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REVIEW ON BOD, COD AND BOD/COD RATIO: A TRIANGLE ZONE FOR TOXIC, BIODEGRADABLE AND STABLE LEVELS

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ABSTRACT

This paper reviewed research works on biodegradability of organic matter containing materilas, attempting to provide a tool for treatment and monitoring strategies. Organic matter parameters were simplified as BOD, COD and BOD/COD ratio. Treatment methods were classified into natural, physical, chemical, biological, phytotechnological and combined treatment. For various operating conditions, it was formulated the zonation of the BOD/COD ratio and characterized by the limits of toxic, biodegradable and acceptable or stable zones.

Key words: BOD, COD, treatment methods, BOD/COD zones

1. INTRODUCTION

Various compounds of organic matter containing materials can be measured in two simple parameters, i.e. biochemical oxygen demand (BOD) and chemical oxygen demand (COD). It is well known that BOD is a standard test for assaying the oxygen-demanding concentration of microbes to degrade organic matter over a given time period, usually 5 days but can be extended to 30 days. COD is a standard test for water to consume oxygen in the form of potassium dichromate during the degradation of organic matter and inorganic chemicals such as ammonia and nitrite for few hours. The potassium dichromate is not specific to oxygen-consuming chemicals either organic or inorganic and therefore, both chemicals are included in COD. As a results, the BOD/COD ratio should be equal or less than 1.0.

Facing to untreated materials such as raw water, wastewater and leachate landfill, on one side, the BOD/COD ratio is higher than 0.5. Leachate sample of young landfill contains high concentrations of BOD and COD, i.e. 60.000 mg/L and 130.000 mg/L respectively [1]. The high BOD/COD ratio can be found in natural waters, which contains BOD of less than 10 mg/L and COD of less than 20 mg/L for yearly turnover [2]. On the other side, the BOD/COD ratio is lower than 0.5. The low BOD/COD ratio can be found in an industrial wastewater, which contains low BOD concentration of less than 100 mg/L and high COD concentration of more than 800 mg/L [3]. The low BOD/COD ratio can be found in seawater, which contains low concentrations of BOD and COD, i.e. less than 14 mg/L and 46 mg/L respectively [4]. Therefore, BOD/COD ratio as such is meaningless without introducing the purpose of using it.

However, researchers used to describe BOD/COD ratio as biodegradability level of materials by which organic matter containing wastewater is readily broken down in the environment. This paper reviewed research works on treatments of organic matter containing materials, attempting to figure out the zonation for the BOD/COD ratio as a useful tool to decide treatment system and environmental monitoring strategies.

2. MATERIALS AND METHODS

Research works were selected according to: 1) the initial BOD and COD concentrations, which cover less than 100 mg/L, 100-1.000 mg/L and more than 1.000 mg/L each; 2) methods of treatment for increasing biodegradability and/or stabilization, i.e. natural, physical, chemical, biological, phytotehnological treatments; 3) process parameters such as detention time, temperature, pH; and 4) climatic conditions. The results of treatment system were classified into single treatment, i.e. natural, physical, chemical, biological, and phyto treatments as well as combined treatment. Based on the treatment classification, zonation of BOD/COD ratio is figure out in connection to the initial BOD and COD concentrations.

3. RESULTS AND DISCUSSION

Treatments of organic matter containing materials

Natural treatment. By natural treatment means an organic materials is decomposed naturally or without man-made intervension such addition of chemicals. The decomposition runs due to detention time as long as the materials placed in an environment. For high concentrations of BOD and COD as well as BOD/COD ratio of leachate decrease with time in a landfill, resulting in the stability of leachate. Chian and DeWalle [5] reported that the BOD/COD ratio decreased rapidly from 0.70 to 0.04 with the aging of the landfills. The degree of solid waste stabilization have a significant effect on leachate characteristics, resulting in low BOD/COD ratio and fairly high concentration of NH3-N. Since a young landfill contains the BOD/COD ratio of greater than 0.5 and the ratio decreased approaching to 0.1, the landfill can be considered old and stable. El-Fadel et al. [1] found that a young landfill leachate contains BOD 60.000 mg/L and COD 100.000 mg/L and the BOD/COD ratio of 0.5-0.8 has fallen below 0.3 during 14 months, confirming that the waste was well into moderately stable stage.

However, investigation of low concentrations of BOD, COD and BOD/COD ratio in ponds was conducted by Abdo [2]) during a year for four successive seasons (winter 2003 to autumn 2003). BOD concentrations ranging from 1.20 to 4.80 mg/L were observed during cold period whereas the BOD levels were observed ranging from 3.50 to 10.00 mg/L during hot period. COD concentrations in the range of 4.40 – 9.20 mg/L were recorded during cold period, and ranging from 10.00 to 18.00 mg/L during hot period. The ranges of BOD/COD ratio were 0.28 – 0.59, 0.43 – 0.93 and 0.24 – 0.71 in three different ponds during a year investigation period. The periodic trend of the BOD/COD ratio were not identified and therefore, BOD and COD concentrations were fluctuative in the limits of stable levels.

As demonstrated by the same detention time for organic matter reduction in natural conditions, the high initial concentrations of BOD and COD in thausand level brought about decreasing the BOD/COD ratio. In contrast, the low initial concentrations of BOD and COD of less than 20 mg/L each were in stable state. Therefore, the significant different results for the BOD/COD ratio may be atributable by the initial BOD and COD concentrations.

Physical treatment. By physical treatment means that organic matter removal runs by means of separation or fractionation processes. An ultra filtration (UF) membrane process is commonly used as a sieving process for separation, concentration and fractionation. When solute is carried to the membrane surface by solvent, the solvent passes through the membrane while the solute is intercepted. Molecules of larger than the pore size of the membrane can not pass through, resulting in the accumulation of the molecules. The rest small molecules pass through as solvent. An attempt to increase biodegradability of landfill leachate by means of single UF process was carried out by Kewu and Wenqi [6]. Leachate influent contains BOD and COD on average 925 mg/L and 18.700 mg/L respectively that amounted BOD/COD ratio was 0.05. The solute passed through the UF membrane with various pressure difference between the two sides of the membrane (ΔP), ranging from 0.1 to 1.3 MPa. COD concentration decreased as ΔP increased, resulting in an increase of BOD/COD ratio in the range of 0.25-0.40.

Chemical treatment. Wastewater of textile industry, containing BOD 175 mg/L and COD 774 mg/L and BOD/COD ratio 0.22 was treated using inorganic and organic coagulants [7]. Treatment variables were varian I (ferric chloride 200 mg/L $FeCl_3$ + 1 mg/L anionic polyelectrolite), varian II (aluminium hydrochlorosulphate 32 mg/L Al^{3+} + 2 mg/L anionic polyelectrolite), varian III (organic coagulant DEC65 1 mL/L). The BOD/COD ratio following treatment by varian I, II and III were 0.41, 0.41 and 0.39 respectively.

Aslam et al. [8] studied the characterization of BOD and COD of textile industry processing wastewater by addition of oxidants namely hydrogen peroxide, sodium hypochlorite, calcium hypochlorite, potassium dichromate and calcium dichromate at temperatures 25^{o}C, 50^{o}C and 100^{o}C and detention time 5min, 90min and 1.440min. The initial BOD and COD were 300 mg/L and 400 mg/L respectively, and the BOD/COD ratio was 0.75. For various operating conditions, it was demonstrated that addition of sodium hypochlorite or calcium hypochlorite resulted in the decrease of BOD/COD ratio in the range of 0.5-0.6. Addition of sodium hypochlorite or potassium dichromate brought about a slight increase of the BOD/COD ratio at the level of 0.8.

An investigation to enhance biodegradability was carried out using ozon. For the initial BOD concentrations in the range of 150 - 600 mg/L, the initial COD concentrations ranging from 1.500 to 2.100 mg/L, and the ranges BOD/COD ratio of 0.08-0.27, ozon addition resulted in an increase BOD/COD ratio, ranging from 0.17-0.32 [9].

Biological treatment. Borglin et al. [10] investigated lechate treatment in aerobic and anaerobic with and without resirculation for 1 year detention time. The results showed that in aerobic tank, BOD 200 mg/L influent, COD 2.200 mg/L influent and BOD/COD ratio 0.09; BOD effluent 4 mg/L, COD effluent 159 mg/L and BOD/COD ratio 0.03. In anaerobic tank, BOD 800 mg/L influent, COD 3.800 mg/L, BOD/COD ratio 0.21; BOD effluent 137 mg/L, COD effluent 305 mg/L and BOD/COD ratio 0.45. It demonstrates that aerobic treatment resulted in stabilization whereas in anaerobic treatment increases biodegradation.

However, an investigation for fresh leachate in batch and semi-continous anaerobic treatment [11] resulted in different end-results. The fresh leachate contains BOD of about 30.000 mg/L, COD 55.000-60.000 mg/L and BOD/COD ratio of 0.5-0.55. In batch treatment, BOD reduced to 4.500 mg/L and COD reduced to 31.000 mg/L and BOD/COD ratio reduced to 0.14 during 3 months. In semi-continous treatment, BOD reduced to 3.000-7.000 mg/L and COD reduced to 26.000-35.000 mg/L and BOD/COD ratio reduced to 0.11-0.2 during 1 month. The results revealed that anarobic microorganisms could treat high concentrations of organic matter even it was proceed long time.

The different results for anaerobic treatment between the two investigations may be attributable by the initial concentrations of BOD and COD. High initial concentration of BOD and COD resulted in reduction of BOD/COD ratio for short detention time (1month) whereas BOD/COD ratio increased for longer time (1 year).

Phytotreatment. A research carried out by Mangkoedihardjo [3] investigated the performance of a low BOD/COD ratio, ranging from 0.05 and 0.11 by means of phytotreatment using a plant species *Eichhornia* *crassipes*. The initial concentrations of BOD and COD were less than 100 mg/L and 1.000 mg/L respectively. The hyacinth treatment in a batch reactor demonstrated that the final BOD/COD ratios increased ranging from 0.3 and 0.5 during 2 months. The hyacinth treatment performances on increasing biodegradability were dependent on the initial COD concentration. For the initial COD of less than 500 mg/L brought about the increasing rate of the BOD/COD ratio was 1.5 times faster than for the initial COD of more than 500 mg/L.

A constructed wetland unit with horizontal and vertical flow and planted with a plant species *Phragmites australis* was carried out by Baskar et al. [12]. The influent flow was chracterized by BOD 265 mg/L and COD 683 mg/L on average. The effluent flow contained BOD 65 mg/L and COD 433 mg/L during 1 month. Therefore, the BOD/COD ratio decreased from 0.39 to 0.15, revealing stabilization of the flow.

The significant different conditions for the two phytotreatments above were flow system and the plant species. More importantly, at the limits of initial BOD and COD up to 100 mg/L and 1.000 mg/L respectively, there was a sign of organic matter toxicity containing COD of more than 500 mg/L that resulted in decreasing the biodegradability rate of organic matter. However, when the limits of initial BOD of more than 200 mg/L could attenuate the initial COD of more than 500 mg/L, resulting stabilization of organic matter.

Combined treatment. Increasing biodegradability of landfill leachate by means of coagulation and ultrafiltration (UF) processes was carried out by Kewu and Wenqi [6]. The combination of coagulation and UF increased the BOD/COD ratio from 0.05 to 0.42 for influent that contains BOD and COD on average 925 mg/L and 18.700 mg/L respectively. Many reseracher carried out various combined treatments that all were attempted to improve biodegradability more effective and efficient.

Zonation of BOD/COD ratio

The BOD/COD ratio is nothing less than an indicator for the outcome effect of organic matter containing materials (notably water, wastewater, leachate, compost and other similar materials) in environmental components of natural and man-made environment (water resources, wetland, soil, solid waste landfill, agricultural land, stabilization pond, water and wastewater treatments and other similar components). Accordingly, the BOD/COD ratio could be classified into zones in which the organic matter containing materials will be treated or disposed. The following classifications are proposed and strategies for problem solving are described.

Toxic zone. By toxic zone means the limit of organic mater that potentially has an adverse effect towards living organisms. The living organisms consist of microbes, plants and aquatic animal. Wang et al. [13] introduced biodegradability as the mass concentration ratio of BOD/COD is the ability of a substance to be broken down into simpler substances by bacteria. The BOD/COD ratio of less than 0.10 reveals the presence of large portions of hard-biodegradable COD. Some non-biodegradable organic molecules such as humic and fulvic acids in the landfill leachate are also characterized by very high contents of dissolved salts, notably chlorides, sodium, carbonates and ammonium [14]. Those organic molecules contributed the low BOD/COD ratio for toxic zone.

Alkassasbeh et al. [15] carried out acute toxicity testing of landfill leachate on behavior of common carp (*Cyprinus carpio* L.) for 96 hours exposure. Three leachate characteritics on BOD and COD were as follows. Leachate AHL contains BOD and COD as much as 1.228 mg/L and 7.600 mg/L respectively with counted BOD/COD ratio of 0.16. Leachate ATL contains BOD and COD as much as 866 mg/L and 3.733 mg/L respectively with counted BOD/COD ratio of 0.23. Leachate SSL contains BOD and COD as much as 507 mg/L and 1.640 mg/L respectively with counted BOD/COD ratio of 0.30. The lethal concentration of leachate by which 50% carp population was not alive at the end of 96 hours (LC50-96h) showed that leachate AHL, ATL and SSL were 1.132%, 2.001% and 3.822% respectively. The results revealed that concentrations of BOD, COD and BOD/COD ratio determined the lethal effect on carp. As BOD and COD increased and BOD/COD ratio decreased, the lethal effect on carp increases.

From the mentioned research works on biological, phytotechnological and toxicological treatments, the Author summarizes the toxic zone for BOD and COD to ensure further treatment runs well for various process conditions as follows (Fig. 1):

1) The maximum BOD/COD ratio is 0.10.
2) The minimum BOD concentration is 10 mg/L for aquaculture treatment, 100 mg/L for microbial and phytotreatments, 50.000 mg/L for natural treatment.
3) The minimum COD concentration is 50 mg/L for aquaculture treatment, 500 mg/L for microbial treatment and phytotreatments, 100.000 mg/L for natural treatment.

Biodegradable zone. By biodegradable zone means the limit of organic mater that can be decomposed by microbes in natural and man-made treatment conditions. Since the toxic zone has been identified, the biodegradable zone is as follows (Fig. 1):

1) The limits BOD/COD ratio is between 0.1 and 1.0. This zone may be segmented into several levels such as low, moderat and high biodegradable that requires further study.
2) The maximum BOD concentration is 10 mg/L for aquaculture treatment, 100 mg/L for microbial and phytotreatments, 50.000 mg/L for natural treatment.
3) The maximum COD concentration is 50 mg/L for aquaculture treatment, 500 mg/L for microbial treatment and phytotreatments, 100.000 mg/L for natural treatment.

Acceptable and/or stable zones. Acceptable zone means that the limit of organic matter that can be safely disposed in environment without significant effect on the overall quality of the environment. Acceptable zone is connected to the quality standard for environmental components that is vary among countries. However, the acceptable zone can be generalized as below biodegradable zone. Within the acceptable zone, organic matter may undergo decomposition at slow rate and finally cease the so called stable zone.

Fig. 1. presented a simple picture, showing the zonation of the BOD/COD ratio that characterized by BOD and COD concentrations.

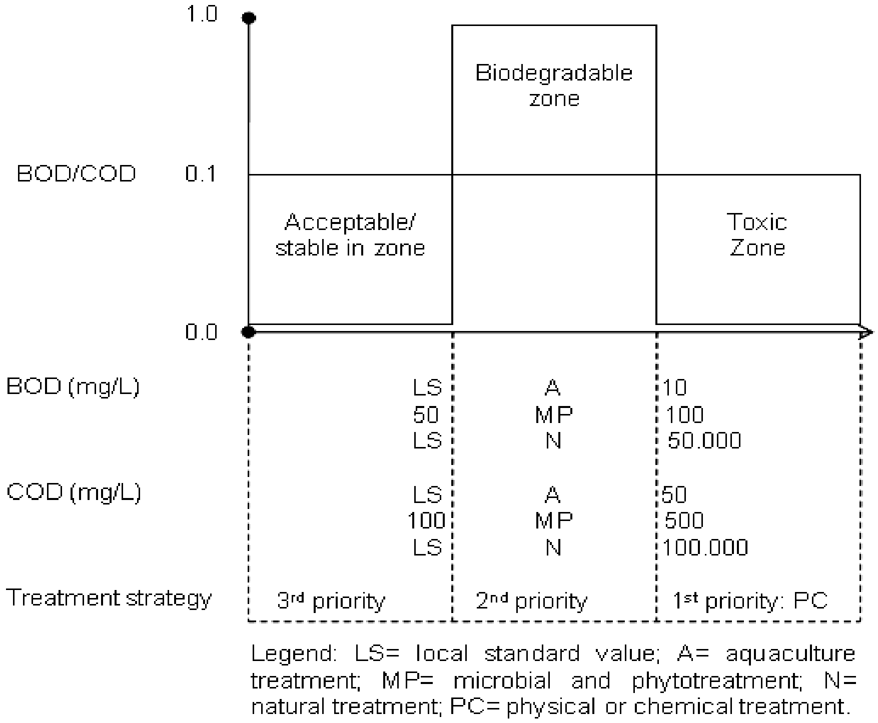

Fig. 1. *Triangle zones for BOD/COD ratio*

Treatment strategy. By using the triangle zones, strategies for problem solving can be proposed. For example, assume that organic matter containing wastewater is characterized by BOD 500 mg/L, COD 5.000 mg/L, and the BOD/COD ratio 0.1. The wastewater will be treated by aerobic microbial treatment. For microbial treatment, the wastewater characteristics is in toxic zone. The first priority is to transform the toxic wastewater into biodegradable wastewater. Transformation can be carried out by a chosen treatment method such as physical and chemical treatment to achieve output BOD < 100 mg/L, COD < 500 mg/L and BOD/COD ratio > 0.1. Following physical or chemical treatment, the wastewater is safe to be treated by biological treatment or phytotreatment to reach acceptable/stable zone for disposal.

4. CONCLUSION

Initial BOD and COD concentrations determined the biodegradability of organic matter containing materials. As a results, the BOD/COD ratio can be categorized into toxic, biodegradable and acceptable or stable zones. By zonation of the BOD/COD ratio, one may identified the treatment strategy to achieve the safe levels of organic matter in an environment.

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