P., Patil., C., L., (2015) Causes and Impacts of Water Pollution on Rivers Marahashtra-A Review, Department of chemistry, Arts science commerce college, Surgana (Nashik) Maharashtra, Department of chemistry B. N.N. College Bhivandi. (Thane) Maharashtra, Department of chemistry, Dnyanasadhana College (Thane) Maharashtra.Research Journal of Chemical and Environmental Sciences.

[9] Malviya, P., and Dwivedi, K., A., (2015) Physico- chemical parameters of Narmada River Water: A review. Department of Chemical Engineering, Ujjain Engineering College, Ujjain, (Madhya Pradesh) India, International Journal of Chemical Studies 2015; 3(2): 01-04

[10] River Network (2017) Lesson 2a: Pollution Discharge Permits. https://www.rivernetwork.org/wpcontent/uploads/2015/08/Our-Story_in-body.jpg [Date of accessed: 8 October 2017]

[11] Nigam, V., Behl., N., Kanchan, C., M., (2013) Physico-Chemical Parameters For Testing Of Water- A Review, Dept. of Botany, Guru Nanak Khalsa College, Yamuna Nagar (Haryana) India, Dept. Of Zoology, Guru Nanak Khalsa College, Yamuna Nagar, Haryana, India, Principal, Guru Harkishan Degree College, Jhansi (U.P.) India.

[12] Narendran, N., (2014) A Review on Environmental Problem Due to Water Pollution. Department of Chemistry PSNA College of Engineering and Technology, Dindigul, Tamilnadu, India, International Journal of Scientific Engineering and Research (IJSER), ISSN (Online): 2347-3878, Impact Factor (2014): 3.05

[13] Samsudin, S., M., Juahir., H., Zain., M., S., and Adnan., H., N., (2011) Surface River Water Quality Interpretation Using Environmetric Techniques: Case Study at Perlis River Basin, Malaysia, *Department of Chemistry, Faculty of Science, Faculty of Environmental Studies, Universiti Putra Malaysia, International Journal of Environmental Protection

[14] PBS Learning Media. (2017) https://www.pbslearningmedia.org/resource/ee8c 197f-9bd5-4017-8ab0-54db41fbf88e/lgreilesson-1-watersheds-101-and-nonpoint-sourcepollution-basics/#.WdXXG2iCzIU [Date of accessed: 05 October 2017]

[15] Awang, H, Daud, D, and Hatta, M, Z, M, (2015) Hydrology Properties and Water Quality Assessment of the Sembrong Dam, Johor, Malaysia, bFaculty of Civil and Environmental Engineering,Universiti Tun Hussein Onn Malaysia, Procedia - Social and Behavioral Sciences 195 (2015) 2868 – 287

[16] Omar, I.H, et al., (2003) National report of Malaysia on the Formulation of transboundary diagnostic analysis and preliminary framework of a strategic action programme for the Bay of Bengal. Prepared for FAO and the BOBLME Programme, 88 pages.

[17] Chislock, F., M., Doster, E., Zitomer, A., R., and Wilson, E., A., (2013) Eutrophication: Causes, Consequences, and Controls in Aquatic Ecosystems. Department of Fisheries and Allied Aquacultures, Auburn University, Nature Education

[18] Teen, P.,L., Gires, U., and Pin, C., L.,(2012) Harmful Algal Blooms in Malaysian Waters. Faculty of resource Science and Technology Universiti Malaysia Sarawak, Kota Samarahan, Sains Malaysiana 41(12)(2012): 1509–1515.

[19] Anton, A., Teoh, P., L., Mohd-Shaleh., R. S., and Mohammad-Noor, N. (2008) First occurrence of Cochlodinium blooms in Sabah, Malaysia. Biotechnology Research Institute, Universiti Malaysia Sabah, Kota Kinabalu, Sabah, Malaysia. Harmful Algae 7 (2008) 331– 336

[20] Ismail, Z, Sulaiman, R, and Karim, R. (2014) Evaluating Trends of Water Quality Index of Selected Kelang River Tributaries, Civil Engineering Department, University of Malaya, Environmental Engineering and Management Journal, January 2014, Vol.13, No. 1, 61-72

[21] Adnan, M.S., Shimatani, Y., and Abd-Rashid, Z,. (2011). Anthropogenic impacts on water quality and water resources of the Pahang River, Malaysia, 5th International Symposium on Integrated Water Resources Management, IWRM 2010 and the 3rd International Symposium on Methodology in Hydrology.

[22] Sh, A. T., Sin, S. H. and Ms, A. (2018) 'A STUDY OF NUTRIENT DISTRIBUTION IN SEDIMENT LAYER AT', MATEC Web of Conferences 150, 3009, pp. 1–6

[23] Bonsdorff, E., Blomqvist, M., E., Matilla, J., and Norkko, A., (1997) Coastal Eutrophication: Causes, Consequences and Perspectives in the Archipelago Areas ofthe Northern Baltic Sea. Department of Biology, Abo Akademi University, Emkarby, Aland Islands, Finland. Estuarine, Coastal and ShelfScience (1997) 44 (Supplement A), 63-72

[24] Wu, C., Maurer, C., Wang, Y., Xue, S., and Davis, L, D. (1999) Water Pollution and Human Health in China, World Resources Institute, Washington, DC,USA; National Conditions Analysis Group, Chinese

Academy of Sciences, Beijing, China; School of Public Health, Shanghai Medical University, Shanghai, China, Environmental Health Perspectives - Volume 107, Number 4, April 19

[25] Sharip. Z. and Zakaria. S. (2008) Lakes and Reservoir in Malaysia: Management and Research Challenges. National Hydraulic Research Institute of Malaysia (NAHRIM). Proceedings of Taal2007: The 12th World Lake Conference: 1349-1355

[26] Minnesota Water Quality Association (2017) http://www.mwqa.com/consumerinformation/types-of-water-treatment-systems/

[27] Rodriguez-Narvaez, M., O., Peralta-Hernandez, M., J., Goonetilke, A., and Bandalla, R., E., (2017) Treatment technologies for emerging contaminants in water: A review, Universidad de Guanajuato, Guanajuato, Mexico, Chemical Engineering Journal 323 (2017) 361–380

[28] Moussa, T., D., El-Naas, H., M., Nasser, M., and Al-Marri, J., M., (2017) A comprehensive review of electrocoagulation for water treatment: Potentials and challenges. Gas Processing Center, College of Engineering, Qatar University, Doha, Qatar. Journal of Environmental Management 186 (2017) 24-41

[29] H. Abu Hasan, S.R. Sheikh Abdullah, A.W.N. Al-Attabi, D.A.H. Nash, N. Anuar, N. Abd. Rahman, H. Sulistiyaning Titah, (2016) Removal of ibuprofen, ketoprofen, COD and nitrogen compounds from pharmaceutical wastewater using aerobic suspension-sequencing batch reactor (ASSBR), Sep. Purif. Technol. 157 (2016) 215-221.

[30] Q. Sui, J. Huang, S. Deng, W. Chen, G. Yu. (2011) Seasonal variation in the occurrence and removal of pharmaceuticals and personal care products in different biological wastewater treatment processes, Environ. Sci. Technol. 45, p 3341–3348.