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Determination of Deoxygenation Rate Constant for BOD Reaction in Mongolia

Bachelor Thesis

Presented by

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Abstract

The objective of this study was to estimate the deoxygenation rate constant and the ultimate BOD of WWTP effluent in Mongolia. The deoxygenation rate was determined and tested in April, 2019. The Deoxygenation rate was 0.31 /day which is a bit higher than values from other countries. The ultimate BOD was in the range of 92- 115 mg /L. Biological oxygen demand values did not meet the limits recommended by the Mongolian National standard throughout entire study period.

This knowledge of ultimate BOD, the rates of deoxygenation in BOD reaction can be significantly valuable for designing reliable of biological treatment processes in WWTP.

Statutory Declaration

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I hereby affirm in lieu of an oath that I provided the submitted bachelor thesis

DETERMINATION OF DEOXYGENATION RATE CONSTANT FOR BOD REACTION IN MONGOLIA

Independently and without undue external help. I did not use any sources other than those stated. In case that the work is additionally submitted on a data medium, I declare that the written and the electronic form are completely identical. The work was not submitted in the same or similar form to any examination authority.

Nalaikh, 5/3/2019	
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ABBREVIATONS

ASP	Activated Sludge Process
BOD	Biochemical Oxygen Demand
BOD5	Biochemical Oxygen Demand (5 days)
COD	Chemical Oxygen Demand
CWWTP	Central Wastewater Treatment Plant
DO	Dissolved Oxygen
EPA	Environmental Protection Agency
l	Liter
m	Meter
m3	Cubic meters
mg	Milligram
WWTP	Wastewater Treatment Plant
WWPP	Wastewater Pretreatment plant

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1. INTRODUCTION

Water is the essential basis for all forms of life. Pollution from urban runoff, sediments, industrial effluents, and wastewater has been greatly blamed on the higher levels of pollution in the Tuul River. Urbanization, industrial development as well as agricultural production have a significant impact on the quality and quantity of the resource water. Developing countries are facing huge challenges in wastewater and pollution. Urban pressures due to urbanization and rapid industrialization with less upgrading of effluent treatment facilities and expansion, has aggravated these challenges. Under the high pressure of population growth, Ulaanbaatar faces a lot of challenges in various sectors related to environmental issues including wastewater, solid waste and soil contamination. Especially the augmentation of municipal wastewater and solid wastes in urban areas can be seen as a direct consequence of the rapidly growing urbanization rate. Today, the lacking coverage of sewage disposal is based on slower developments of urban infrastructures in the municipal areas. In fact, the capacity of wastewater treatment is still limited. In the majority of cases, incomplete treating wastewater is discharged directly or indirectly into surface waters through the polishing pond and infiltrates the groundwater resource. Insufficiently treated or completely untreated wastewater from industries and enterprises in the Ulaanbaatar and Nalaikh district draining into Tuul River is the basic reason of river water pollution.

Since 1964 WWTPs has started to put into operation in Mongolia. After 90s' number of WWTPs abandoned and stopped its operation. According to 2010 records, there are 18 domestic WWTPs, 9 industrial WWPPs and in total 27 WWTPs in Ulaanbaatar. The daily average of 160-170 thousand m^3 wastewater is discharged into Tuul River from WWTPs operating in the Tuul river basin. It deteriorates the self-purifying process of river water and leads partly to a potential threat to human health and the environment (1). Starting from the point at Nalaikh where treated wastewater discharges into the Tuul River from Nalaikh WWTP and from the Ulaanbaatar CWWTP until the point where the river passes through Lun soum center of Tuv aimag, river is significantly polluted due to WWTP out of date equipment and technology, unsatisfactory primary cleaning of the industries and enterprises wastewater, insufficient capacity (1). In 2012 (1) reported that treatment productivity is no more than 60-70 percent. According to (1) (2) the river water in this section was determined as impossible to be consumed as drinking water and inappropriate to consider the surface water in this part as a possible usable water resource. The effluents from any WWTP in a remote or pre-urban area where is not closely located to any rivers or streams are mostly discharged into polishing ponds.

After the transition period of Mongolian new economic and social system, there were abandoned and unused many WWTPs of service. One of the abandoned WWTPs was in Gordok Town, Nalaikh, which is located in the Upper Tuul River Basin. Hence, wastewater from Gordok town in Nalaikh District used to be discharged directly into the upper part of The Tuul River without treatment until the WWTP renovation in 2016.

1.1. Statement of the Problem

The treated wastewater of the CWWTP is included in the 'extreme polluted' category of the surface water standard due to the concentration of dissolved oxygen (3). The water use of Ulaanbaatar has increased considerably by cause of the rapid industrial development and population growth, somewhat due to the migration from rural areas (4). The water supply of the capital city wholly hinges on groundwater abstraction from the alluvial aquifer of the Tuul River Basin because surface waters freeze during winter (4).

Tuul river pollution used to be self-purified at 100 km. In present, it does not treat itself at this distance. It has negative impacts on river water quality, ecological condition and hydrobiological regime (1). The groundwater quality of the river floodplain might be affected by municipal pollution of the Tuul River near Ulaanbaatar city since the groundwater system surrounding Ulaanbaatar recharges from both the Tuul River and from precipitation (1, 4).

For the last decades as the runoff decrease in river occurs while evaporation increases, many rivers, ponds, springs, and lakes have disappeared. It is estimated that the total evaporation will increase by 6-10 times than precipitation based on summarizing the total surface evaporation studies (5) in the first half of the 21st century. Created an opportunity to collect the treated wastewater in specifically designed ponds without delivering it into the Tuul River and the Central WWTP.

The most of wastewater treatment plant is operated by biological treatment with aeration processes in Mongolia. The higher the BOD/COD ratio the more amenable the wastewater is to biological treatment. Although there are conventional treatment facilities such as activated sludge systems, aeration tanks, trickling filters, waste stabilization ponds system has been found to be an appropriate technology for most developing tropical nations where land and labor are still relatively cheap and the climate favors natural operations at a tropical temperature. However, in our harsh climate country, there is no evidence that the rate constant could be used for design was based on empirical data.

For the design of biological treatment processes such as trickling filters, activated sludge units, waste stabilization ponds such as primary oxidation ponds facultative anaerobic ponds and maturation ponds, the knowledge of ultimate BOD, the rates of deoxygenation in BOD reaction are essential and important. Therefore, it needs to describe the deoxygenation rate constant in the condition of our country in order to level up the efficiency of wastewater treatment.

1.2. Study aim and Objective

This thesis has the following objectives:

- To study the effects of rate deoxygenation
- To determine the rate deoxygenation in Mongolian condition and its differences from other countries

The main aim of the study was to estimate the rate of deoxygenation of BOD reaction in wastewater in Mongolian condition using effluent from WWTP in Gorodok town of Nalaikh.

1.3. Hypothesis

The BOD removal rate of effluents in Mongolian condition might be different than in other countries due to its harsh climate.

2. STATE OF THE ART

The situation in Mongolia is very typical for urban areas in developing countries, where collection and suitable discharge or treatment of wastewater are insufficient. In 1964, urban areas' wastewater treatment was generally established in Mongolia by introducing science-based advanced technologies and operating control systems on a regular basis with the assistance from developed countries (1). It was an important contribution to prevent negative impacts of wastewater discharge on the environment and the natural ecology system.

The Ulaanbaatar's sewerage system includes 147.7 km long sewerage pipelines, a Central wastewater treatment plant with treating capacity of 230.0 thousand m3 /per day. There are 27 WWTPs in 7 districts of Ulaanbaatar. As of 2010, there were 15 domestic WWTP, a mining camp domestic WWTP, a skiing camp domestic WWTP, 2 hospital WWPP, 5 tannery, wool and cashmere industrial WWPP and 2 meat processing industrial WWPP in Ulaanbaatar City (1).

The Tuul River originates from the Baga Khentii Mountain and flows into the Orkhon river, the main tributary of the Selenge River which is part of the Arctic Ocean basin. As of 2010, the Tuul River Basin comprised 43% of Mongolia's population or 1.19 million people and 2.72 million livestock. In Mongolia, the basin has the highest water demand and importance by its socio-economic development since the most economic activities including thousands of economic entities, food processing industries, construction activities, building material industries, quarries, and crop production, etc. take place in the basin (1). The highest renewable groundwater resources are found in the upstream part at 160 mm/year km^2 and along the river valley at 40-100 mm/year km

2.1. Biological Wastewater Treatment

2.1.1. Activated Sludge Process (ASP)

Typical wastewater treatment plants have the three basic steps of wastewater treatment, which are mechanical, biological and chemical treatment. Majority of the municipal WWTP in Mongolia uses biological process especially ASP for the treatment. Different biological treatment processes exist besides ASP. For instance: sequencing batch reactor (SBR); trickling filter (TF); rotating biological contactor (RBC); anaerobic contact process (ACP); anaerobic filter (AF); upflow anaerobic sludge blanket (UASB) and anaerobic fluidized bed reactor (AFBR).

There are two main types of wastewater treatment processes which are suspended growth process and attached growth process

1. Suspended growth process — The microorganisms are kept in suspension in a biological reactor by suitable mixing devices. The process can be aerobic or anaerobic. Examples of suspended growth processes include activated sludge process, sequencing batch reactor, ponds and lagoons, digesters, etc.

2. Attached growth process — The microorganisms responsible for bioconversion attach themselves onto an inert medium inside the reactor, where they grow and form a

layer called biofilm. The wastewater flowing through the reactor comes in contact with the biofilm, where conversion and removal of organic matter take place. The inert medium is usually rock, gravel, slag, or synthetic media. The process can be operated aerobically or anaerobically. Examples are trickling filters, bio towers, and rotating biological contactors (RBCs).

A conventional ASP consists of standard pretreatment steps, an aeration tank, and a secondary clarifier as shown in Fig. 1.

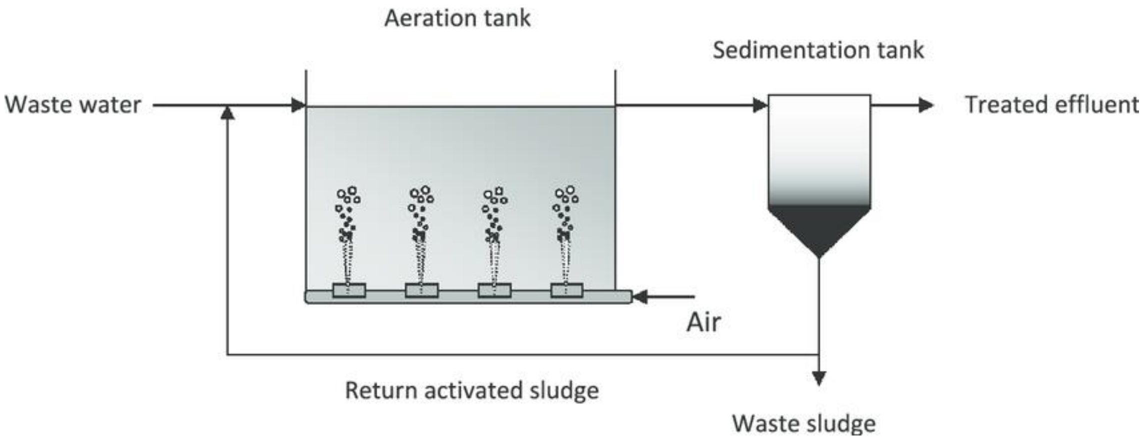

Figure 1: Typical steps of domestic wastewater treatment by ASP (6)

Wastewater flows continuously into the aeration tank or biological reactor. Air is introduced to mix the wastewater with the microorganisms, and to provide the oxygen necessary to maintain aerobic conditions. The microorganisms degrade the organic matter in wastewater and convert them to cell mass and waste products. The mixture then goes to the secondary clarifier, where clarification of effluent and thickening of settled solids takes place. The clarified effluent is discharged for further treatment or disposal. The thickened solids are removed as underflow. A portion of the underflow is wasted (called waste activated sludge, WAS), while the remainder (20% to 50%) is returned to the aeration tank as return activated sludge (RAS). There turn sludge helps to maintain a high concentration of active biomass in the aeration tank.

A large number of variations of the activated sludge process have been developed and are currently in use. Descriptions of these processes are provided later in this chapter. The biological reactor may be operated as completely mixed (continuous flow stirred tank reactor, CSTR) or plug flow reactor. In recent times, activated sludge processes are used more frequently for BOD removal in conjunction with removal of nitrogen and/or phosphorus. The importance of the reaction rate constant “k” for BOD is that “k” values must be known for a particular environmental condition for proper evaluation of ultimate BOD status.

2.1.2. Natural Purification Mechanism

Microbial degradation is one of the natural purification mechanisms such as dilution, sedimentation, filtration, and heat transfer, etc. active in streams and river to diminish the levels of the pollutants to acceptable or negligible concentrations. The processes are slow and can refine the health of water bodies over a period of time, depending on the concentration of the pollutants. Nowadays, as industrialization has increased, so natural purification mechanisms become insufficient to reduce the levels of pollutants. Engineered systems, designed based on the principles of natural purification processes, are used for wastewater treatment plants to reduce the pollutant concentrations to acceptable levels in a short period of time prior to discharge to streams and rivers. The difference lies in the rates of reaction and conversion.

Municipal wastewater contains a large amount of organic matter. When it is drained into streams and rivers without treatment, the organic matter is used as food by bacteria, protozoa, and other microorganisms in the water bodies. Oxygen consumption of aerobic microorganisms during aerobic oxidation of organic matter causes an extensive oxygen demand in the water body and can lower the dissolved oxygen concentrations significantly. The oxygen in water bodies is replenished by transfer from the atmosphere.

Mostly, the organic matter content in wastewater is measured by parameters of 1-biochemical oxygen demand (BOD), 2-chemical oxygen demand (COD), and 3-total organic carbon (TOC). BOD is the most widely used parameter for measuring the amount of biodegradable organic matter present in wastewater. Standard BOD test results are obtained after five days. This is described in more detail in the following section.

2.1.3. Biochemical oxygen demand (BOD)

BOD denotes the amount of biodegradable organic matter that is present in wastewater. BOD is defined as the amount of oxygen utilized by different types of microorganisms during aerobic oxidation of organic matter at a controlled temperature of 20°C for a specified time. BOD is one of the most important parameters for the design and operation of a water pollution control plant because it is used as a measure of not only the amount of organic pollution in water body but also the strength of sewage.

Actually, the complete degradation of organic matters by microorganisms takes time usually 20 days or more under ordinary circumstances. 20-days is the period when the oxidation of the carbonaceous organic material is about 95% complete. In the wastewater industry, the BOD_5 in mg/L of O_2 is used as a standard value that is obtained from a BOD test conducted for five days. It is assumed that about 60% to 70% of the organic matter is oxidized after five days. The total amount of oxygen used to stabilize all the organic matter present in a given volume of water is called ultimate BOD, or BOD_{L}.

After six to seven days the nitrifying bacteria will also exert a measurable demand if the wastewater contains proteins and other nitrogenous matter. The slow growth rate of the nitrifying bacteria, as compared with the growth rate of the heterotrophic bacteria responsible for the exertion of the carbonaceous oxygen demand typically known as carbonaceous BOD or simply BOD, causes the delay in the exposition of the nitrogenous oxygen demand (NOD).

Dissolved Oxygen (DO) is the amount of oxygen dissolved in water that is available to sustain life. DO exert a greater influence on the type of organisms found in a water ecosystem. The local oxygen supply may deplete faster than it is replenished. When the BOD levels from decomposition are higher than the local DO content in the water, there is not enough oxygen left for other organisms causing them to die.

Higher DO levels indicate good quality water whilst the low level of DO reflects high water pollution. The low dissolved oxygen content from most of the sampling sites is an indicator of high organic contamination (7). Presence of high concentration of DO can even balance the noticeable toxicity of CO2. An input of the DO in a water body is mainly due to atmospheric diffusion through the water surface and partly due to its production by photosynthesis. Temperature directly affects the amount of oxygen in water—the colder the water, the more oxygen it can hold (8).

2.1.3. BOD kinetics

Among the deterministic representations proposed to describe mathematically deoxygenation kinetics of a wastewater, first-order kinetics is the most widely accepted model. The model was originally proposed by Streeter and Phelps (9) and later developed by Theriault (10). The ultimate BOD (L) and the first-order rate coefficient (k) are the parameters for deterministic first-order BOD kinetics. Meanwhile, reliable values of these parameters are necessary for adequate use of the model, particular attention have therefore been paid to the parameter estimation issue (11).

Peavy et al. assumed that the rate at which organic matter is utilized is proportional to the amount of organic matter remaining (11). This is expressed as follows:

$$\frac{dL_t}{dt} = -kL_t \tag{1}$$

Where:

L_t= oxygen equivalent of organic matter remaining at time t, mg/L

k = reaction rate constant, d^{-1}

Integrating and rearranging Equation (1):

$$\int_{L_0}^{L_t} \frac{dL_t}{L_t} = -k \int_0^t dt \tag{2}$$

$$ln \frac{L_t}{L_0} = -kt$$

$$L_t = L_0 e^{-kt} \tag{3}$$

Where:

L_0= oxygen equivalent of total organic matter at time 0.

Since L_0 is the oxygen equivalent of the total amount of organic matter, the amount of oxygen used in the degradation of organic matter, or the BOD, can be determined from the L_t value.

$$BOD_t = L_0 - L_t \tag{4}$$

Substituting equation 3 into equation 4:

$$BOD_t = L_0 - L_0 e^{-kt} \tag{5}$$

The ultimate BOD is equal to the initial total amount of organic matter present in the sample. Thus, (9, 10) work resulted in the use of the following well-known first order reaction equation to describe the deoxygenation kinetics of a waste water:

$$BOD_t = BOD_{ult}(1 - e^{-kt}) \quad (6)$$

For municipal wastewater, values of BOD_{ult} ranges normally from 100 mg/L to 300 mg/L or more. The value of the deoxygenation rate constant k denotes the rate of the reaction and is temperature dependent. The k value increases with temperature because microorganisms are more active at higher temperatures. In order to determine k at any temperature the Hoff-Arrhenius equation is used when k at 20°C is known (10).

$$k_T = k_{20}\Theta^{(T-20)} \quad (7)$$

Where:
Θ = Arrhenius coefficient value, of 1.047 often used for BOD

Θ coefficient is found to be 1.047 as a result of experimental results using both wastewater and river water for the temperature range 10 to 37.5 ° C by Streeter and Phelps (9).

2.1.4. BOD measurement methods

Conventionally, the BOD measurement is carried out according to a standardized method, so-called the closed bottle test, described in the International Standards ISO 5815-1:2003 (12). To determine the microbial diversity found in the environment, these tests are based on microbial samples normally taken from the environment. Reviewing the previous literature of Jouanneau S. et. al (13) classified the BOD assessment methods into the following main technological categories.

a. Modified reference method: improvement of the oxygen measurement
b. Photometric methods
c. Manometric methods
d. Biosensors based on bioluminescent bacteria
e. Microbial fuel cells
f. Biosensors with redox-mediators
g. Biosensors with entrapped bacteria
h. Biosensors based on the bioreactor/chemostat technology

Two criteria are usually used to estimate the BOD, the oxygen consumption (reference method, modified standard methods, immobilized bacteria-based biosensors and bioreactor-type biosensors) and the cellular activity (bioluminescent bacteria based biosensors, microbial fuel cells and mediator-type bio-sensors) due to the biodegradation metabolism.

3. METHODOLOGY

3.1. Sampling Area

Gorodok town WWTP lies at north latitude 47.79° and east longitude 107.41° in Nalaikh, one of the 9 districts of the Mongolian capital of Ulaanbaatar which covers 687 square km area as 2019 statistic information. 32900 inhabitants live in Nalaikh district (14). Based on a UNICEF survey in 2016, 58.2 percent of inhabitants uses drinking water from public water kiosks, 21.9 percent uses drinking water that is piped and connected to the central system, 8.4 percent uses tanker truck, 6.6 percent uses drinking water from bore holes, 2.7 percent uses surface water, 1.6 percent uses protected or unprotected wells or springs and 0.6 percent use other sources in Nalaikh district. Overall 21.8 percent of household population in Nalaikh district is connected to piped sewer system. In addition 61.7 percent of 5th khoroo ,where Gorodok town locates in, has piped sewer system facility (15).

In order to prevent wastewater from flowing into Tuul River, the WWTP in Gorodok Town was commissioned in July 2015 and put into operation in 2016. The facility has projected capacity of treating 1000 cubic meters of water per day using a biological treatment method. However, right now the plant is receiving a daily average of 250 cubic meters of wastewater.

The samples of municipal wastewater effluent were collected from Gorodok WWTP in Nalaikh district on April 2019 repeatedly.

3.3. In Situ Measurements

In-situ measurement and laboratory analysis of parameters are conducted during the study. In situ measurements were taken for pH, temperature and DO using **HANNA multi-parameter.** Sensors used during measurements were:

- HI7698194-2, a replaceable galvanic dissolved oxygen membrane sensor for DO measurement. The HI7698194-2 sensor contains a silver cathode and zinc anode.

- HI7609829-1, containing a glass pH sensing tip with a platinum ORP sensing pin for pH measurement.

3.4. BOD Determination

The BOD was measured on 15 consecutive days in order to estimate the rate constant of deoxygenation. I took 12^{th} days' BOD value as an ultimate BOD for estimation of the rate constant “k” because values were drastically decreased after 12 days. However, for BOD measurement, every sample is mostly analyzed for 15 days using a Lovibond BOD-System BD 600 (Tintometer INC. Sarasota, FL). BOD measurement was carried out by the method of pressure differential in a closed system (respirometry BOD measurement). The Lovibond BOD-System BD 600 is a closed system containing test bottle and BOD detector. There is a gas section with a defined quantity of air within the test bottle. The microorganism in the wastewater filled in the bottle consumes the oxygen dissolved in the sample over the course of BOD measurement. It is substituted by air oxygen from the gas section of the test bottle. At the same time developing carbon dioxide is chemically bound by the potassium hydroxide in the seal cap of the test bottle. Hence, a pressure drop happens in the system, which is measured by the BOD detector and shown directly within the display as a BOD value in mg/l O2.

The measurement system records values each hour on the first day, each alternative hour on the second day, and once every twenty-four hours starting on the third day up to 5th day.

4. RESULTS.

The outcome of the present study is illustrated as follows:

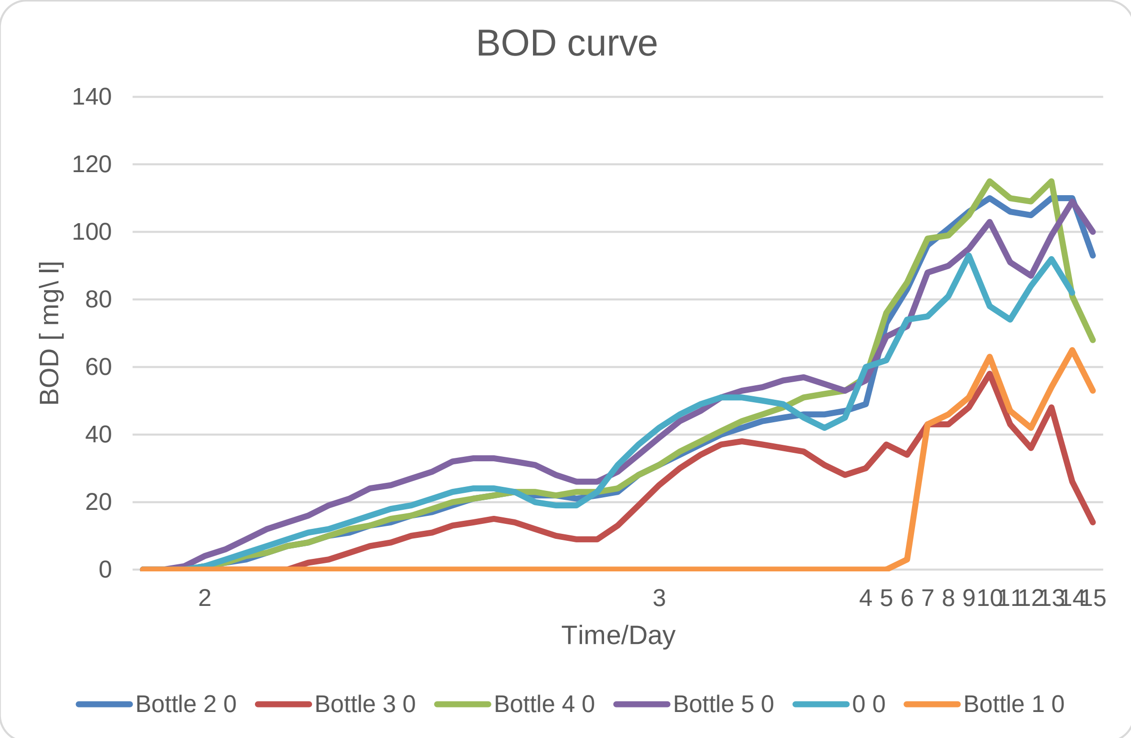

Figure 2: Curve progression of the BOD over time in effluent samples at 20 °C

	Bottle 2	Bottle 3	Bottle 4	Bottle 5	Bottle 6	Average	Standard deviation
BOD_5, mg/L	83	43	85	72	74	71.4	16.8315
BOD_{12}, mg/L	110	48	115	99	92	92.8	26.6214
K, 1/d	0.28093	0.45235	0.26875	0.25986	0.32628	0.31763	0.07953
Temperature, °C	10.99	15.58	10.99	11.04	11.04	11.928	2.04168
pH	7.7	7.45	7.7	7.83	7.83	7.702	0.15515
DO, mg/L	19.35	14.76	19.35	31.01	31.01	23.096	7.46352

Table 1: BOD measurement data

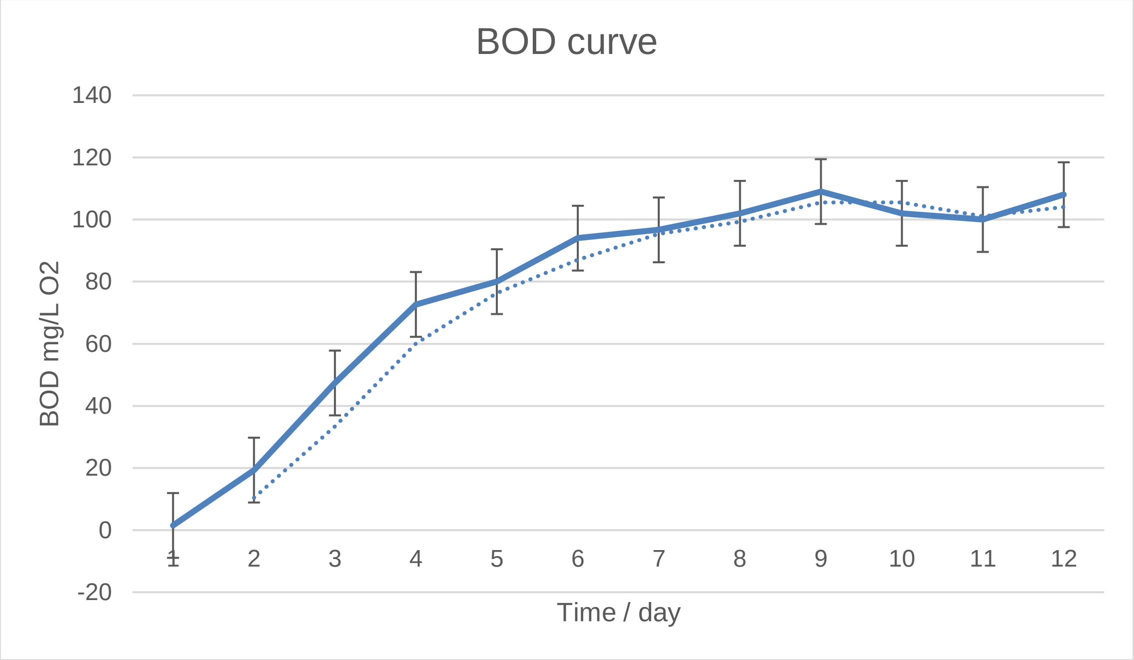

Figure 3: BOD curve for average BOD values obtained from experiment

The effluent pH was in the range of 7.4 – 7.8, with an average value of 7.7. The optimum pH values, where the bacteria can properly dominate for efficient biological treatment, are in the range of 6.5 to 8.0.

5. DISCUSSION

Table 1 shows data of Bottle 1 is excluded from the calculation and the result of Bottle 3 is significantly higher than other samples. Theoretically, samples may be kept for no more than 48 hours before beginning the BOD test. Samples in 1st and 3rd bottles were taken from the WWTP 7 days prior to incubation and were stored in the refrigerator. Previous measurements on the sample failed due to electricity drop at the GMIT campus. Hence, it was analyzed again with the next samples. For that reason, values from 1st and 3rd bottle is excluded from calculation of average value.

At 20 °C a significant rise in BOD occurred steadily following the 6-day incubation period in the 5 test bottles conducted at this temperature.

Ultimate BOD as shown in Table 1 is in the range of 92 to 115 mg/ L excluding Bottle 3. It indicates that the value of ultimate BOD under investigation is in the range of typical domestic WWTP effluent values. Ultimate BOD has taken as of 12 days' data by considering the BOD curve of the samples.

According to von-Sperling (16), the importance of the coefficient k_1 and BOD, a relativity concept may be considered when two different samples have the same value as BOD_5, which apparently could lead to the conclusion that the impact in terms of dissolved oxygen uptake is the same in both situations. However, BOD values varied daily over the samples. This is due to different deoxygenation rates in samples, emphasizing that the interpretation of BOD data must always be linked to the concept of deoxygenation ratio and therefore the oxidation rate of the organic matter.

Thomann R. (17) defined range of the deoxygenation coefficients for different water as follows:

- 0.35-0.7 for untreated wastewater
- 0.1-0.35 or the treated wastewater
- 0.1-0.25 for polluted river
- Less than 0.05 for unpolluted river

The deoxygenation coefficient for Gorodok wastewater treatment plant has found to be in a range of 0.26/day to 0.32/day.

For the entities which discharge water into the environment in Mongolia, the maximum allowable concentration of BOD_5 according to MNS4943:2015 is 20 mg/L (18). However, the values of BOD_5 in WWTP effluent is significantly higher than the standard. It indicates that efficiency of Gorodok WWTP is insufficient to comply with national guideline and is in need of improvement.

To reduce BOD_5, it is necessary to supply enough aeration for aerobic bacteria. Methane-forming bacteria is not able to live in a small quantity of oxygen presence. Therefore, aeration was regulated in the anaerobic system for having better growth of anaerobic bacteria.

Chemical kinetics of BOD is considered to be a first-order reaction with rate constant “k” ranging from 0.1 to 0.6 per day at 20°C for the domestic wastewaters (17).

5. CONCLUSION

The parameters that are generally considered sufficient to assess the BOD rate constant and the ultimate BOD of effluent are pH, DO, temperature and BOD. In the present study, the deoxygenation rate constant for effluent from Gorodok town WWTP is estimated to be around 0.31/day calculating average of values obtained from all samples. It is close value to result of other studies conducted in different countries. According to (19) deoxygenation rate for Obafemi Awolowo University, Ile-Ife's residential institutional waste in Nigeria was found to be 0.23/day.

The oxygenation rate coefficient is inversely proportional to the level of treatment provided prior to be effluent release into environment. The lower rate constants fart rated server to compare it with raw sewage result from the fact that easily degradable organics are more completely remove it and less readily degradable organic steering wastewater treatment

Most of the collected municipal wastewater discharges, into rivers, channels or lakes, for instance. As a consequence, poorly treated waste (wastewater and solid wastes) potentially interrupts the possibilities of people and livestock to live in a healthy and safe environment.

The deoxygenation rate constant of WWTP effluent from Gorodok town was 0.27/day. The ultimate BOD was determined to be in the range of 92 to 115 mg L.

The main limitation of the study was an accurate temperature controlling during incubation period. It was impossible to keep temperature of laboratory room constantly at 20 °C. I tried to maintain temperature at 20 °C by opening windows when ambient temperature rises. It might have affected the validity of my result in certain extent since deoxygenation rate coefficient relies on temperature.

This study contributes towards a better understanding of pollution dynamics in WWTP effluent in and design of biological treatment process in Mongolian condition. From this study, it was possible to support reliable models and improve the management of water resources.

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APPENDICES

Annex 1. Measured values of BOD concentration for effluent from Gorodok town WWTP

Bottle Number		1		2		3		4		5		6	
Measurement Date		Time	BOD [mg\l]	Time	BOD [mg\l]	Time	BOD [mg\l]	Time	BOD [mg\l]	Time	BOD [mg\l]	Time	BOD [mg\l]
Day 1	9.4.2019	19:32:01	0	19:28:28	0	19:31:41	0	19:33:57	0	19:29:49	0	19:29:06	0
	9.4.2019	20:32:01	0	20:28:28	0	20:31:41	0	20:33:57	0	20:29:49	0	20:29:06	0
	9.4.2019	21:32:01	0	21:28:28	0	21:31:41	0	21:33:57	0	21:29:49	0	21:29:06	0
	9.4.2019	22:32:01	0	22:28:28	0	22:31:41	0	22:33:57	0	22:29:49	1	22:29:06	0
	9.4.2019	23:32:01	0	23:28:28	1	23:31:41	0	23:33:57	1	23:29:49	4	23:29:06	0
Day 2	10.4.2019	0:32:01	0	0:28:28	2	0:31:41	0	0:33:57	2	0:29:49	6	0:29:06	1
	10.4.2019	1:32:01	0	1:28:28	3	1:31:41	0	1:33:57	4	1:29:49	9	1:29:06	3
	10.4.2019	2:32:01	0	2:28:28	5	2:31:41	0	2:33:57	5	2:29:49	12	2:29:06	5
	10.4.2019	3:32:01	0	3:28:28	7	3:31:41	0	3:33:57	7	3:29:49	14	3:29:06	7
	10.4.2019	4:32:01	0	4:28:28	8	4:31:41	2	4:33:57	8	4:29:49	16	4:29:06	9
	10.4.2019	5:32:01	0	5:28:28	10	5:31:41	3	5:33:57	10	5:29:49	19	5:29:06	11

	10.4.2019	6:32:01	0	6:28:28	11	6:31:41	5	6:33:57	12	6:29:49	21	6:29:06	12
	10.4.2019	7:32:01	0	7:28:28	13	7:31:41	7	7:33:57	13	7:29:49	24	7:29:06	14
	10.4.2019	8:32:01	0	8:28:28	14	8:31:41	8	8:33:57	15	8:29:49	25	8:29:06	16
	10.4.2019	9:32:01	0	9:28:28	16	9:31:41	10	9:33:57	16	9:29:49	27	9:29:06	18
	10.4.2019	10:32:01	0	10:28:28	17	10:31:41	11	10:33:57	18	10:29:49	29	10:29:06	19
	10.4.2019	11:32:01	0	11:28:28	19	11:31:41	13	11:33:57	20	11:29:49	32	11:29:06	21
	10.4.2019	12:32:01	0	12:28:28	21	12:31:41	14	12:33:57	21	12:29:49	33	12:29:06	23
	10.4.2019	13:32:01	0	13:28:28	22	13:31:41	15	13:33:57	22	13:29:49	33	13:29:06	24
	10.4.2019	14:32:01	0	14:28:28	23	14:31:41	14	14:33:57	23	14:29:49	32	14:29:06	24
	10.4.2019	15:32:01	0	15:28:28	22	15:31:41	12	15:33:57	23	15:29:49	31	15:29:06	23
	10.4.2019	16:32:01	0	16:28:28	22	16:31:41	10	16:33:57	22	16:29:49	28	16:29:06	20
	10.4.2019	17:32:01	0	17:28:28	21	17:31:41	9	17:33:57	23	17:29:49	26	17:29:06	19
	10.4.2019	18:32:01	0	18:28:28	22	18:31:41	9	18:33:57	23	18:29:49	26	18:29:06	19
	10.4.2019	19:32:01	0	19:28:28	23	19:31:41	13	19:33:57	24	19:29:49	29	19:29:06	23
	10.4.2019	21:32:01	0	21:28:28	28	21:31:41	19	21:33:57	28	21:29:49	34	21:29:06	31
	10.4.2019	23:32:01	0	23:28:28	31	23:31:41	25	23:33:57	31	23:29:49	39	23:29:06	37
Day 3	11.4.2019	1:32:01	0	1:28:28	34	1:31:41	30	1:33:57	35	1:29:49	44	1:29:06	42
	11.4.2019	3:32:01	0	3:28:28	37	3:31:41	34	3:33:57	38	3:29:49	47	3:29:06	46

	11.4.2019	5:32:01	0	5:28:28	40	5:31:41	37	5:33:57	41	5:29:49	51	5:29:06	49
	11.4.2019	7:32:01	0	7:28:28	42	7:31:41	38	7:33:57	44	7:29:49	53	7:29:06	51
	11.4.2019	9:32:01	0	9:28:28	44	9:31:41	37	9:33:57	46	9:29:49	54	9:29:06	51
	11.4.2019	11:32:01	0	11:28:28	45	11:31:41	36	11:33:57	48	11:29:49	56	11:29:06	50
	11.4.2019	13:32:01	0	13:28:28	46	13:31:41	35	13:33:57	51	13:29:49	57	13:29:06	49
	11.4.2019	15:32:01	0	15:28:28	46	15:31:41	31	15:33:57	52	15:29:49	55	15:29:06	45
	11.4.2019	17:32:01	0	17:28:28	47	17:31:41	28	17:33:57	53	17:29:49	53	17:29:06	42
	11.4.2019	19:32:01	0	19:28:28	49	19:31:41	30	19:33:57	57	19:29:49	56	19:29:06	45
Day 4	12.4.2019	19:32:01	0	19:28:28	73	19:31:41	37	19:33:57	76	19:29:49	69	19:29:06	60
Day 5	13.4.2019	19:32:01	3	19:28:28	83	19:31:41	34	19:33:57	85	19:29:49	72	19:29:06	62
Day 6	14.4.2019	19:32:01	43	19:28:28	96	19:31:41	43	19:33:57	98	19:29:49	88	19:29:06	74
Day 7	15.4.2019	19:32:01	46	19:28:28	101	19:31:41	43	19:33:57	99	19:29:49	90	19:29:06	75
Day 8	16.4.2019	19:32:01	51	19:28:28	106	19:31:41	48	19:33:57	105	19:29:49	95	19:29:06	81
Day 9	17.4.2019	19:32:01	63	19:28:28	110	19:31:41	58	19:33:57	115	19:29:49	103	19:29:06	93
Day 10	18.4.2019	19:32:01	47	19:28:28	106	19:31:41	43	19:33:57	110	19:29:49	91	19:29:06	78
Day 11	19.4.2019	19:32:01	42	19:28:28	105	19:31:41	36	19:33:57	109	19:29:49	87	19:29:06	74
Day 12	20.4.2019	19:32:01	54	19:28:28	110	19:31:41	48	19:33:57	115	19:29:49	99	19:29:06	84
Day 13	21.4.2019	19:32:01	65	19:28:28	110	19:31:41	26	19:33:57	81	19:29:49	109	19:29:06	92

Day 14	22.4.2019	19:32:01	53	19:28:28	93	19:31:41	14	19:33:57	68	19:29:49	100	19:29:06	82
Day 15	25.4.2019	20:13:20		20:13:20		20:13:20		20:13:20		20:13:20		20:13:20	

Figure 4: Polising pond of Gorodok WWTP

Figure 5:The Lovibond BOD-System BD 600 used for BOD Measurement