Optimal Management of Anaerobic Digestion Systems: Instrumentation, Control Strategies and Implementation in Anaerobic Treatment

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Abstract
Astonishing progress made in the field of anaerobic technology during the last 40 years has resulted in its expanded applicability to the treatment of various wastewater streams. Despite numerous successfully commissioned anaerobic treatment plants recorded, consistency in achieving desired treatment performance has been a challenge because the process can be destabilized in the presence of parameter uncertainty and input disturbance. This paper aims to underpin the operational control strategies and innovative improvements in the design of the anaerobic digestion process, specifically in its application to effluent from a palm oil mill. Ultimately, the objective is to achieve optimization in the anaerobic process and biogas output.

Introduction
Anaerobic digestion is a complex microbial decomposition of organic matter by microorganisms in an oxygen depleted environment. The process produces biogas (principally consisting of methane and carbon dioxide) and nutrient-rich bio-solids. Historically, anaerobic digestion is one of the oldest processing technologies used by mankind. Until the 1970s, it was commonly used only in the wastewater treatment plants waste management (Palmisano et al. 1996) but there is also considerable interest in plant-biomass-fed anaerobic digesters, since the biologically produced methane is a useful source of energy.

In the past, anaerobic lagoons and ditches are universally employed to treat palm oil mill effluent (POME) because of the low capital and operating cost. Nevertheless, this anaerobic digestion process suffers from a lack of suitable control system and mixing mechanism which appear to be susceptible to treatment failure, leading to environmental problems. Also, the rising biogas will bring along with it the fine suspended solids which gradually develop into scum and presence of residual oil in the pond will worsen the problem by forming sticky scum. Consequently, the digester capacity will be tremendously reduce and shorten the HRT, entailing with a trade-off in treatment efficiency. Apparently, anaerobic process is exceptionally sensitive to its environment and only operates optimally within a relatively narrow range of physical conditions. On the contrary, anaerobic process conducted in tank digesters would enable better system control and consistency and would appear to be most compatible for the anaerobic treatment of POME.

A formidable challenge in the development of an optimal management of an anaerobic digestion system is the operational control and implementation strategy catering to the anaerobic process complexity that unfortunately often suffers from instability. Regularly, such instability causing digester failure can be addressed via two main categories: environmental and operational. It is often caused by feed overloading, feed under-loading, inadequate pH and temperature control or an entry of inhibitor. All described changes may have a negative effect and drastically disrupt the total biogenic process. Anaerobic digester and biogas plant operators therefore have a vested interest in running their anaerobic system as efficiently as possible in order to minimize system failure that entails cost-intensive restart.

Fundamentally, the management of an anaerobic digestion system is the management of biological process and biogas yield. This will essentially improve the digestion efficiency, meet standards for effluent discharge from the system especially during period of heavy flow, ensure consistency and quality in biogas output, increase useful life of facilities and enhance plant safety. Optimization of the operational conditions can only be executed on a well-controlled and well-monitored anaerobic system.
Table 1: Main factors contributing to instability of an anaerobic system.

<table>
<thead>
<tr>
<th>Environmental</th>
<th>Operational</th>
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<tr>
<td>pH and alkalinity</td>
<td>Hydraulic retention time (HRT)</td>
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<tr>
<td>Temperature</td>
<td>Organic loading rate (OLR)</td>
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<tr>
<td>Nutrients</td>
<td>Solids retention time (SRT)</td>
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<td>Inhibition and toxicity</td>
<td>Mixing</td>
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The key strategies to manage an anaerobic digestion system essentially comprise of three approaches:

- Detailing out the anaerobic operation system
- Installing a comprehensive anaerobic process management control system
- Administration and process monitoring in practice

Operation structure of a closed anaerobic digester and biogas plant

A schematic flow of the anaerobic treatment process of POME is portrayed in Figure 1. The technology developed by Konzen Clean Energy (KCE) to perform anaerobic treatment of POME is in a closed anaerobic digester of Continuous Stirred Tank Reactor (CSTR) type under mesophilic condition. The anaerobic digester plant has been divided into few sections with aim to ease plant control implementation besides enabling efficient plant troubleshooting procedure. The main four systems are listed below:

i. Pre-treatment system
ii. Anaerobic digestion system
iii. Biogas handling system
iv. Post-treatment system

Figure 1: Schematic flow of a typical CSTR anaerobic digester plant developed by KCE.

In the first system, the substrate for digestion process is made available, treated and equalized in accordance with requirements and fed into the anaerobic digestion system. In the second system, the anaerobic fermentation process takes place in the digester within a mesophilic range of temperature between 38-45°C, yielding biogas. Thirdly, the produced biogas is treated, stored and utilized. Finally, the digested residues are treated, utilized or discharged.
Pre-treatment system
In the palm oil mill, the raw POME streams from various processes in the mill via the sterilization of Fresh Fruit Bunch (FFB), clarification of the extracted crude palm oil and other wastewater converging into a the cooling pond. The cooled POME will be pumped from the cooling pond into the pre-treatment system.

Comprising of collection tank, oil separation tank and pH adjustment tank, the pre-treatment system is crucial for the entire process as to avoid adversely loading the digester with oil, silt and acid. First and foremost, the incoming POME flows into the collection tank with preliminary pH monitoring approach installed. POME will then overflow into the oil separation tank for excess oily scum removal. Grit and sand collector will contain heavier settled solids in the oil separation tank. The settled grit and sand can be manually removed. The amount of grit and sand entering the digester tank must be kept at minimum as they will cause stratification and deposition in the digester tank resulting in diminishing effective volume of the digester tank. The regularity of sand and grit removal has been determined and a removal schedule has been established when the system is in its operational stage.

After the oil separation tank, POME overflows into pH adjustment tank for pH fine-tuning process. In most scenarios, the pH is self-regulating. Primary treated sludge will be recycled and mixed with fresh feed in order to achieve pH adjustment target. The pH of the incoming POME would be estimated at about 4 and thus it is necessary to be adjusted to about neutral level of 7. Maintaining the pH up or near the neutral is a prerequisite for a stable operation of the anaerobic digester as methanogenesis occurs optimally in the narrow pH window between 6.5 and 7.5. Alkalinity level of about 4000 mg/L CaCO$_3$ has to be achieved. In start-up case where a low pH value has been established and sludge from clarifier is unavailable, external alkalinity has to be introduced. A lime dosing system has been incorporated for initial pH tuning procedures. Supplementary amounts of bicarbonate of soda can be added to improve the alkalinity in the digester feed in order to prevent uncontrolled pH fluctuations during the plant commissioning. All pH measurement and monitoring devices must be well-maintained and calibrated regularly as pH level critically affects the anaerobic bacteria activity.

Anaerobic digestion system
The digester feed pumps are in place to deliver the pre-treated POME into the digester in a constant volume and controlled manner. The operation of the CSTR anaerobic digester is designed to run continuously. Good mixing of the digester content is ensured by recycling biogas via a draft tube fitted with a helical structure in the digester tank to provide the draft draw of fluids from the bottom of the digester and discharged from the top. Hence, this creates a convection fluid flow regime in the digester tank. It is imperative to ensure the POME is well-mixed in the digester tank to achieve homogeneity of the digester content, equalize temperature and pH distribution, promote nutrients and food spreading among bacteria and avoid toxic substances from accumulating in dead zone. Therefore sufficient volume of biogas must be re-circulated at the designated temperature and pressure throughout the operation to promote better stability to the digestion operating regime. The use of biogas mixing appears to ease operation and maintenance works as compared to conventional mechanical mixers. During initial feeding, the mixing shall be operated continuously so that the digester contents are homogenized and sharp temperature gradients are evaded in the vessel. The liquor circulation operation should be maintained in a continuous basis except prior to de-sludging operation and should not be stopped for more than a pre-defined period to prevent stratification of the solids and scum formation.

Methane-forming bacteria groups become less active with decreasing pH, while fermentative bacteria remain active and continue to produce fatty acids that destroy alkalinity, depressing pH and resulting in inhibition of methane-forming bacteria. Moreover, there will be an increase in the quantity of hydrogen sulfide and hydrogen cyanide with decreasing pH at which these two inorganic compounds appear to be highly toxic to the methane-forming bacteria. Likewise, an increase in the quantity of ammonia occurs with increasing pH value. Therefore, anaerobic digesters to be operated at a near neutral pH value must be monitored closely to ensure a suitable pH environment and alkalinity residual.

The operating temperature of the anaerobic digester must be maintained constantly within the mesophilic range throughout the geometry of the tank to ensure optimum micro-organism’s growth and activity. Any significant temperature gradients will not directly be harmful to the methane-forming bacteria but the
fluctuations may inhibit the methanogenesis process. Thus, fluctuations in the operating temperature of the anaerobic digesters should be kept minimal.

To minimize the temperature variations, digestion vessels requires some level of insulation or heating consideration. The digester tank is designed with re-heating forethought by heat recovery from the biogas compression process. Biogas gain heat content after being compressed and the heat is being transferred to the digester content when the biogas is recycled to the digester for mixing purpose. The temperature of the recycling biogas can be controlled via the compressed biogas cooling facility to obtain the desired biogas temperature entering the digester. The temperature of recycling biogas would have to be carefully calibrated during the system start-up stage to accomplish the essential condition of the digester feed and recycle streams.

The digester is designed with a membrane roof cover to capture biogas generated and the biogas is stored at a desired pressure. As the biogas is inflammable and has explosive potential, the vicinity around the anaerobic digester has to be kept flame free and spark free zone. Therefore, all electrical and rotating equipment must be explosion proof and shall comply with local fire safety regulations and practices.

**Biogas handling system**

Fundamentally, biogas generated from the anaerobic digestion process is a highly flammable gas mixture. Biogas generated from the anaerobic digester will be stored in a membrane storage facility. The biogas streams in the system are equipped with spark arrestors and pressure relief facilities in an explosion-free zone. Other safety features comprises of the low and high pressure switch, axial fan to ensure combustion temperature not exceeding 1000°C, temperature thermocouple and ionization rod (UV detector) for flare monitoring.

The biogas produced will be analyzed by online gas analyser and gas flow transmitter installed to monitor the volumetric flow rate and the gas characteristics (contents of methane, carbon dioxide, hydrogen sulphide, etc.). The methane destruction efficiency of the biogas flaring can also be accessed by measuring the methane, oxygen and hydrogen sulphide level prior and after flare. An online gas flow totalizer will record the volume of gas being combusted. Acquiring the biogas data, anaerobic digester performance can be examined and these serve as the best possible planning tool to determine the distribution of the biogas for utilization. With the biogas data, we can execute precise planning to keep carbon dioxide emissions to a minimum.

The biogas recycling subsystem comprises of roots blowers and biogas cooling package. The biogas will be drawn from the biogas storage using roots blowers to the mixing manifold in the digester. Biogas heats up after compression and will be cooled via an online water cooling system to obtain the desired recycling biogas temperature at below 50°C.

*Figure 2: (a) Biogas flow measuring instrument (b) Biogas characteristics analyzer.*

Any unutilized biogas will be flared off safely in the enclosed flare system. Water separators (with filter and auto drain) are installed to prevent condensation in pipe line besides improving combustion process. Blowers conveying biogas from digester to designated facility are fitted with flame arrestors to prevent flame to spread in case of explosion. Utilizing enclosed flare system, the destruction of methane anticipated at 90% efficiency
and above with flaring temperature above 500°C can be achieved and this will contribute to environmental benefits. Also, this approach meets the United Nations Framework Convention on Climate Change (UNFCCC) requirement and enabling the project to be qualified as a Clean Development Mechanism (CDM) project.

**Post-treatment system**

Treated POME mixed liquor from anaerobic digester tank will overflow into a primary discharge sump for temporary storage before feeding into the clarifier tank for solid-liquid separation process. The desludging of the digester will be done via desludge pipe on a daily basis.

The clarifier tank receives treated POME from primary discharge sump by running submersible pumps or gravity flow. The clarifier tank was completed with clarifier scrapper and static floculating system. The heavy sludge shall settled down at the center of the clarifier tank while clear treated POME will overflow and being transferred to subsequent aerobic treatment facilities.

The sludge settled at the center of the clarifier tank will be conveyed by pumps to sludge collection pond. Also, a portion of the settled sludge will be recycled to the pre-treatment system for anaerobic condition adjustment purpose.

**Process monitoring management and parameter control system**

An effective anaerobic degradation of organic matter requires relevant healthy bacteria populations to be working in synergy. A meticulous process design will favour the maintenance of a stable population of methanogens while a successful process depends on an accurate balance of the ecological system via stringent management on the suitable environmental requirement of anaerobic digestion. Targeting to achieve optimal control of the degradation process in the anaerobic digester and biogas plant, a detailed knowledge of the key physical and chemical parameters is essential.

Figure 3 illustrates the major systems of the overall anaerobic digestion and biogas plant management control system. Figure 4 outlines the schematic layout of the control parameters in each system of the anaerobic digestion treatment plant.

*Figure 3: Overall anaerobic digestion and biogas plant management control system.*

The anaerobic digester plant is constructed with required instrumentation and detailed programming in order to enable effective plant management and consequently maintaining consistent process deliverables. The Programmable Logic Control (PLC) and Supervisory Control and Data Acquisition (SCADA) system have been incorporated into the plant operation. The 4-20mA output signal from the measuring instruments in the plant will be transmitted to the industrial Ethernet main switch for processing and appropriate output will be produced for further action, for example, SMS alarm, etc. Similarly, the 4-20mA output signal from the field
instruments will also be linked to SCADA panel by Ethernet. The intelligent systems will assist and ease plant operators in controlling and monitoring the condition of the plant in a continuous manner.

*Figure 4: Schematic layout of control parameters in an anaerobic digester plant developed by KCE.*

The degree of automation and manual control management approach required for a particular plant is governed by a few factors which include throughput of the process, criticality of the process conditions, complexity of the process, plant utilization requirements. The PLC has been incorporated and will control the operation of the four major systems in the plant.

Each of the process pumps will be accountable within each system as a logical group to ensure the integrity of the systems in the event of a critical malfunction. The PLC has been designed to disable a faulty system resulting from the aforesaid condition without impacting the rest system.

*Figure 5: Biogas quality and output monitoring results.*

**Biogas Quality and Output Monitoring**

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Benefits of an anaerobic treatment plant with process control and monitoring management include:

- Good anaerobic treatment process can be obtained throughout the plant operations
- Accurate and orderly bookkeeping of biogas output and quality, improving resources management (Figure 5).
• Maximum utilization of biogas is possible.
• Plant downtime due to sudden critical parameter variations can be avoided.
• Access to logged data which ease plant performance evaluation and interpretation procedures.
• Minimum manpower at plant because monitoring will be in the control room and the plant is operated in a semi-auto mode.
• Some of the mechanical equipments will be controlled automatically and hence improving general working environment
• Easy and safe operation.

pH and temperature
Both pH and temperature transmitters come with probe will measure the pH and temperature values of the POME and trigger the condition adjustment process where required. The transmitters provide a 4-20mA output to the SCADA and the value display at SCADA page will assist the operator on the overall system control purpose. The interlocking function of the transmitters with the pumps enables the transmitters to work immediately once the pumps are automatically switched on and they stop on delay timers (about 10 minutes) once the pumps are switched off automatically.

During operation, the pH readings (Figure 6) remained in the range near neutral in the digester, the average was 7.26 with a minimum of 7.15 and a maximum of 7.39. The temperature readings (Figure 6) remained in the mesophilic range of 38-45°C in the digester. The average was 41.02°C and fluctuated between 39.15 and 44.33°C. The results obtained portray that the pH and temperature in a digester are not constant but fluctuate as suggested by Figure 6. The sudden temperature spike observed could be due to external factors with the likelihood of an increased milling activity resulting in higher temperature influent into the anaerobic system. However, with the control system installed, the parameter variation can be immediately rectified and actions to be taken to return the system back to the acceptable mesophilic range of 38-45°C.

Figure 6: Measurements from the mesophilic CSTR anaerobic digester developed by KCE.

It is crucial to have continuous pH and temperature measurements to obtain an early indication of any acute disruption of the digestion process. Simple metering of pH and temperature values based on current value will not always be reliable especially on a plant with digester tank designed at a large buffer capacity. An unintentionally overloading of organic acids or high temperature content does not necessarily contribute to a drop in pH level or a rise in temperature level. If the pH in an anaerobic reactor decreases, the rectifying approach could be to stop feeding the digester, providing the methanogens sufficient time to consume excess fatty acids and raise the pH level to an acceptable value. Other alternatives would be to increase buffering capacity by adding external alkalinity.
Having appropriate positioning of the probes in the control zone, the conditions of the pre-treatment system, anaerobic digestion system and post-treatment system can be accurately determined and monitored via human machine interface, enabling trend study and necessary action and remediation.

**Nutrients and chemical oxygen demand (COD)**

The nutritional requirements of anaerobic bacteria are important as nutrients supply ensure bacteria growth and enable enzyme synthesis by the cell. Nutrients deficiency will result in low conversation rates and inhibition of microbial activity. The nitrogen to carbon ratio of 1/20 to 1/30 is to be maintained. Microbial incorporation of phosphorus in anaerobic digestion would be approximately 1/7 of that established for nitrogen. POME samples are sent to accredited laboratory for analysis on nutrient contents periodically.

COD portrays the measurement of the organic matter contained in the substrate. This suggests that the percentage of COD destruction can serve as an indicator to represent the digester performance. Also, COD has a direct indicative factor to the biogas output. Methane formation increases with an increase in the COD removal efficiency. Theoretically, amount of methane produced per unit of COD converted under anaerobic conditions at 35°C is equal to 0.40 m³ per kilogram of COD (Metcalf and Eddy, 2003). Utilizing different anaerobic treatment approaches and practices, methane formation rates lies between 0.15-0.42 litre per gram of COD removed with COD removal efficiency of 70-97% (Lam MK and Lee KT, 2011). Periodic monitoring of COD before and after digestion is important to evaluate the anaerobic digester performance.

In order to acquire onsite COD results based on fresh samples taken from the digester feed and digested wastewater stream, COD can be monitored using chemical or photometric tests. The onsite laboratory devices enable biologically active samples to be tested immediately. This is important to monitor digester performance and enable early process troubleshooting should there be any process instability or inhibition of the biogas productivity to occur. Reference analysis will be performed by the appointed laboratory with corresponding standard method (APHA 5220D). Effectively, the period between the on-site analysis and laboratory analysis should be kept as short as possible for comparability of the results.

**Inhibition/ toxicity**

According to two valuable definitions within the area of general restriction of biological processes by Speece (1996), toxicity is an adverse effect (not necessarily lethal) on bacterial metabolism, while inhibition is an impairment of bacterial function. The presence of certain chemicals may cause imbalance in the microecology within the digester or process inhibition.

Some weak acids and bases contributing to toxicity which is related to pH, determine the degree of dissociation. Typically, the components found in the wastewater to be digested include sulphides, metals, organic acids and ammonium. Sulphides are resulting from the mineralization of sulphur containing proteins and converted by the sulphate reducing bacteria in the anaerobic digester. Normally the sulphide concentrations remain at acceptable range and will not inhibit methanogenic activity severely and on the other hand the sulphide can neutralize heavy metals that are toxic to the anaerobic digestion process, forming insoluble salts. The control of organic acids would be indicated by monitoring of pH condition. A rise in acid concentration will be portrayed by a drop in pH below 7. Ammonia produced during the anaerobic treatment of wastewaters contain proteins and amino acids. Generally, it is an important buffer in the anaerobic treatment process and an essential nutrient for microorganisms, however high concentration may lead to inhibitory effect. When the pH increases, production of ammonia becomes favourable. Hence, there shall be close monitoring on pH and regular checks on ammonium content of the digester.

Besides, excessive oil (palm oil) may incur disruption in the anaerobic degradation process due to the complexities of oil and grease decomposition and solidification in the piping and vessel causing choking and leading to an increase in mixed liquor viscosity. Oxygen is another inhibitory factor for anaerobic digestion process. In the mixed culture in the digester, however, there are facultative anaerobic microorganisms present that will rapidly consume any oxygen in the digester. Oxygen level in the digester can be measured by gas analyzer and immediate inspections can be performed at alarming oxygen level. Also, by having a water seal in the design of the digester outlet, any ingress air into the digester vessel can be prevented.
Operational factors
Solids retention time (SRT), hydraulic retention time (HRT) and organic loading rate (OLR) in relation to substrate composition and concentration as well as mixing pertaining to promoting distribution and contact between organic matter and microorganisms, are all operational factors affecting the performance of anaerobic digestion.

SRT can be equivalent to HRT in a single-phase completely mixed digester. Higher substrate concentration or solids content in the mixed liquor in the digester requires longer retention time to degrade. The retention time shall be extended if more complex substrates are introduced. In order to be able to retain high concentration of plant biomass in the digester, SRT shall be increased with resulting declined HRT. The solids content in the digester will be determined by the digester feed substrate loading and digester outlet solids stream (sludge). To accommodate to variations in POME due to seasonal milling activity, the digester loading rate and sludge recycling ratio can be periodically determined and managed via solids content analysis on the POME sample. A digester desludging schedule is developed to regulate SRT of the digester.

OLR of the digester is expressed in terms of COD. The digester feed flow rate is closely monitored via flow transmitters installed in POME lines while also having the digester feed pumps to run with stand-by unit readily available so feed flow will not be disrupted during the maintenance or mechanical failure of the operating unit. Also, the digester content level is monitored with level transmitters. Maintaining the digester content at optimum level is vital to ensure nutrient loading in the digester. When decreasing in water level is observed in the digester, immediate inspection for sudden leakage or opened valve must be carried out in order to rectify the sudden variation.

Optimal mixing or agitation of the digesting material is to maintain a fluid velocity so that all the solids remain in suspension with aim to improve the digestion process. The level and type of mixing will affect the growth rate of the microorganisms, substrate distribution and utilization rates, granule formation and gas production (Smith et al., 1996). Gas-liquid mixing using recycled biogas had been shown to be beneficial for many digesters and provide better stability in the digestion process, entailing with enhance in biogas output consistency. However, the system requires minimum biogas storage to ensure sufficient biogas available for mixing. A higher storage buffer capacity provides a more reliable operation. Also, an optimum mixing cycle has been developed as there were reports showing that excessive mixing could eventually leading to a reduction in digester performance. The experimental results by McMahon et al. (2001) demonstrated that continuously mixing reactors may not necessary for good performance and may cause inhibition at high loading rates, possibly due to the disruption of syntrophic relationships and spatial juxtaposition.

Plant administration and standard procedures
In order to realize a well-conceived and correctly operated anaerobic digestion treatment plant, some operational aspects should be identified and emphasized, for example:

- system start-up and shut down guidelines
- operational routine and maintenance schedule
- troubleshooting and corrective actions
- data processing and documentation
- personnel duty roster, best practice and training plan
- quality assurance procedures and audit
- emergency action plan and safety information

Regular assessments and specific performance evaluations for the anaerobic digester plant are required to ensure compliances with the installation and operation permits as well as related threshold levels.

Operational routine and maintenance
To start up the anaerobic digestion treatment plant, effluent obtained from an operating anaerobic facility could serve as excellent inoculums to accomplish a fast start up of an anaerobic digester treating POME. When the desirable environmental factors (temperature, pH, nutrients amount) are favourable after equipment testing, the key start-up guidelines in accordance to be highlighted are as follows:
Perform a detail analysis of the characteristics of the POME in an accredited laboratory.

Check functionality of every process unit.

Load digester gradually, allowing time for adaptation.

Monitor and record all process parameters for evaluation.

Supplement necessary alkalinity to the system to maintain pH close to neutral level.

Monitor and maintain temperature inside the digester at the ideal mesophilic range of 38-45°C.

Perform onsite COD analysis and monitor biogas output and quality to evaluate digester condition.

Monitor toxic compounds to be out of inhibiting concentrations or otherwise allow time for microorganism acclimatization.

Perform mixing with atmospheric air and gradually replace with biogas produced.

Maintain the running of the digester in operational mode when methane content in the biogas storage is recorded at about 60%.

Targeting to prolong the plant life, operational routine and maintenance frequency must be identified. System servicing agenda and maintenance routine shall include the following:

- spare parts replacement list
- system inspection and housekeeping works
- system performance monitoring
- incident recording and reporting
- instruments calibration routine
- continuous system improvement evaluation program
- digester performance results validation and documentation
- general consultancy and training on related issues

With these aspects strictly adhered to, optimized operational conditions can be accomplished besides meeting the goal of cost reduction and minimizing plant downtime.

**Information management and personnel administration**

One of the steps to achieve tip top anaerobic treatment plant performance is the establishment of an effective communication between different people involved in the operation and maintenance of the anaerobic treatment plant. In general, roles and responsibilities of the members in the project organization chart dedicated for the anaerobic treatment plant will be described. Training will be conducted for the two working groups in the anaerobic treatment plant: unskilled labour and qualified personnel. The scopes for unskilled labour basically involve daily operation and maintenance of the equipments while the qualified personnel shall be the key person responsible for the management of practical and analytical works of the project including operational stability monitoring activities and inspection works for risk management. Annual assessment on the plant operators’ competency besides conducting trainings to them will be essential.

Plant performance can only be evaluated via a deliberate and neat data recording and documentation system. Continuous data recording can be processed and stored at the data logger while manual recordings will be properly archived for subsequent data analysis and evaluation purposes. Also, the treatment plant data trending recorded in data logger will be printed out as hardcopy record. Any alarming spike or odd results will be highlighted and root cause will be underlined by the system operator for future audit purpose. The out-of-limit step by step troubleshooting guidelines are readily available at plant site to aid operator in executing immediate remedial measures.

Besides, the local supervision system is completed with a remote internet-based supervision system collecting data from several processes and running a database diagnosis. It will perform comparison on the data obtained directly with the recommended range or set points. All data is saved in computer hard disk. The apparent advantage of such implementation is to remotely monitor the plant critical parameters, enabling prompt response to abnormal operating condition at any time.
Conclusion

The anaerobic digestion process in a commercially operated treatment plant takes place in a sensitive microbiological system. Investment in proper plant management system package and well-trained plant operators enable cost-effective, accurate and real time monitoring of the anaerobic degradation process and thus a consistency in the treatment outcomes and biogas yield. Insufficient and ineffective control strategy of the anaerobic environment may result in risks associated with uncontrolled process and poor administrative issues.

Operating each process unit at its best may not always result in the best plant performance and yet the performance of one process unit is always interconnected with another process. Poor performance or operational failure of one process unit can incur chain impact to either upstream or downstream functions.

Plant-wide operation experience shows that anaerobic digestion process must be thoroughly understood, closely monitored and carefully evaluated in order to achieve optimization in the anaerobic process and biogas output yet a profitable operation of the entire anaerobic digestion treatment system. With the integration of programmed control system and practical plant management strategy, results obtained from the systemized approach have been both beneficial and encouraging.

References


UNFCCC, United Nation Framework Convention on Climate Change, available online: http://unfccc.int/2860.php