

Biological Aspects of the Wastewater Treatment Plant “Mahala Marhoom” in Egypt and Modified with Bardenpho Processes

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Abstract: In this study, we are concerned with the Mahala Marhoom wastewater treatment plant 20,000 m³/day using oxidation ditch techniques for twelve months during 2013 in EL-Garbia governorate-Egypt. Oxidation ditch process is used to treat the municipal and domestic sewage. The purpose of wastewater treatment is to remove the contaminants from wastewater with the objective that it is treated enough to be released back into the environment. The untreated sewage generates fouling smell, harmful bacteria, etc. which is hazardous for public health and degrades the environment by liberating noxious gases. An oxidation ditch is a form of extended aeration activated sludge. The aeration basin is a large oval shaped tank that resembles a racetrack. Wastewater enters the ditch and is circulated around the track by means of a large horizontal brush/rotor. The rotor assembly is partly submerged in the ditch. As it rotates it pushes the mixed liquor around the "track". The rotor also provides the needed aeration to maintain a DO level of about 2-3 mg/L in the basin. The oxidation ditch effluent passes to the secondary clarifier and RAS is returned to the ditch. Samples were collected from the influent and the effluents of plants. The samples were analyzed following standard procedures for the determination of BOD₅, COD, ammonia, Total Nitrogen, nitrite, nitrate, total phosphorus, TSS, VSS and other parameters. We found the efficiency removal of total nitrogen and phosphorus not high and needed to upgrade. The pilot plant was designed to improve the quality of the effluent so we used biological nutrient removal process. BNR systems are designed to remove only TN or TP, while others remove both. Bardenpho Process (Four-Stage) – continuous-flow suspended-growth process with alternating anoxic/aerobic/anoxic/aerobic stages and Modified Bardenpho process with addition of an initial anaerobic zone.

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Key words: Sewage, Oxidation ditch, Enhanced Nutrient Removal, nitrogen, phosphorus, nutrient limitation, nitrification, denitrification.

1. Introduction

Sewage/wastewater treatment plants generally perform biological treatment using microorganisms called activated sludge. Activated sludge contains diverse microorganisms which form a complex ecological system involving reproduction, death, and predation. Consequently, microorganism treatment performance naturally changes with the change in the operating condition of the plant, but also with one in influent quality. At sites where plant design and operation control are performed, it had been considered difficult to adapt simulation technologies to sewage/wastewater treatment plants, and until now, simulation technologies have not reached practical application Chaussade et al.,(2007).

An oxidation ditch is a modified activated sludge biological treatment process that uses long solids retention times (SRTs) to remove biodegradable organics. The typical oxidation ditch is equipped with aeration rotors or brushes that provide aeration and

circulation. The wastewater moves through the ditch at 1 to 2 ft/s. The ditch may be designed for continuous or intermittent operation Tchobanoglous et al.,(2003).

An oxidation ditch is a modified activated sludge biological treatment process that utilizes long solids retention times (SRTs) to remove biodegradable organics. Oxidation ditches are typically complete mix systems, but they can be modified to approach plug flow conditions. (Note: as conditions approach plug flow, diffused air must be used to provide enough mixing. The system will also no longer operate as an oxidation ditch). Typical oxidation ditch treatment systems consist of a single or multichannel configuration within a ring, oval, or horseshoe-shaped basin. As a result, oxidation ditches are called “racetrack type” reactors. Horizontally or vertically mounted aerators provide circulation, oxygen transfer, and aeration in the ditch. Qasim (1999).

Some ditches are designed with a concrete wedge at the exit of each bend. As the flow comes "out of the

turn", the wedge forces the water at the outside to the inside as it comes down the "straightaway". This helps mix the flow and creates turbulence where settling is most likely to occur. Oxidation ditches, as with other extended air systems, do not have primary treatment. Pretreatment maybe limited to bar screens. This means that grit will not be removed until it settles out in the oxidation ditch. The grit buildup in the ditch can result in odors and loss of detention time. It should be removed anytime the unit is drained for service Seviour (2010).

Surface aerators, such as brush rotors, disc aerators, draft tube aerators, or fine bubble diffusers are used to circulate the mixed liquor. The mixing process entrains oxygen into the mixed liquor to foster microbial growth and the motive velocity ensures contact of microorganisms with the incoming wastewater. The aeration sharply increases the dissolved oxygen (DO) concentration but decreases as biomass uptake oxygen as the mixed liquor travels through the ditch. Solids are maintained in suspension as the mixed liquor circulates around the ditch. If design SRTs are selected for nitrification, a high degree of nitrification will occur. Oxidation ditch effluent is usually settled in a separate secondary clarifier. An anaerobic tank may be added prior to the ditch to enhance biological phosphorus removal Metcalf & Eddy (2003).

The oxidation ditch system combines the processes of oxidation and sedimentation by means of

mechanical aeration and final clarification. The system involves a closed ring-shaped ditch in which untreated wastewater is introduced into the ditch where it is mechanically aerated by a paddle wheel or brush aeration rotor. The rotor is mounted on a revolving horizontal shaft that is partly submerged in the wastewater for oxygenation and circulation of the ditch contents. The ditch effluent is clarified and the settled sludge is returned to maintain a desirable MLSS concentration. The MLSS concentration generally ranges from 2,500 mg/l to 3,500 mg/l; however, this is dependent upon the surface area provided for sedimentation, the rate of sludge return, and the aeration process Ghaly and Thistle (2011)

Bardenpho Process

4-Stage bardenpho

The four-stage bardenpho process to create two anoxic zones to achieve a high level of total nitrogen removal. The bardenpho process uses an anoxic basin followed by a standard BOD/nitrification process, but no clarification. Mixed liquor is returned to the front of the process instead of RAS. Another extended anoxic basin is used to reduce the dissolved oxygen and create denitrification. The effluent passes to an aeration basin where the gas stripping process occurs and then to clarifiers. The RAS is returned to the head of the process. The main disadvantage of the bardenpho process is the extended detention time in the two anoxic processes Stensel et al.,(2000).

Table 1: Monitoring requirements for four-stage Bardenpho process

Reactor	Parameter	Rationale
First anoxic	Nitrate-N, Dissolved oxygen	Will reduce de-nitrification rate. Inadequate load limits de-nitrification. High nitrate recycled to aerobic zone may cause filamentous bulking.
Aerobic	Mixed liquor recycle, Dissolved oxygen	Controls nitrate load. High DO may inhibit upstream de-nitrification. Low DO may inhibit nitrification.
Second anoxic	Nitrate	High nitrification in aerobic zone may overwhelm endogenous de-nitrification capacity, resulting in NO ₃ in effluent.
Second aerobic	Dissolved oxygen	High DO will inhibit endogenous de-nitrification.

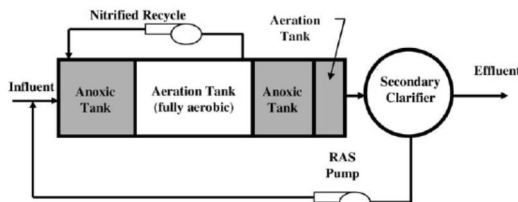


Figure 1: Four-stage bardenpho process.

5-Stage bardenpho

The 5-stage bardenpho process consists of the 4-stage process with an anaerobic zone added to the front of the system. A nitrate-rich liquor is recycled from the first aerobic stage to the first anoxic zone. The RAS is recycled from the clarifier to the beginning of the anaerobic zone. Since the nitrates in the RAS are typically low (from 1 to 3 mg/L), they do not have the potential to significantly interfere with the phosphorus removal process. The second

anoxic zone for complete denitrification Barnard (2006).

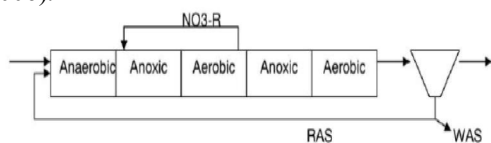


Figure2: Modified Bardenpho process configuration
 The Bardenpho process was originally developed for nitrogen removal, and, with the addition of an anaerobic zone at the head of the process configuration, successful phosphorus removal was ensured. The modified bardenpho has an internal mixed liquor nitrate recirculation stream (NO₃⁻R), providing continued feed of nitrate into the anoxic zone. Similar phosphorus removal response is achieved in the modified bardenpho process; however, significantly lower effluent nitrogen concentrations can be achieved. Again, depending on the COD:P ratio of the influent, the PHAs stored in the anaerobic zone will determine how much phosphorus will be taken up in the later zones under the presence of the electron acceptors nitrate and oxygen Barnard et al.,(2004).

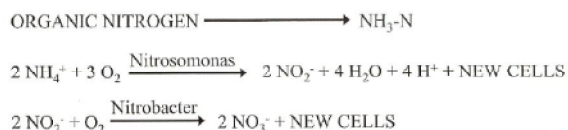
Nitrogen Transformation in Biological Treatment

The first goal of wastewater treatment is to remove suspended solids and BOD. Suspended solids created sediment in the receiving waters and organics will continue to decompose, using up oxygen that the aquatic wildlife needs. There is another problem that affects aquatic wildlife and directly impacts the water quality of the receiving waters. Nitrogen and phosphorous compounds in the wastewater effluent can be toxic to fish, as is the case with ammonia, and can act as natural fertilizers that increase the growth rate of aquatic plants like algae. This can result in algae blooms that can choke out other aquatic life in the lake or river. The nitrogen cycle that occurs, as ammonia is oxidized to nitrates, also results in a reduction of dissolved oxygen (DO) in the receiving waters. The first treatment processes that dealt with the nitrogen issue were nitrification processes. The intent was to convert the ammonia present in the secondary processes to nitrates. This would create a more stable form of nitrogen and minimize the oxygen depletion that would occur in the river. But the nitrates still acted as an aquatic fertilizer that created algae problems. Denitrification processes were developed to convert nitrates to elemental nitrogen gas that can be stripped from the effluent by aeration Benisch et al.,(2007).

Nitrification by Autotrophic Bacteria

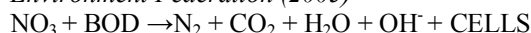
Nitrification of wastewater will occur after most of the BOD has been removed. If enough dissolved oxygen is available, nitrifying bacteria like

Nitrobacter and *Nitrosomonas* will begin oxidizing ammonia (NH₃) into nitrites (NO₂) first and then nitrates (NO₃) Carroll et al.,(2005).



Denitrification by Heterotrophic Bacteria

The most common process used to remove the nitrogen completely is known as denitrification. It follows the nitrification process. It utilizes denitrifying bacteria to remove the oxygen from the nitrate compounds. Nitrates are converted into nitrogen gas (N₂), which effectively removes the nitrogen from the waste flow. All bacteria need oxygen for respiration. The aerobic bacteria get their oxygen for dissolved oxygen (O₂) in the water. The anaerobic and facultative bacteria still need oxygen too. When no DO is present, they get oxygen from stripping oxygen from sugars, starches, and sulfates (releasing CO₂, CH₄, and H₂S in the process). Denitrifying bacteria are facultative and can use oxygen from nitrates. In order for them to use this chemically bound oxygen, the DO must be less than 0.1 mg/L. This is known as an anoxic condition. Anoxia is the chemical equivalent of anaerobic biological conditions, *Proceedings of the Water Environment Federation* (2005)



	Free Oxygen Present?	Nitrate (NO ₃ ⁻) Present?	Used For
Aerobic	Yes	--	Nitrification & BOD Removal
Anoxic	No	Yes	Denitrification & BOD Removal
Anaerobic	No	Yes	Biological Phosphorous Removal

Phosphorous Removal

Biological phosphorus removal is a biological process in which alternation of anaerobic and aerobic stages favors biophosphorus (bio-P) or PAOs, which are the heterotrophic organisms that are responsible for biological phosphorus removal. In the anaerobic stage, bio-P organism does not grow, but convert readily available organics material (i.e., acetate and propionate) to energy-rich carbon polymers called poly-hydroxyl alkanooates (PHAs). Biophosphorus

organisms use energy during acetate uptake and its conversion to PHA. This energy is generated through breakdown of polyphosphate (poly-P) molecules, which results in an increase in phosphate concentration in the anaerobic stage (i.e., phosphorus release). Polyphosphate is made up of many phosphate molecules combined together. Magnesium and potassium ions are concurrently released to the anaerobic medium with phosphate. In addition, for bio- P organisms to produce PHA, a substantial amount of reducing power is required, Crawford et al., (2006).

The reducing power is generated from the breakdown of glycogen, another form of internal carbon storage. In the aerobic zone, PAOs can oxidize previously stored PHAs to obtain energy. The energy and the carbons are used for growth and maintenance requirements. Under aerobic conditions, energy reserves are restored through phosphate uptake and polymerization. The effluent from the EBPR reactors is now low in phosphorus, and all the phosphorus stored in the biomass can now be wasted through regular solids wastage. This results in a net phosphorus removal from the system and the wastewater. In addition, some of the energy and carbon is used to restore the glycogen stores for the reactions to continue when mixed liquor is recirculated to the head of the anaerobic zones. ⁽¹⁴⁾

2. Materials and Methods:

2-1 The Study Area

The results have been monitoring of Mahala Marhoom WWTP operating with Oxidation ditch system during 2013 and capacity design of 20,000 m³/day. Sample were collected per month with the work of analysis of chemical and biological parameter during this period, it was noted some of the problems at the plants, such as excess in raw wastewater over the capacity of plant and the parameter in some months in the plant may be not good although the oxidation ditch is the modification of conventional activated sludge and produce good treated water but the reality does not occur due to defect in operation.

Table 2: Characteristics of Mahala Marhoom wastewater treatment plant

Plant	Mahala Marhoom wastewater treatment plant
Governorate	EL-Gharbia
system	Oxidation ditch
Capacity	20,000m ³ /day
Wastewater pumping station	3 pump Station
Time for collecting samples	1 year
No of collecting samples for month	1 times
Description of loading	Moderate

2.2 Pilot plant

2.2.1.- 4-Stage bardenpho Process



Figure 3: 4-Stage Bardenpho Process

2.2.2.- 5-Stage Bardenpho Process



Figure 4: 5-Stage Bardenpho Process

3-Results and discussion

Investigations of sewage were carried out in the period of 2013, 2014year.

3-a. Monitoring the result during 2013

Table (3): Result of Mahala Marhoom wastewater treatment plant during 2013

Item	Jun		Feb.		March		April		May		Jun		Jul		August		Sept.		October		Nov.		Dec.	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
TSS	312	33	226	31	217	29	242	28	266	26	255	31	297	33	402	39	350	25	300	24	258	28	304	24
BOD	410	64	395	45	365	36	395	66	400	39	340	46	380	42	344	48	450	40	350	35	300	36	370	34
COD	672	100	562	70	547	68	644	98	889	51	677	64	420	73	560	69	750	70	580	59	636	68	731	68
T.N	47	25	37	22	36	21	45	18	64	16	46	20	35	22	37	22	56	22	39	18	43	21	53	23
SO ₃	8	1	6.2	1.1	6	1.8	7	1.5	14	0.5	14	2.5	8.5	1.7	5.5	1.1	6	1	6.5	0.6	7.4	0.8	9	1.2
PO ₄	5.5	2.8	4	1.7	3.5	1.8	5.7	2.8	7	3.45	4.5	1.9	3.2	1.5	3.6	1.7	5.3	3.4	3.7	1.7	3.7	1.8	5.4	3

The data show the efficiency removal during 2013 not good in some months.

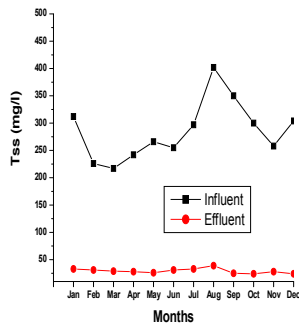


Fig. (5): TSS values in wastewater treatment plant

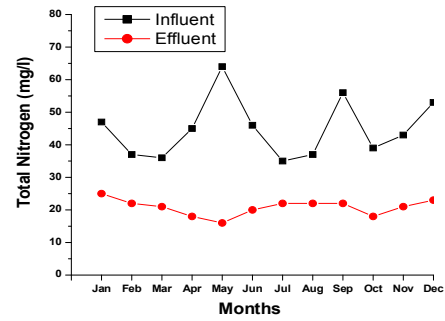


Fig. (8): Total nitrogen values in wastewater treatment plant

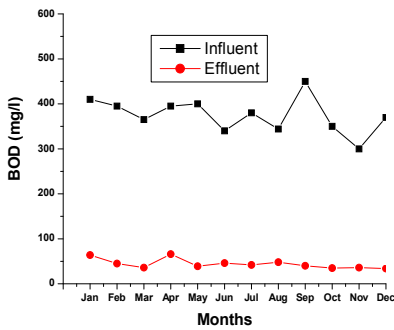


Fig. (6): BOD values in wastewater treatment plant

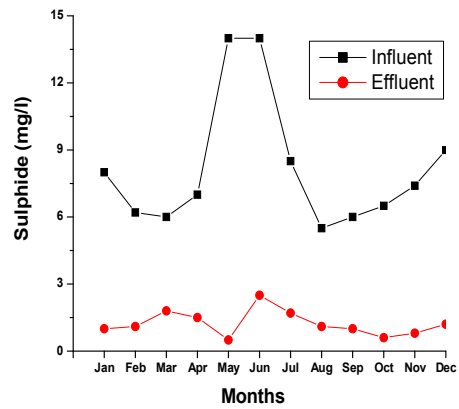


Fig. (9): Sulphide values in wastewater treatment plant

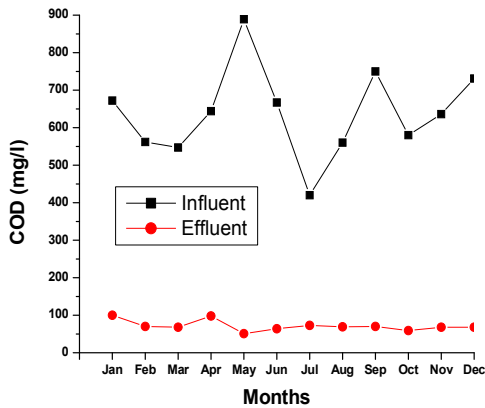


Fig. (7): COD values in wastewater treatment plant

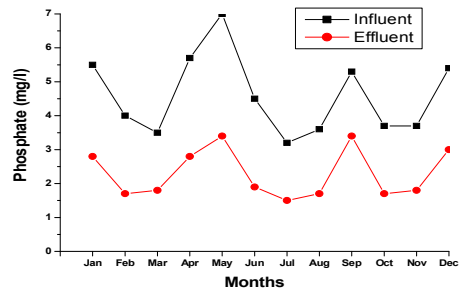


Fig. (10): phosphate values in wastewater treatment plant

3-b Cmparison the result between Mahala Marhoom WWTP and *bardepho Pilot plant*

Table (4): Mahala Marhoom WWTP and *bardepho Pilot plant* in January 2014.

Test	In	Out	4-Stage Bardenpho Process	Five-Stage Bardenpho Process
Temp	19.9	20.3	20.6	20.6
PH	7.46	7.69	7.8	7.82
TSS	220	55	8	3
BOD	318	63	10	8
COD	542	87	18	15
T.N	35	24	6	3
Amm	22	1.3	0.1	0
Nitrite	0.5	1.2	0	0
Nitrate	0.5	20	4	1
Sulphide	5.8	1.7	0.1	0
Phosphate	5.5	3.3	1.7	0.7
R-CL	-	0.9	0.7	0.7
TCF/100 ml	2X10 ⁸	10000	50	20

Table (5): Mahala Marhoom WWTP and *bardepho Pilot plant* in Feb 2014

Test	In	out	4-Stage Bardenpho Process	Five-Stage Bardenpho Process
Temp	20	20.5	20.6	20.8
PH	7.5	7.71	7.75	7.78
TSS	268	26	7	3
BOD	340	42	10	6
COD	574	72	17	15
T.N	41	24	6	3
Amm	25	4.3	0.4	0.2
Nitrite	0.7	2.2	0.1	0
Nitrate	0.5	16	4	1
SO3	7	1.9	0.1	0
PO4	3.6	2.0	1.6	0.7
R-CL	-	0.8	0.7	0.7
TCF/100 ml	2X10 ⁸	5000	50	20

Table (6): Mahala Marhoom WWTP and *bardepho Pilot plant* in March 2014

Test	In	out	4-Stage Bardenpho Process	5-Stage Bardenpho Process
Temp	22.9	23.5	23.7	23.7
PH	7.55	7.73	7.76	7.8
TSS	312	33	8	3
BOD	470	64	10	6
COD	672	100	17	15
T.N	47	25	6	3
Amm	26	2.0	0.3	0.1
Nitrite	1	1.9	0	0
Nitrate	0.8	19	4	1
SO3	8.5	1	0.1	0
PO4	5.5	2.8	1.9	0.8
R-CL	-	0.6	0.7	0.7
TCF/100 ml	2X10 ⁸	5000	50	20

Table (7): Mahala Marhoom WWTP and *bardepho Pilot plant* in April 2014

Test	In	out	4-Stage Bardenpho Process	Five-Stage Bardenpho Process
Temp	24.8	25.3	25.4	25.5
PH	7.42	7.6	7.67	7.7
TSS	270	52	7	3
BOD	310	52	10	6
COD	621	84	16	15
T.N	42	26	6	3
Amm	25	5.0	0.2	0.1
Nitrite	1.0	1.2	0.1	0
Nitrate	0.7	19	4	2
SO3	7	2.4	0.1	0
PO4	4	2.1	1.8	0.9
R-CL	-	0.5	0.7	0.7
TCF/100 ml	2X10 ⁸	10000	50	20

Table (8): Mahala Marhoom WWTP and *bardepho Pilot plant* in May 2014

Test	In	Out	4-Stage Bardenpho Process	Five-Stage Bardenpho Process
Temp	26	26.5	25.4	25.6
PH	7.5	7.59	7.8	7.8
TSS	260	48	7	3
BOD	300	36	11	6
COD	590	68	18	15
T.N	43	21	6	3
Amm	28	4.2	0.1	0
Nitrite	0.8	1.8	0	0
Nitrate	0.6	14	4	1
SO3	7.4	1.5	0.1	0
PO4	3.7	1.8	1.4	0.7
R-CL	-	0.5	0.7	0.7
TCF/100 ml	2X10 ⁸	1000	50	20

Table (9): Mahala Marhoom WWTP and *Bardenpho Pilot plant* in June 2014

Test	In	out	4-Stage Bardenpho Process	Five-Stage Bardenpho Process
Temp	29.2	29.6	29.8	29.9
PH	7.69	7.81	7.92	7.96
TSS	219	29	7	3
BOD	369	36	11	6
COD	557	68	18	15
T.N	36	21	6	3
Amm	29	3.5	0.3	0.1
Nitrite	0.5	0.8	0.1	0.1
Nitrate	0.4	15	4	2
SO3	8	2	0.1	0
PO4	3.5	2.1	1.8	0.6
R-CL	-	0.3	0.7	0.7
TCF/100 ml	2X10 ⁸	1000	50	20

3.b.1 Total suspended solid (TSS) content:

Solids analyses are important in the control of biological and physical wastewater treatment processes and for assessing compliance with regulatory agency wastewater effluent limitations, American Public Health Association (2005).
 Total solids = Suspended solids + Dissolved solids
 (non filterable residue) (filterable residue)

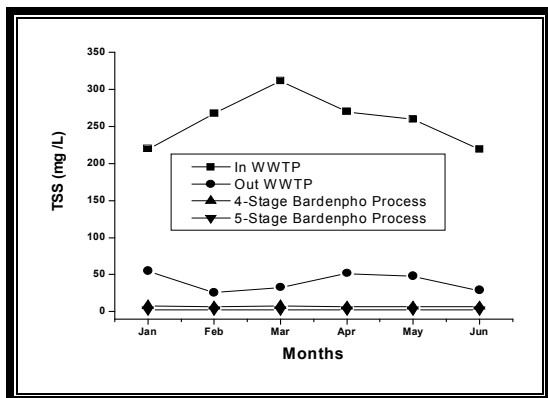


Fig. (11): TSS values in Mahala Marhoom WWTP and Bardenpho pilot plant

The concentration of total suspended solids recorded in tables (4-9), and represented graphically in Figures (11) for Mahala Marhoom WWTP and bardenpho pilot plant shows the decrease in the concentration of TSS in Mahala Marhoom WWTP and bardenpho pilot plant and time.

The data show the efficiency removal was (75 - 90 %) of TSS concentration in Mahala Marhoom WWTP (after 12 h), the efficiency removal was (96.5 %) of TSS concentration in 4 stage bardenpho pilot plant (after 14h) and the efficiency removal was (99 %) of TSS concentration in 5 stage bardenpho pilot plant (after 14 h).

3.b.2. Biochemical oxygen demand.

The amount of organic matter that can be biologically oxidized under controlled conditions. A measure of the amount of food available to the microorganisms in a particular waste. It is measured by the amount of dissolved oxygen used up during a specific time period (5 days at 20°C in the dark), ASTM (2006).

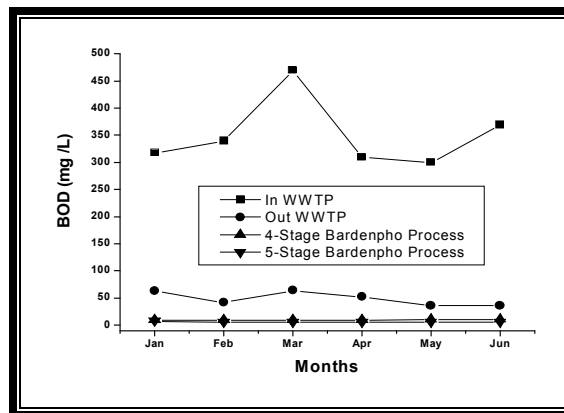


Fig. (12): BOD values in Mahala Marhoom WWTP and Bardenpho pilot plant.

The concentration of BOD₅ recorded in table (4-9), and represented graphically in figures (12) for Mahala Marhoom WWTP and bardenpho pilot plant shows the decrease in the concentration of BOD₅ in Mahala Marhoom WWTP and bardenpho pilot plant with time.

As indicated in tables (4-9), the efficiency removal was (80 - 96 %) of BOD₅ concentration in Mahala Marhoom WWTP (after 12 h), the efficiency removal was (98 %) of BOD₅ concentration in 4 stage bardenpho pilot plant (after 14 h) and the efficiency removal was (99 %) of BOD₅ concentration in 5 stage bardenpho pilot plant (after 14 h).

3.b.3. Chemical oxygen demand.

Chemical oxygen demand (COD) is a measure of the capacity of water to consume oxygen during the decomposition of organic matter and the oxidation of inorganic chemicals such as ammonia and nitrite. COD measurements are commonly made on samples of waste waters or of natural waters contaminated by domestic or industrial wastes, Water Environment Federation (2002b).

The concentration of COD recorded in tables (4-9), and represented graphically in figure (13) for Mahala Marhoom WWTP and bardenpho pilot plant shows the decrease in the concentration of COD in Mahala Marhoom WWTP and bardenpho pilot plant with time

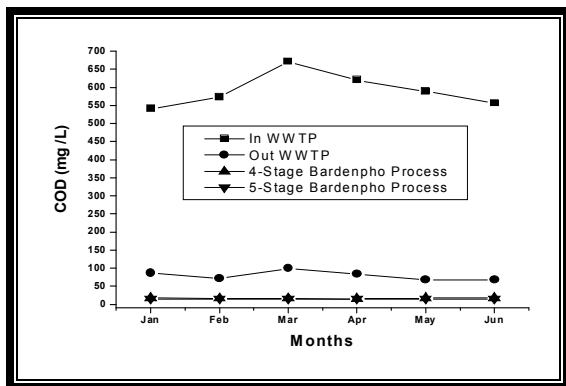


Fig. (13): COD values in Mahala Marhoom WWTP and Bardenpho pilot plant

As indicated in Tables (4-9), the efficiency removal was (80- 86 %) of COD concentration in Mahala Marhoom WWTP (after 12h), the efficiency removal was (97%) of COD concentration in 4stage bardenpho pilot plant (after 14 h) and the efficiency removal was (99 %) of COD concentration in 5 stage bardenpho pilot plant (after 14 h).

3.b.4. Total nitrogen

Nitrogen appears in wastewater as ammonia, nitrite, nitrate and organic nitrogen. Organic nitrogen is decomposed to ammonia, which in turn on one hand is assimilated to bacterial cells, leading thus to net growth, on the other hand is oxidized to nitrite and nitrate. In a second step, nitrate is converted to gaseous nitrogen and is removed from the wastewater. Denitrification is known to proceed as conversion of nitrates to nitrites and subsequent conversion of nitrites to nitric oxide, nitrous oxide and nitrogen gas, Physical-chemical treatment of water and wastewater (2002).

Ammonia (NH_3^+) is a colorless gas with a strong pungent odor. It is easily liquefied and solidified and is very soluble in water. Ammonia will react with water to form a weak base.

High concentrations of ammonia are toxic to humans and animals that is why sanitation engineers and government are working closely in removing ammonia from wastewater. Untreated volumes of ammonia in wastewater can disperse on the air, and affect those who have inhaled the chemical. This can also bring serious illnesses and skin disorders due to physical contact or consumption of ammonia, Hazen and Sawyer (2007).

Biological treatment process utilized to convert ammonia into nitrate using aerobic autotrophic bacteria. The biological infiltration uses two types of bacteria: the bacteria that oxidize ammonia to nitrite (nitrosomonas) and the bacteria that oxidise nitrite to nitrate (nitrobacter). Both types of autotrophic

bacteria need proper biomass, right environment, and sufficient air to treat biochemical oxygen demand. Nitrification requires ample amount of oxygen to carry out the process.

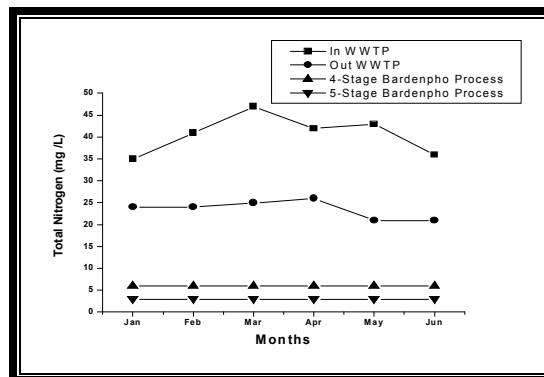


Fig. (14): Total nitrogen (mg/l) in Mahala Marhoom WWTP and bardenpho pilot plant

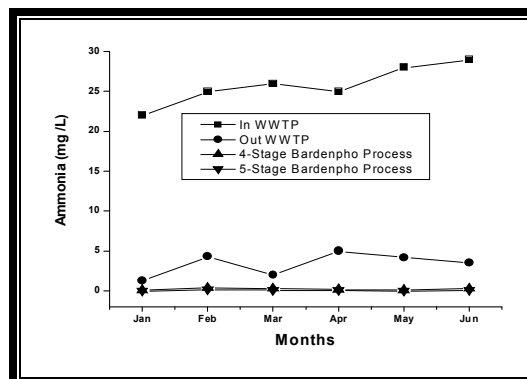


Fig. (15): Ammonia (mg/l) in Mahala Marhoom WWTP and bardenpho pilot plant

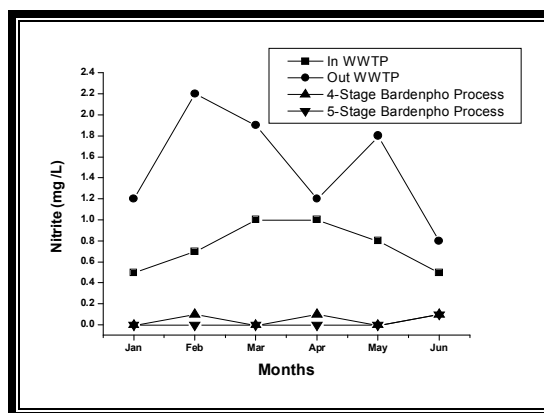


Fig. (16): Nitrite (mg/l) in Mahala Marhoom WWTP and bardenpho pilot plant

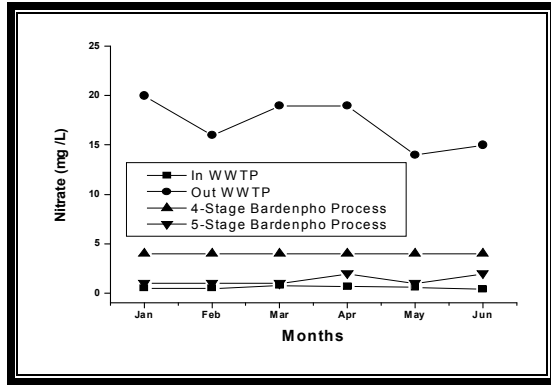


Fig. (17): Nitrate (mg/l) in Mahala Marhoom WWTP and bardenpho pilot plant

As indicated in Tables (4-9), the efficiency removal was (38-50%) of total nitrogen concentration in Mahala Marhoom WWTP (after 12h), the efficiency removal was (97 – 98%) of total nitrogen concentration in 4 stage bardenpho pilot plant (after 14 h) and the efficiency removal was (99 %) of total nitrogen concentration in 5 stage bardenpho pilot plant (after 14 h).

3.b.5. Sulphide

Hydrogen sulphide is a colourless, flammable gas under normal conditions. It is commonly known as stink damp, and sewer gas because it smells like rotten eggs. People can smell it at low levels.

Characteristic feature of hydrogen sulphide is that the gas is heavier by weight as normal air is. It is a highly toxic gas, which interferes with cellular respiration just like carbon monoxide and hydrogen cyanide. It is not simply a byproduct of some chemical processes but it can arise from some other sources e.g. decomposition of organic matter such as sewage, which in some instances has generated highly toxic, even fatal concentrations. Frank (2009).

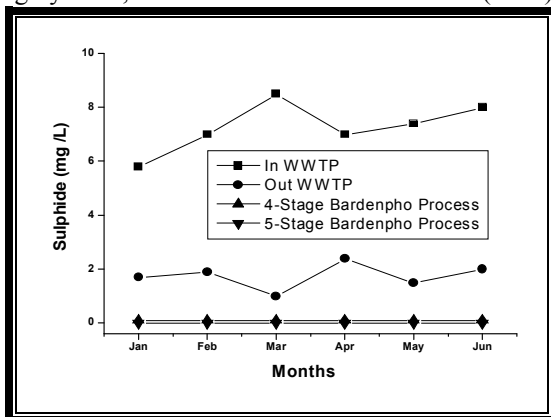


Fig. (18): Sulphide (mg/l) in Mahala Marhoom WWTP and bardenpho pilot plant

The concentration of sulphide recorded in tables (4-9), and represented graphically in figure (18) for

Mahala Marhoom WWTP and bardenpho pilot plant shows the decrease in the concentration of sulphide in Mahala Marhoom WWTP and bardenpho pilot plant with time.

The data show the efficiency removal of Sulphide concentration in Mahala Marhoom WWTP (after 12 h) reached 70% and the result not agree with law 48 . The efficiency removal of Sulphide concentration reached 99 .5 % after 14 h in 4 stage bardenpho pilot plant. The efficiency removal of Sulphide concentration reached 100 % after 14h in 5 stage bardenpho pilot plant.

3.b.6. Phosphate

Phosphorus (P) is commonly found in municipal and agricultural waste and wastewater, originating from the digestion of phosphorus-containing food sources. Soluble reactive phosphorus, typically in the form of orthophosphate (PO_4^{+3}), can be a nutrient for aquatic plants, such as algae, which can be either a health risk to aquatic life or an aesthetic nuisance to those living near or using the waterways. In the case of blue-green algae, toxic by-products can be produced, which create health issues if a lake or reservoir would be used as a source of drinking water USEPA (2004).

The usual forms of phosphorous found in aqueous solutions include:

- Orthophosphates: available for biological metabolism without further breakdown
- Polyphosphates: molecules with 2 or more phosphorous atoms, oxygen and in some cases hydrogen atoms combine in a complex molecule. Usually polyphosphates undergo hydrolysis and revert to the orthophosphate forms. This process is usually quite slow.

The concentration of Phosphate recorded in tables (4-9), and represented graphically in figure (19) for Mahala Marhoom WWTP and bardenpho pilot plant shows the decrease in the concentration of Phosphate in Mahala Marhoom WWTP and bardenpho pilot plant with time

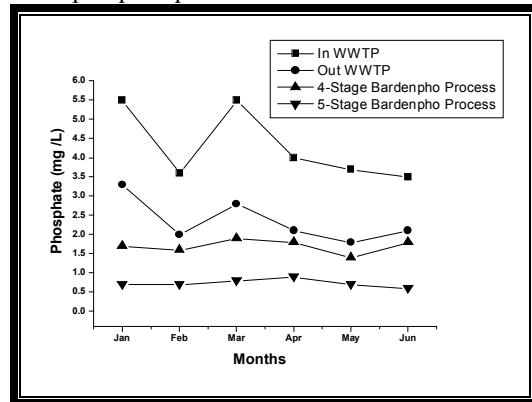


Fig. (19): Phosphate (mg/l) in Mahala Marhoom WWTP and bardenpho pilot plant

The data show the efficiency removal of Phosphate concentration in Mahala Marhoom WWTP (after 12 h) reached 40 % and the result not agree with law 48. The efficiency removal of Phosphate concentration is from 44 % to 69.5 % after 14 h in 4 stage bardenpho pilot plant and the result not agree with law 48. The efficiency removal of Phosphate concentration from 80 % to 88 % after 14 h in 5 stage bardenpho pilot plant.

4-Conclusions

- EBNR has higher capital costs and lower Operations and Maintenance O&M costs.
- These bardenpho processes eliminated the need for adding external organic substrate (i.e. methanol) to improve denitrification performance.
- Nitrate loading to the anaerobic reactor must be less than the oxygen demand of the wastewater. After the plant modifications, the average effluent nitrate-N concentration was reduced to 1 mg/L.
- Removal of the phosphorus-rich biomass from the process via the waste activated sludge effectively removes the phosphorus from the wastewater. Short chain VFAs required for BEPR can either be:
 - Naturally present in the wastewater as a result of acid fermentation in the collection system.
 - Generated on-site at the wastewater treatment plant through primary sludge fermentation.
- Costs increase dramatically for effluent limits P <1 mg/L and TN 3-6 mg/l
- 4-step process designed to achieve complete denitrification Anoxic/aerobic/anoxic/aerobic
- 5-stage bardenpho. The bardenpho process is considered because it uses biological processes to achieve high levels of nitrogen and phosphorus removal with reduced usage of chemicals. An anaerobic zone and an additional anoxic zone would be needed for conversion to the bardenpho process.

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