Pipeline Design for Effluent Transport in Common Effluent Treatment Plants

ecp consulting
infusing intelligence

TABLE OF CONTENTS

Pipeline Design for Effluent Transport in Zero Discharge Common Effluent Treatment Plants

S.ESWARAMOORTHI
ECP CONSULTING

Introduction

Nowadays the concept of zero discharge is growing along with the adoption of Common Effluent Treatment Plants (CETPs). Already existing CETPs, such as Patencheru CETP in Andhra Pradesh, were criticized for insufficient and/or, inefficient operation. Even the successfulness of the concept of CETP was questioned. But the problems faced in CETPs are not uncommon in Individual Effluent Treatment Plants (ETPs) where, effluent from one particular industrial unit is treated. Apart from volume of treated water, the main difference between an IETP and CETP is in the complexity of organics present in the effluent – that too when the CETP member units handle entirely different processes that generate different types of effluent. Thus, the successfulness of a waste water treatment facility mainly depends on:

1) Adopting the right treatment process to achieve desired purpose.
2) Reducing the variability in the nature of the effluent to improve stability, treatability and performance.
3) Tuning the performance of all treatment units.

However, at first, the feasibility of establishing a CETP mainly depends on our ability to set up a proper collection and conveyance system for transport of effluent from each member unit to the CETP. The collection and conveyance system should meet the following criteria:

1) Once established, it should be durable – as frequent maintenance work along the buried pipeline shall be very tedious and not favourable for any reason.
2) The pipe material should be able to handle the harshness of the effluent for a long time.

3) The pipeline should be able to withstand necessary pressure, and should not deform over a period of its estimated lifetime significantly to an extend that affect the flow characteristics along the pipeline.
4) Jointing and bending of the pipe should not pose severe threat to its strength and stability to withstand the pressure.

This article discusses some of the important aspects of pipeline design for Zero Discharge Common Effluent Treatment Plants. The main difference between a CETP treating waste water for discharging into the natural systems and the one that achieves zero discharge are:

1) The zero discharge CETP should have additional pipeline for the return of reusable water to its member units.
2) It should also consider all measures related to flow measurement and pressure control along the returned water distribution line.

Advantages of Zero Discharge CETP

There are several advantages, as given here, in adopting the concept of CETP for industrial waste water treatment:

1) When collectively treated, the capital cost contribution of each member unit towards machineries got reduced significantly – as the cost of waste water treatment units and machineries does not linearly increase with their capacity. This provide a better opportunity for small industrial units to actively take part in common effluent treatment programme and reduce environmental pollution.
2) Collective treatment minimizes variability in effluent characteristics that improves plant performance.
3) Most of the CETPs are constructed with in-house secured landfill for hazardous waste storage (secured landfill). Thus, the need for transportation of hazardous waste generated in the treatment process is significantly reduced, and maintenance becomes easier. Whereas, in the case of IETPs, hazardous waste storage facilities normally exist outside their premises – mostly as a common facility for multiple IETPs. This increases the overhead of hazardous waste storage facility management.

4) Monitoring the performance of a CETP is relatively easier compared to observing several IETPs. Future up-gradation or, process modification can be carried out with comparatively lower costs.
5) Collective treatment reduces operation and maintenance costs. Human resource required to manage a CETP is comparatively less when compared with several individual effluent treatment plants.

In addition to the above, certainly many advantages can be obtained by implementing zero discharge in CETPs *viz.,*

1) Reduced pollution load on the environment.
2) Diminution in the contamination of rivers, lakes and reservoirs.
3) Prevention of ground water depletion.
4) Recovery of useful materials and water.
5) Ability to obtain reusable process water with desired quality for industrial purposes
6) Reduction of expenditures towards water purchase

Locating the Common Effluent Treatment Plant (CETP)

Establishment of a CETP requires the following steps to be undertaken.

1) Identification of CETP location based on aerial/satellite imagery and/or ground survey. The CETP has to be located at the lowest elevation point to ensure collection of effluent by gravity. This is a very crucial decision to be made before a CETP is established. A suitably located CETP reduces energy consumption – as effluent can be supplied to the CETP through gravity flow. As treated water has to be transported from CETP to the member units, if CETP is located at lower level, then pumping of treated water may be necessary. Thus, at first, the concept of energy saving may be questioned. However, since only 70-80% of water in the effluent is recovered for reuse in the member units, we can save the energy equivalent to pumping 20-30% of water. As member units may not be withdrawing treated water continuously, treated water can also be supplied from CETP to the member units from a over head tank. In this case, water shall be withdrawn from the overhead tank only when necessary. Whereas, in the case of pumping, pumping

has to be continuous and the flow has to be automatically regulated to avoid breaking up of the pipeline due to irregular withdrawal. Thus, choosing overhead tank for the supply of treated water distribution reduces overhead associated with setting up an automatically regulated pump. These things reduce energy consumption associated with pumping. Selecting a suitable pipe material and size is also important in this aspect and that shall be discussed later. Thus, at first the CETP location should meet the criteria that it should be located at comparatively lower place when compared with all member units or, at the least, a maximum number of member units (the member units that lie lower than the CETP has to pump the effluent). Otherwise, this shall raise total project cost as additional motors and pumps have to be installed - each one with a standby.

2) Some other factors that are to be considered are i) access to road; ii) proximity to hazardous waste storage facility; iii) very good drainage; iv) safety from floods; v) enough areal extension for establishment of solar evaporation pond; vi) additional space for later expansion.

3) After having located the CETP, it is essential to draw a plan for pipeline. Before deciding the pipeline route, existing drinking water pipelines and other utilities have to be taken into account. This shall ensure that accidental breaking up of effluent pipeline does not result in any catastrophe.

4) Having established all these things, an optimum pipeline route has to be found after conducting rapid GPS ground surveys. Once a tentative pipeline route is decided based on rapid GPS surveys, an optimum route can be selected using Geographical Information System. The optimum pipeline route is the one that shall minimize total pipeline distance and, at the same time, shall improve flow characteristics of the effluent through the pipeline. After the pipeline route is tentatively decided, a detailed conventional level survey should be conducted to establish elevation and direction of places where proposed pipeline shall pass through. The slope of the pipelines and the feasibility of laying the pipeline with desired slope have to be considered using the sub-surface geology. If the terrain is rocky, then this may pose some practical problems. Depending on the member unit location, in some cases, it may be necessary to implement pumping. Choosing the

location of the CETP should minimize the number of member units that are required to pump effluent to the main line. Under these circumstances, energy consumption for all possible different configurations of the pipeline have to be taken into account.

5) During pipeline design phase itself, it is necessary to locate tanks or sumps for waste water collection. Depending on the topography and distribution of member units, there may be a few sumps, each one collecting effluent from a group of industries located nearby and from a particular direction or, a particular pathway. All such collection sumps shall finally drain their effluent to the equalization tank of the CETP. There are many advantages associated with establishing such sumps in between member units and the CETP. At the sump, the effluent from various member units are homogenized to some extend. This reduces the variability of effluent characteristics received at the CETP, thereby reducing shocks. Secondly, during maintenance period of the CETP, excess effluent can be stored in these sumps and then treated later.

6) In the case of gravity flow, the pipeline design phase should also consider placement of manholes. Each manhole should be located in places where there is an abrupt change in slope is desired or, found unavoidable. In addition to this, whenever change in direction occurs, the manhole should be located at that place. The distance between each manhole should not exceed 30 to 50 m to enable cleaning up of the pipeline when desired. This also helps in identification of broken pipeline segment – as flow to the following manhole got reduced.

7) The height and design of the manholes should ensure that flooding does not result in mixing up of rainwater with the effluent. The space within the manhole should be enough for undertaking cleaning up operation.

8) The invert of the manhole should be well below the bottom of the pipeline supplying effluent to the manhole to ensure that stagnancy in the draining pipeline – if that occurs – does not prevent or, slowdown the flow of the effluent to the manhole. Similarly, the draining pipeline should be placed well above the invert of the manhole. The reason for this configuration is that the particles that are carried by

the effluent – if any – have the chance to get accumulated at the bottom of the manhole for later cleaning.

9) The pipeline should also have pressure release valves for the release of air-lock (which shall otherwise blow-up the pipeline), and flow meters for measuring effluent input from each member units to the CETP. Similarly, flow meters can also be fixed for measuring treated water consumption by each member unit. If necessary, these meters can be integrated through a network and flow measurement can be automated as per the requirement. Automating significantly improves pipeline maintenance, leakage detection, water theft, and billing for treated water consumption.

Pipeline Design

Pipeline design for gravity flow is based on *Manning*'s equation, and for pumped flow *Hazen-Williams* equation is utilized. Depending on the level (with respect to Mean Sea Level) of the each member unit and the proposed location of the CETP, either gravity flow or, pumped flow can be chosen.

The following information should be collected before designing the pipeline.

1) At first, level survey should be conducted from stipulated place of CETP to all possible member units. The data obtained from level survey is very much essential to decide whether gravity flow of effluent from each member unit to the CETP can be achieved or not.
2) Total number of member units, their distance and the route in which the pipeline should be laid should be tentatively decided.
3) A list of expected road-crossings, drinking water pipeline, and other utilities along the proposed pipeline route should be carefully studied. Crossing of rivers, tanks, lakes and water logged areas should also be considered. As far as possible, the pipeline meant for effluent transport should be well away from drinking water pipelines. And, the pipeline should not interfere with already existing the infrastructure created for other utilities.
4) The proposed pipeline route should enable routine maintenance works to be undertaken – both on short-term as well as on long-term basis. The maintenance

works includes maintenance of manholes, cleaning up of debris along the pipeline, and pipeline replacement when necessary,

5) The sub-surface geology of the region should be studied – as rocks buried near the surface can hamper laying the pipeline with desired slope (in the case of gravity flow). If sub-surface geology does not allow laying the pipeline with desired slope, then pumping should be considered. The possibility of choosing alternate pipeline route may have to be explored in some cases.
6) Normal flow and peak flow from each member unit should be estimated. This information is essential in deciding the capacity of the pipeline to be put in place. As far as possible, measures for reducing frequent peak flow through the pipeline should be avoided. One such measure is utilization of already existing or, construction of new tank/sump at each member unit for storing the effluent. In this case, the detention time of the tank/sump should be, at the least, one day discharge capacity of the relevant member unit. This ensures continued operation of the member unit while maintenance work is being undertaken in the CETP. There are certainly other benefits associated with this design that 1) the differential volumetric flow between peak flow and normal flow is minimized; 2) the debris in the effluent shall get deposited in the tank; 3) the homogeneity of effluent let down the pipeline increases and that reduces variability in the characteristics of the effluent to be treated at the CETP.
7) The distance between the proposed pipeline route and natural waterways such as, rivers and lakes, should be measured. As far as possible, the pipeline route should maximize this distance. This ensures that, if pipeline breaks due to unexpected reasons, then the effluent does not get mix up with the fresh water resources.
8) Similarly, the distance between proposed pipeline route and populated areas, environmentally protected areas, and ethically important places should be maximized.
9) If the locality does not permit implementation of gravity flow, pumping should be adopted for effluent transport. In this case, the possibility for returning treated water by gravity flow from the CETP to the respective member unit shall be considered – as the CETP level shall be higher when compared with the relevant member unit.
10) The minimum design flow velocity should be enough to prevent the deposition of suspended solids along the pipeline. Normally, a minimum self-cleaning velocity of 0.6 m/sec is adopted in the US. This is to ensure that suspended particles are not

getting deposited along the pipeline. This is applicable both for gravity flow as well as for pumped flow.

11) In gravity lines, the Froude number calculated for normal flow should be greater than 1. Froude number is essentially the ratio between the inertial force onto a column of flowing water to that of downward gravitational force. The pipeline slope, for design flow volume, should have a Froude number > 1. This essentially means that there shall be no stagnation of waste water along the pipeline. This shall ensure that no suspended particles are getting deposited during the flow. It should be noted that the Froude number is dependent on water depth in the pipeline. The water depth for normal flow should be taken for calculation.
12) The material chosen for the pipeline should be corrosion resistant, durable, amenable for jointing and bending and easily non-distortable.
13) Whenever bends are unavoidable in the design, the slope of the pipeline should be increased to compensate for energy loss in the bends. This also applies wherever flow control valves, flow meters and any other thing that reduces the energy of flow are fixed along the pipeline.
14) If temperature gradient is inevitable along the pipeline, then changes in density and viscosity of the waste water that alters friction loss should be considered. If this change is significant, the design should be made accordingly.

Laying the Pipeline

It is a very important aspect of any pipeline design. The following things should be strictly adhered to in the construction of a pipeline:

1) A minimum depth of cutting of 1 m should be employed to protect the pipeline from any damage.

2) As far as possible, abrupt bends and sudden change in slope should be avoided throughout the pipeline. This shall reduce air-lock events and subsequent breaking up of the pipeline.

3) Uniform slope should be adopted in the design. This shall ensure uniform flow through the pipeline. In places where uniform slope is not maintainable, the slope

should be adjusted with the aid of a manhole and made to approach the desired uniform slope.

4) The pressure rating of the pipeline should be at the least 2.5 times the expected maximum pressure insider the pipeline[1]. In the case of pumped flow, the burial depth should be more than enough to compensate for pressure built-up inside the pipeline due to effluent flow.

5) While refilling, necessary sand cushion should be provided. The provision of sand cushion ensures uniform distribution of pressure on all sides of the pipeline. Sharp materials, stones and other materials that may damage the pipeline should be avoided while refilling.

6) Air-lock releasing valves should be fixed in places where dramatic bends and sudden change in slope are unavoidable.

7) While crossing natural waterways, such as rivers, the pipeline may be laid over the surface to detect any possible leakage and break-up of the pipeline. In this case, the effect of buoyancy on to the pipeline during flooding should be considered.

8) Necessary clamps should be provided and the pipe tightly clamped to the ground in places where disturbance to the pipeline is expected. The same applies when the slope of the pipeline exceeds 0.02.

Pipeline Security

Though pipeline is designed and laid with much care, there are other possible ways in which the pipeline may tend to break due to:

1) Increase in roughness coefficient of the pipe material over a period of time that reduces flow rate and results in stagnation of the effluent.

1 2.5 times means around 99% confidence interval. The basis here is that the pipeline pressure is not expected to go beyond this limit in 99% of cases – so the frequency of breaking up of the pipeline is drastically reduced to less than 0.01%.

2) Accumulation of dust, pieces of cloth, *etc.*, in the effluent (if any) along the pipeline due to reduced flow velocity that aggravates flow characteristics of the effluent.

3) Corrosion of the pipeline over a period of time due to the nature of the effluent.

4) Fractures along joints and bends of the pipeline due to overpressure and/or ageing of the pipeline.

In order to prevent these problems, the following measures may be adopted:

1) The effluent meant for flow through the pipeline should be free from floating materials and dust particles. To achieve this purpose, it is essential to employ coarse and fine filters before the effluent is being let down the pipeline to filter out materials that may pose operational problems along the pipeline.

2) To reduce corrosion, the effluent should be neutralized and cooled to ambient temperature before delivery to the pipeline.

3) Provision of flow meters at each manhole or, at regular intervals, in addition to entry (member unit) and exit points (CETP), and its continuous monitoring shall make it easier to find where the pipeline has broken. Any significant difference in feed volume to that of output volume at the CETP should be interpreted as pipeline damage with due care for false signals (as it takes some time for the effluent to reach the CETP through the pipeline).

4) Pressure along the pipeline may be measured and logged using automated pressure sensors and data loggers for early detection of possible pipeline damage. This is a preventive measure that saves lot of problems that may occur in the pipeline in its entire lifetime.

5) In the case of pumping line, pressure along the pipeline should be monitored. Any pressure built-up beyond the design limit should be interpreted as due to some problems along the pipeline. The pipeline segment in which pressure is building up should be immediately observed. Alarms based on pressure gauges can also be installed for immediate warning.

6) If pressure built-up in one segment of the pipeline is followed by a pipeline segment where pressure declines than the normal level, possible interruption of flow due to faulty pipeline segment should be suspected. Most probably, it ought to be an air-lock - as it tends to build up pressure along the upstream pipeline segment and, at the same time, tends to reduce the pressure downstream from the place of the air-lock.

7) In the case of treated water distribution lines from the CETP to the member units – the member units may be withdrawing water at their own desire. This shall produce pressure fluctuations (shocks) and that may pose severe problems to the pipeline structure. This is most dominant where pumping line is utilized – though gravity lines may also pose some problems but that shall not be as severe as the pumping line. To circumvent this problem, constant pressure maintaining pumps may be installed. These pumps utilize pressure sensors and adjust the pumped flow through the pipeline by adjusting the motor speed through a variable drive. If this is not done, there should be, at the least, a pressure sensor that triggers automatic shut down of the pump when the pipeline pressure exceeds the desired limit.

Pipeline Flow Control

It is essential to continuously measure the flow through the pipeline. This is required for several purposes; among them are:

1) To check whether the flow is exceeding desired flow rate due to unknown reasons.

2) To check whether flow is stopped or, lower than normal flow rate is observed due to breaking up of the pipeline.

3) To log the flow so that each member unit can be charged for water treatment charges according to their discharged quantity of the effluent. This is also useful in deciding how much treated water they can be allowed to consume on daily basis.

4) To reveal any irregularity in pipe flow due to air-lock or other problems. This is essential for early detection and corrective measures.

5) Flow control is also essential when pipeline breaks up. Wherever necessary, valves should be placed along the pipeline to stop the flow during unexpected events. When this is done, the inflow to the pipeline should also be stopped immediately.

Pipeline Optimization

Pipeline optimization essentially means several things: 1) choosing the pipeline route that minimizes the total pipeline distance, reducing the required pipe size, and maximizing the effluent flow through the pipeline within the given time frame; 2) achieving overall reduction in energy requirement for effluent/treated water transport. Apart from this the optimization problem should also consider the following:

1) In places where flow is highly irregular, the pipe size should be chosen to meet the maximum flow rate.

2) Flow control valves and air-lock release valves should be placed in all desired places.

3) The pipeline route for effluent transport should be well away from natural water reservoirs, drinking water pipelines, and places where developmental activities are likely to happen.

4) Geophysical survey can be conducted in places where necessary to infer the depth to the bed rock. This is required to optimize the slope of the pipeline. In places, where the depth to the bed rock is minimal, the invert of the pipeline can be adjusted by suitably adjusting pipe size.

5) Future expansion, increase in roughness coefficient of the pipe that retards flow through the pipeline, and peak flow analysis should all be considered while establishing the pipeline network.

*****