Biological Nutrient Removal in Bardenpho process

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Abstract: Nitrogen and phosphorus waste loads in streams, lakes, and coastal estuaries can cause algae proliferation, eutrophication and low oxygen levels. The process for biological nitrogen and phosphorus removal from wastewater is widely accepted. Nitrogen removal requires aerobic–anoxic stages, while phosphorus removal requires alternating anaerobic–aerobic stages. Typical conventional biological nutrient removal (BNR) systems include three sequential separated stages: anaerobic / anoxic / aerobic, concluding with a secondary clarifier. In this study, we are concerned with the sewage treatment plant (Fisha Selim wastewater treatment plant).The system used in this plant is rotating biological contactors (RBC). Samples were collected during 2013 from the influent and the effluents of plants. The samples were analyzed following standard procedures for the determination of sludge BOD_5, COD, ammonia, Total Nitrogen, nitrite, nitrate, total phosphorus, TSS, VSS and other parameters. The results demonstrated that the treated water is not good in some months. So the defect was returned to the operation and RBC system is not good in nutrient removal. The pilot plant was designed to improve the quality of the effluent so we constructed bardenpho processes which remove more pollutants and this modified the pilot plant (A/O process) which I studied in my master.The first two stages of the 4-stage Bardenpho are identical to the MLE system. The third stage is a secondary anoxic zone to provide denitrification of the portion of the flow that is not recycled to the primary anoxic zone. The fourth and final zone is a re-aeration zone that serves to strip any nitrogen gas and increase the dissolved oxygen (DO) concentration before clarification. The average removal efficiency in terms of chemical oxygen demand (COD), biochemical oxygen demand (BOD_5), total suspended solids (TSS), total nitrogen (Total-N) and total phosphorus for 4 stage bardenpho pilot plant was 97%, 98%, 97%, 97% and 50%. The removal efficiency of chemical oxygen demand (COD), biochemical oxygen demand (BOD_5), total suspended solids (TSS), total nitrogen (Total-N) and total phosphorus for 5 stage bardenpho pilot plant was 99%, 99%, 99%, 99% and 90%.
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1-Introduction

Rotating biological contactor (RBC) is an attached-growth biological process, which consists of a series of rotating plastic media all coated with a layer of biofilm. The biofilm or slime on the media aerobically react with substances in a waste stream for bio-oxidation and nitrification, or anaerobically react with the substances for denitrification Barnard(2006).

Rotating biological contactors (RBCs) were originally developed in Europe and recently accepted by America and Asia. The process system is primarily a fixed-film biological reactor consisting of a synthetic medium mounted on a horizontal shaft and placed in a contour-bottomed tank. The general concept of rotating biological contactors is to let wastewater flow through the tank, and to rotate the medium in the wastewater to be treated, alternatively exposing the medium (and the attached biological growth) to air and the wastewater. The slowly rotated media are about 40% immersed in the wastewater for aerobic removal of organic waste by the biological film developing on the media. The lattice-structured medium, and to a lesser extent the disc structure, is fragile and should be protected from direct exposure to wind, sun, and weather fluctuation. Therefore, the media are usually enclosed in a superstructure or individual shaft covers. Aguilera et al.,(2003).

The rotating biological contactor is an aerobic treatment system and can be conceptually described as a series of circular discs mounted on a horizontal shaft in a open semi-circular cylindrical tank. The discs which are made up of PVC, asbestos, wood, etc. are partially submerged in the wastewater and are continuously rotated with the help of a motor and reduction gear unit so as to provide mixing inside the tank. When the biofilm containing aerobic bacteria sufficiently grows on the surface of the discs, the bacteria attached on the surfaces alternately come in contact with atmospheric oxygen and wastewater. This oxygen is utilized by the bacteria for aerobic degradation of organic matter present in the wastewater. Over a period of time, the thickness of biofilm increases and a stage comes when the biofilm gets detached or sloughed off from the disc surface. The contents of the tank along with sloughed solids are then passed on to settling tank where separation of suspended solids takes places and a clear supernatant is taken for discharge and disposal,Henze et al.,(2003).

Media rotation can be provided by either mechanical drives or air-motivated rotation. Rotation not only results in exposure of the film to the atmosphere as a means of aeration, but also provides rotational shear forces for stripping off the excess biomass on the medium. The stripped biological solids are maintained in suspension by the mechanical mixing action of the rotation medium, or by supplemental diffused air, depending on the driving force of rotation. The air-driven system, in rotating the media by diffused air generated near the tank bottom, alleviates the development of undesirable anaerobic Conditions, and also reduces the oxygen limitation, which often is the limiting factor in biological oxidation by attached growth systems, Costley and Wallis(2001).

Wastewater treatment efficiency in terms of carbonaceous oxidation and nitrification can be significantly increased by the multiple staging of rotating biological contactors. A complete rotating biological contactors' system could consist of two or more parallel trains with each train consisting of multiple stages, Primary clarifiers are optional whereas secondary clarifiers are required for solids separation. RBC systems can also be used for biological denitrification, Griffin and Findlay(2000).

The result from this plant during 2013 were studied and this indicate the efficiency removal in chemical oxygen demand (COD), biochemical oxygen demand (BOD_5), total suspended solids (TSS),total nitrogen (Total-N) and total phosphorus was 82%, 86%, 63%, 54% and 50%.

Biological Nitrogen Removal

Biological nitrogen removal reactions are nitrification and denitrification. Other related reactions Include ammonification (conversion of organic nitrogen to ammonia nitrogen) and nitrogen uptake for cell growth, Water Environment Federation (2004).

Nitrification

Nitrification is the oxidation of ammonia to nitrite and nitrate. The key organisms involved are thought to be Nitrosomonas and Nitrobacter. These are autotrophs that oxidize inorganic nitrogen compounds for energy:

Nitrosomonas

$$NH_4^+ + \frac{3}{2}O_2 \xrightarrow{aom} NO_2^- + H_2O + 2H^+ + energy$$

Nitrobacter

$$NO_2^- + \frac{1}{2}O_2 \xrightarrow{nom} NO_3^- + energy$$

Carbon for cell growth is obtained from carbon dioxide. Consequently, organic substrate (BOD) is not a prerequisite for the growth of nitrifiers. Nitrite accumulation is typically not encountered in a fully nitrifying system because Nitrosomonas is slower growing; however, there is some indication that at wastewater temperatures of above 25 ^oC to 30 ^oC, nitrite-to-nitrate conversion may become rate-limiting, resulting in increased chlorine demand for disinfection. It is now known that organisms other than Nitrosomonas and Nitrobacter can also mediate the nitrification process; therefore, the term ammonia oxidizing bacteria (AOB) is used to refer to them collectively. Nitrification results in the conversion of nitrogen from a reduced form (ammonia) to an oxidized form (nitrate) Wang et al.,(2009).

Denitrification

Denitrification is done by *heterotrophic microorganisms*—organisms that use organic materials as a source of nutrients and metabolic synthesis as a source of energy. Heterotrophic organisms spend less energy on synthesis than autotrophic organisms do, so they grow more quickly and yield more cell mass, Bott et al.,(2007).

Denitrification must follow nitrification to achieve significant total nitrogen removal. Denitrification is the reduction of nitrate to nitrogen gas by certain heterotrophic bacteria. The process requirements are anoxic conditions and a source of rapidly biodegradable organic matter (RBOM). Anoxic refers to the presence of combined oxygen (nitrate and nitrite) and the absence of free or dissolved oxygen (DO) Bott et al.,(2009).

The simplified reaction is:

$$NO_3^- + RBOM \rightarrow (N_2\ (gas) + CO_2 + H_2O + OH^- + \text{New cells})$$

Biological phosphorus removal is realized by creating conditions favorable for the growth of phosphate-accumulating organisms (PAOs). An initial anaerobic zone allows the PAOs to take up VFAs into their cells and store them as poly hydroxyl buterate (PHB). The polyphosphate stored just prior to this is oxidized and used as an energy source, producing ATP; and it is thereby released into the liquid phase. The anaerobic uptake of organic matter is inherently related to the accumulated polyphosphate. After the mixed liquor reaches the aerobic zone, the stored PHB is used by the PAOs for cell growth and to provide energy for reforming polyphosphate from all the available orthophosphate and also for the synthesis of poly glucose (glycogen).By going through both anaerobic and aerobic conditions, PAOs are adequately established and become predominant in the biomass community after several weeks, Clark et al.,(2010).

The PAO's are the only bacteria being able to store substrate in a first anaerobic reactor and to oxidize them in a second aerobic reactor. This is only possible by enrichment of the Poly–P storage. This enrichment of the PAOs containing a high concentration of polyphosphate leads to the establishment of biological phosphorus removal. The net elimination of the process results from the bacterial cell growth and the removal of surplus sludge at the point when the phosphate is taken up to a higher level than that released in the anaerobic stage, Clippelieret al.,(2009).

The Bardbnpho Process

The bardenpho process is an activated sludge process specially designed to accomplish biological phosphorus and nitrogen removal. The original process developed by Barnard is a single-sludge, four-stage (anoxic–aeration–anoxic–aeration) system intended for nitrogen removal through nitrification and denitrification. For the purpose of P removal, the bardenpho process has been modified by adding an anaerobic stage ahead of the original four-stage Bardenpho nitrogen removal system. Such a modification allows for the creation of an anaerobic–aerobic contacting condition necessary for biological phosphorus uptake, DeBarbadillo et al.,(2008).

In the modified bardenpho process, the recycled activated sludge separated from the clarifier is mixed with the influent wastewater prior to the anaerobic contactor. Such a mixing strategy can initiate luxury phosphorus uptake by releasing phosphates first. The mixed liquor from the anaerobic contactor then flows into the first anoxic denitrification stage in which it is further mixed with the internally recycled mixed liquor from the aerobic nitrification zone. In the first anoxic stage, nitrate is denitrified to nitrogen gas using the influent BOD as carbon source. About 70% of the nitrate–nitrogen produced in the system can be removed in the first anoxic stage. Then, the mixed liquor flows into the aerobic nitrification zone in which luxury phosphorus uptake, ammonium oxidation, and additional BOD removal occur. Following the aerobic nitrification stage, a second anoxic stage can further provide the possibility to enhance additional denitrification, which is designed to remove additional nitrate in order to minimize nitrate fed back to the anaerobic contactor. The final aerobic stage provides a short time period of mixed liquor aeration prior to clarification to minimize anaerobic conditions and phosphorus release in the second clarifier, Dold et al.,(2008).

The pilot plant was designed to improve the quality of the effluent so we constructed bardenpho processes which remove more pollutants and this modified the pilot plant (A/O process) which I studied in my master, Mostafa et al.,(2010).

2-Materials and Methods

2-1 The Study Area

Investigations of sewage were carried out in the period of 2014 year and performed some parameters as pH, biochemical oxygen demand, chemical oxygen demand, total nitrogen, organic nitrogen, ammonia, some heavy metals, and others are determined before and after treatment and compared with each results from *bardenpho pilot plants* until reach to optimum condition for removing of the studied pollutants.

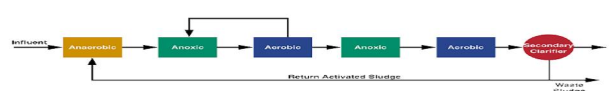
Table 1: charecteristics of Fisha Selim wastewater treatment plant

Plant	Fisha Selim wastewater treatment plant
Governorate	EL-Gharbia
System	Rotating biological contactors
Capacity	6000m3/day
Time for collecting samples	1 year
No of collecting samples for month	1times
Description of loading	high

2-2 Pilot plant

2-2-1 4-Stage Bardenpho Process

2-2-2 5-Stage Bardenpho Process



3-Results and discussion

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

3-1 Bardenpho Process

3-1-1 4-Stage Bardenpho Process

The 4-Stage Bardenpho Process is a continuous-flow suspended-growth process with alternating anaerobic/aerobic/anaerobic/aerobic stages, utilized primarily for nitrogen removal. The overall process is similar to a conventional activated sludge process; however, each stage of the process creates specific treatment conditions, as described below:

The Stage 1 reactor serves as the first anoxic stage. Nitrate rich mixed liquor from the second stage reactor is mixed with influent wastewater in the absence of oxygen. Bacteria utilize the BOD in the influent, reducing the nitrate to gaseous nitrogen, which is released to the atmosphere. Approximately two-thirds of the influent nitrogen is removed within this stage.

The Stage 2 reactor serves as the first nitrification stage. Oxygen is introduced to oxidize the BOD and ammonia. BOD is converted to new cell mass and carbon dioxide. Ammonia is converted to nitrite, then nitrate. Mixed liquor from this stage is recycled back to the head of stage 1 for de-nitrification.

The stage 3 reactor serves as the second anoxic stage. Nitrate not recycled to stage 1 is introduced, in the absence of air, where it is reduced to nitrogen gas and released to the atmosphere. This stage is designed to produce low effluent nitrate concentrations.

The Stage 4 reactor serves as the re-aeration stage. Subjecting the waste to reaeration introduces additional oxygen to the mixed liquor, ensuring that it remains aerobic for improved settling within the final clarifier, Selock (2008).

3-1-2 5-Stage Bardenpho Process

The 5-Stage Bardenpho Process is also a continuous-flow suspended-growth process with alternating anaerobic/aerobic/anaerobic/aerobic stages, however; an additional reactor is used at the head of the plant for both nitrogen removal and enhanced phosphorus removal. The overall process is similar to a conventional activated sludge process with each stage of the process creating specific treatment conditions, as described below:

The Stage 1 reactor serves as the fermentation stage. Activated sludge consisting of a broad spectrum of organisms is returned from the clarifier to the fermentation reactor. This sludge is mixed with plant influent to produce the appropriate stress conditions that allow large quantities of phosphorus to be removed biologically in the subsequent aerobic stages. Organism stress occurs in the absence of dissolved oxygen and nitrates.

The Stage 2 reactor serves as the first anoxic stage. Nitrate rich mixed liquor from the third stage reactor is mixed with conditioned wastewater from the fermentation reactor in the absence of oxygen. Bacteria digest the carbonaceous BOD in the wastewater by using the bound oxygen in the nitrate, thus reducing the nitrate to gaseous nitrogen, which is released to the atmosphere. Approximately two-thirds of the influent nitrogen is removed within this stage.

The Stage 3 reactor serves as the first nitrification stage. Oxygen is introduced to oxidize the BOD and ammonia. BOD is converted to new cell mass and carbon dioxide. Ammonia is converted to nitrite, then nitrate. Mixed liquor from this stage is recycled back to the head of stage 2 for de-nitrification. Luxury phosphorus uptake by the organisms also occurs within this stage.

The Stage 4 reactor serves as the second anoxic stage. Nitrates not recycled to stage 1 are introduced, in the absence of air, where they are reduced to nitrogen gas and released to the atmosphere. This stage is designed to produce low effluent nitrate concentrations.

The Stage 5 reactor serves as the re-aeration stage. If the sludge is allowed to become septic, phosphorus could be released in the final clarifier. Subjecting the waste to reaeration introduces additional oxygen to the mixed liquor, insuring that it remains aerobic for improved settling within the final clarifier. The settled phosphorus rich sludge is returned to the head of Stage 1 for regeneration of the entire process, Ahn et al.,(2010).

Table (2): Fisha Selim WWTP and *Bardenpho Pilot plant* in January 2014

Test	In	out	4-Stage Bardenpho Process	Five-Stage Bardenpho Process
Temp	17.5	17.9	18.0	18.0
PH	7.7	7.9	7.98	8.0
TSS	280	54	7	3
BOD	350	46	10	8
COD	498	62	18	15
T.N	37	24	6	3
Amm	24	2.0	0	0
Nitrite	0.2	1.8	0	0
Nitrate	0.1	19.7	4	1
Phosphate	4.5	3	2.4	0.8
Nickel	0.5	0.37	0.16	0.08
Iron	1.3	1.0	0.2	0.11

Table (3): Fisha Selim WWTP and Bardenpho 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	7.42	7.68	7.71	7.72
TSS	360	28	7	3
BOD	400	29	10	6
COD	520	42	16	15
T.N	42	20	6	3
Amm	27	3.0	0.3	0.1
Nitrite	0.3	1.5	0.1	0
Nitrate	0.4	15.5	4	1
Phosphate	5.0	3.2	2.0	0.7
Nickel	0.6	0.32	0.19	0.07
Iron	1.2	1.0	0.24	0.1

Table (4): Fisha Selim WWTP and *Bardenpho Pilot plant* in March 2014

Test	In	out	4-Stage Bardenpho Process	5-Stage Bardenpho Process
Temp	23	23.4	23.6	23.9
PH	7.53	8.3	7.8	7.9
TSS	308	30	7	3
BOD	396	38	10	6
COD	711	51	16	15
T.N	45	24	6	3
Amm	30	2.0	0.3	0.1
Nitrite	0.8	1.8	0.1	0.1
Nitrate	0.6	19.5	4	1
PO4	4	2.2	1.9	0.8
Nickel	0.5	0.24	0.15	0.07
Iron	1.43	1.1	0.28	0.1

Table (5): Fisha Selim WWTP and Bardenpho Pilot plant in April 2014

Test	In	out	4-Stage Bardenpho Process	Five-Stage Bardenpho Process
Temp	24.4	25	25.2	25.3
PH	7.46	7.7	7.8	7.9
TSS	216	26	7	3
BOD	290	38	10	6
COD	630	56	16	15
T.N	40	21	6	3
Amm	26	1.9	0.2	0
Nitrite	1.6	1.4	0.1	0
Nitrate	0.9	16.2	4	1
PO4	3.8	2.9	2.5	0.8
Nickel	0.42	0.34	0.25	0.06
Iron	1.4	1.1	0.48	0.09

Table (6): Fisha Selim WWTP and *Bardenpho Pilot plant* in May 2014

Test	In	out	4-Stage Bardenpho Process	Five-Stage Bardenpho Process
Temp	25	25.3	25.4	25.6
PH	7.47	7.7	7.8	7.8
TSS	294	25	7	3
BOD	395	35	11	6
COD	737	50	18	15
T.N	45	19	6	3
Amm	28	4	0	0
Nitrite	1.0	1.4	0	0
Nitrate	0.8	14	4	1
Phosphate	4.5	3.1	2.9	0.8
Nickel	0.43	0.27	0.18	0.06
Iron	1.4	1.0	0.5	0.08

3. 2 Comparison of results between Fisha Selim WWTP and Bardenpho pilot plant.

3. 2.1 Total suspended solid (TSS):

Most pollutants found in wastewater can be classified as solids. Wastewater treatment is generally designed to remove solids or to convert solids to a form that is more stable or can be removed. Solids can be classified by their chemical composition (organic or inorganic) or by their physical characteristics (settleable, floatable, and colloidal). Suspended solids include silt and clay particles, plankton, algae, fine organic debris, and other particulate matter. These are particles that will not pass through a filter. Higher concentrations of suspended solids can serve as carriers of toxics, which readily cling to suspended particles. This is particularly a concern where pesticides are being used on irrigated crops. Where solids are high, pesticide concentrations may increase well beyond those of the original application as the irrigation water travels down irrigation ditches. Higher levels of solids can also clog irrigation devices and might become so high that irrigated plant roots will lose water rather than gain it.

Table (7): Fisha Selim WWTP and ***Bardenpho Pilot plant*** in June 2014

Test	In	out	4-Stage Bardenpho Process	Five-Stage Bardenpho Process
Temp	27.2	27.6	27.8	27.9
PH	7.6	7.96	7.98	8.0
TSS	396	32	7	3
BOD	480	42	11	6
COD	670	64	18	15
T.N	43	24	6	3
Amm	27	3.5	0.3	0.1
Nitrite	1.3	1.8	0.1	0.1
Nitrate	1.1	19	4	2
Phosphate	5	3.4	2.8	0.9
Nickel	0.48	0.36	0.22	0.06
Iron	1.4	1.1	0.6	0.09

3. 3 Comparison of results between Fisha Selim WWTP and Bardenpho pilot plant.

3. 3.1 Total suspended solid (TSS):

Most pollutants found in wastewater can be classified as solids. Wastewater treatment is generally designed to remove solids or to convert solids to a form that is more stable or can be removed. Solids can be classified by their chemical composition (organic or inorganic) or by their physical characteristics (settleable, floatable, and colloidal). Suspended solids include silt and clay particles, plankton, algae, fine organic debris, and other particulate matter. These are particles that will not pass through a filter. Higher concentrations of suspended solids can serve as carriers of toxics, which readily cling to suspended particles. This is particularly a concern where pesticides are being used on irrigated crops. Where solids are high, pesticide concentrations may increase well beyond those of the original application as the irrigation water travels down irrigation ditches. Higher levels of solids can also clog irrigation devices and might become so high that irrigated plant roots will lose water rather than gain it.

The concentration of total suspended solids recorded in Tables (2-7), and represented graphically in Figures (3) for Fisha Selim WWTP and bardenpho pilot plant shows the decrease in the concentration of TSS in Fisha Selim WWTP and bardenpho pilot plant and time.

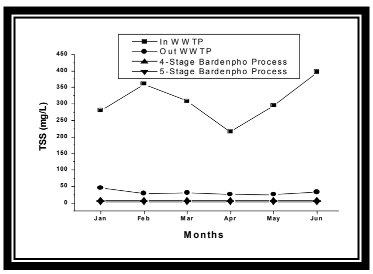


Fig. (3): TSS values in Fisha Selim WWTP and bardenpho pilot plant

The data show the efficiency removal was (83 - 90 %) of TSS concentration in Fisha Selim WWTP (after 12 h), the efficiency removal was (98 %) of TSS concentration in 4 stage bardenpho pilot plant (after 14 h) and the efficiency removal was(99 %) of TSS concentration in 5 stage bardenpho pilot plant (after 14 h)

3.3.2 Biochemical oxygen demand.

Biochemical oxygen demand (BOD) is a measure of the amount of biodegradable matter in the wastewater. It is normally measured by a 5-day test conducted at 20°C. The BOD_5 for domestic waste is normally in the range of 100 to 300 mg/L. [14]

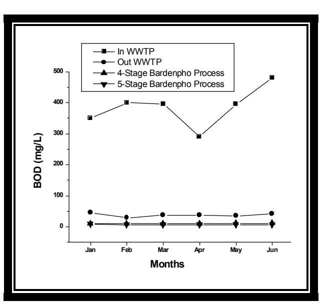


Fig. (4): BOD values in Fisha Selim WWTP and bardenpho pilot plant.

The concentration of BOD_5 recorded in Table (2-7), and represented graphically in Figures (4) for Fisha Selim WWTP and bardenpho pilot plant shows the decrease in the concentration of BOD_5 in Fisha Selim WWTP and bardenpho pilot plant with time.

As indicated in tables (2-7), the efficiency removal was (83 - 90 %) of BOD5 concentration in Fisha Selim WWTP (after 12h), the efficiency removal was (98 %) of BOD5concentration in 4 stage bardenpho pilot plant (after 14h) and the efficiency removal was (99 %) of BOD5 concentration in 5 stage bardenpho pilot plant (after 14 h).

3. 3.3Chemical oxygen demand.

The amount of a specified oxidant that reacts with the sample under controlled conditions (where the quantity of oxidant consumed is expressed in terms of its oxygen equivalence). In short, it provides a measure of how much oxygen a sample will consume (oxygen demand), and it does so in three or four hours. The COD test, therefore, provides a means to quickly estimate the five-day BOD (BOD_5) of a sample.

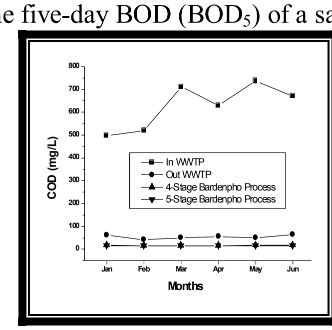


Fig. (5): COD values in Fisha Selim WWTP and bardenpho pilot plant

The concentration of COD recorded in Tables (2-7), and represented graphically in Figure (5) for Fisha Selim WWTP and bardenpho pilot plant shows the decrease in the concentration of COD in Fisha Selim WWTP and bardenpho pilot plant with time.

As indicated in Tables (2-7), the efficiency removal was (87 - 90 %) of COD concentration in Fisha Selim WWTP (after 12 h), the efficiency removal was (97%) of COD concentration in 4 stage bardenpho pilot plant (after 14 h) and the efficiency removal was (99 %) of COD concentration in 5 stage bardenpho pilot plant (after 14 h).

3.3.4 Total nitrogen

Total effluent nitrogen comprises ammonia, nitrate, particulate organic nitrogen, and soluble organic nitrogen. The biological processes that primarily remove nitrogen are nitrification and denitrification. During nitrification ammonia is oxidized to nitrite by one group of autotrophic bacteria, most commonly *Nitrosomonas*. Nitrite is then oxidized to nitrate by another autotrophic bacteria group, the most common being *Nitrobacter.*

Denitrification involves the biological reduction of nitrate to nitric oxide, nitrous oxide, and nitrogen gas. Both heterotrophic and autotrophic bacteria are capable of denitrification.

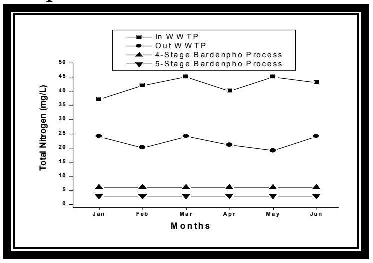


Fig. (6): Total nitrogen (mg/l) in Fisha Selim WWTP and *bardenpho* pilot plant

Complete nitrification and denitrification occur in bardenpho pilot plant after14 h but in the plant we found the ratio of ammonia pass 1 mg/l and this does not agree with environmental low also the ratio of nitrite point to defect in operation. The ratio of nitrate indicate to the denitrification not occur in the plant but the value of nitrate agree with environmental law. As indicated in Tables (2-7), the efficiency removal was (45-50 %) of Total nitrogen concentration in Fisha Selim WWTP (after 12 h), 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).

3.3.5 phosphate

Phosphorus appears in water as orthophosphate (PO_4^{-3}), polyphosphate (P_2O_7), and organically bound phosphorus. Microbes utilize phosphorus during cell synthesis and energy transport. As a result, 10 to 30 per cent of all influent phosphorus is removed during secondary biological treatment. More phosphorus can be removed if one of a number of specially developed biological phosphorus removal processes is used. These processes are based on the exposure of microbes in an activated-sludge system to alternating anaerobic and aerobic conditions. This stresses the microorganisms, so that their uptake of phosphorus exceeds normal levels.

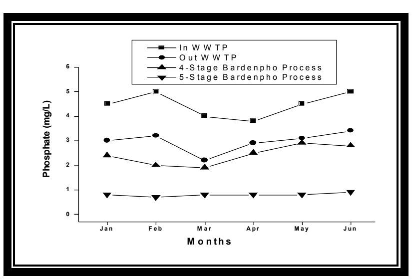


Fig. (7): Phosphate (mg/l) in Fisha Selim WWTP and Bardenpho pilot plant

The typical phosphorus content of MLSS in conventional secondary treatment is approximately 2 percent by weight. Enhanced biological phosphorus removal (EBPR) refers to phosphorus uptake greater than these metabolic requirements by specialized aerobic heterotrophs called Phosphorus Accumulating Organisms (PAOs).

Acinetobacter is the most widely recognized PAO. The phosphorus content of the biomass can be as high as 10 percent by weight, but is typically in the range of 3 to 5 percent; hence, the biological phosphorus removal capability of a system is directly related to the fraction of PAOs in the MLSS, Environmental and Water Resources Institute (2005).

In the anaerobic zone (**Figure 8**), the PAOs take up and store VFAs as carbon compounds such as poly-b-hydroxy butyrate (PHB). Those PAOs, being aerobes, cannot use the VFAs for cell growth in the anaerobic zone. Instead, the VFAs are used to replenish the cell's stored PHB for subsequent utilization in the aerobic zone. In other words, in the anaerobic zone the PAOs do not multiply, but get fat! The energy required for PHB accumulation is provided by the cleavage of another storage product, the inorganic polyphosphate granules. This splitting of release of phosphorus and may be likened to a battery discharging wastewater treatment plant Global(2007).

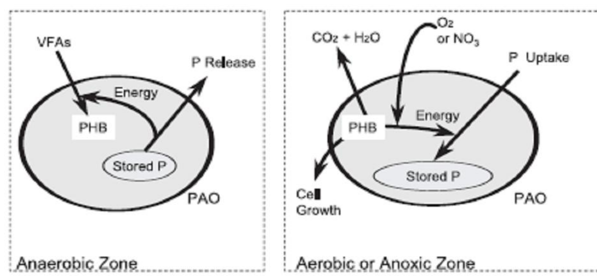


Figure 8: Biological Phosphorus Removal

In the subsequent aerobic zone, the PAOs use the internally stored PHB as a carbon and energy source and take up all the phosphate released in the anaerobic zone and additional phosphate present in the influent wastewater to renew the stored polyphosphate pool (recharging of the battery). This is because 24 to 36 times more energy is released by PHB oxidation in the aerobic zone than is used to store PHB in anaerobic zone; hence, the phosphorus uptake is significantly more than the phosphorus release.Net phosphorus removal is realized when sludge is wasted. When the phosphorus rich return sludge is recycled to the anaerobic zone, the process is repeated (**Figure 9**).

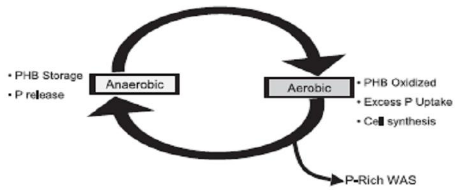


Figure 9: Anaerobic-Aerobic Cycling for EBPR

In short, the complex biochemical reactions of the EBPR process are fueled by the cyclical formation and degradation of stored organic compounds (e.g. PHB), in concert with the degradation and formation of inorganic polyphosphate granules. Some PAOs have the capability to denitrify. Denitrifying PAOs (DePAO) use nitrate instead of free oxygen to oxidize their internally stored PHB and effect phosphorus uptake in the anoxic zone.

The PAOs require higher energy than other heterotrophs (non-PAOs) to accomplish the cyclical reactions associated with the EBPR process. The two most critical factors that favor the proliferation of PAOs, and therefore the reliability of EBPR are: (1) the integrity of the anaerobic zone and (2) the availability of VFAs, Manariotis et al,m(2010).

The data show the efficiency removal of Phosphate concentration in Fisha Selim 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 low 48. The efficiency removal of Phosphate concentration from 80 % to 88 % after 14 h in 5 stage bardenpho pilot plant.

3-3-6 Nickel Content

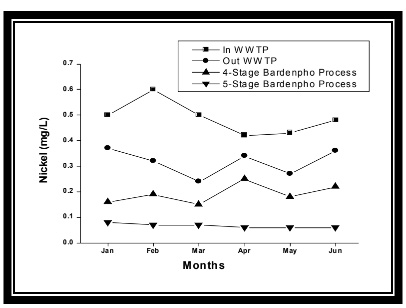


Fig. (10): Nickel (mg/l) in Fisha Selim WWTP and bardenpho pilot plant

3-3-7 iron Content

The data show the efficiency removal of heavy metal Fisha Selim WWTP (after 12 h) ranged between (10-30 %).The efficiency removals of heavy metal reached 70 % after 14 h in 4 stage bardenpho pilot plant. The efficiency removal of heavy metal concentration reached (90 -100)% after 14 h in 5 stage bardenpho pilot plant.

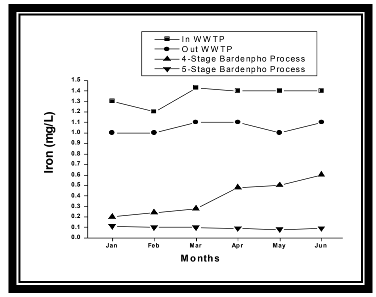


Fig. (11): Iron (mg/l) in Fisha Selim WWTP and bardenpho pilot plant

The data show the efficiency removal of heavy metal Fisha Selim WWTP (after 12 h) ranged between (10-30 %). The efficiency removal of heavy metal reached 70 % after 14 h in 4 stage bardenpho pilot plant. The efficiency removal of heavy metal concentration reached (90 -100)% after 14 h in 5 stage bardenpho pilot plant.

-Conclusion:

The Bardenpho process is a proven method of removing nutrients using naturally occurring microorganisms. The primary objective of BNR plant operations is to achieve regulatory compliance consistently. Other objectives often include operational cost savings; process optimization; and a safe, clean workplace. Meeting these objectives demands proper design, operation, and management. Designers should incorporate features that would provide maximum process flexibility and ease of operation and maintenance.

The 4-stage Bardenpho process involves an anoxic zone, followed by an aerobic zone (with an internal recycle to the first anoxic zone), which is followed by a second anoxic zone and a small aerobic zone. With pumps and zone sizes typically set large enough to accommodate a 400 percent internal recycle rate, the first anoxic zone accomplishes the bulk of the denitrification. The second anoxic zone removes nitrates from the first aerobic zone that are not recycled to the first anoxic zone.The second aerobic zone removes the nitrogen gas from the wastewater before the wastewater enters the secondary clarifiers. By aerating, the possibility of denitrification in the clarifier is removed. The sludge tends to settle better, and overall operation of the secondary clarifier is improved.

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.

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