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Wastewater treatment for high incomes

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THE TARGET OF the United Nations Water Supply And Sanitation Decade was to provide "Safe Water Supply And Adequate Sanitation For All" by the year 1990. Though this has not been achieved, much progress has been made particularly in the provision of safe drinking water. During the decade, the population lacking safe water supply in developing countries, reduced from 56% in 1980 to 31% in 1990, but the population lacking adequate sanitation facilities only reduced by 10% from 54% to 44%. The situation is particularly bad in the urban sector where the population lacking safe water reduced by as much as 15%, while the population lacking adequate sanitation reduced by just a mere 3%.(Carter,Tyrell & Howsam.1993) The urgent need for providing adequate wastewater treatment and disposal facilities in these densely populated urban areas is very clear, and must be considered seriously.

A significant proportion of the urban population in developing countries can be categorised as a "High Income Group". This group is generally supplied through a piped water supply system with individual house connections; but rarely are they provided with a sewerage system to carry away the considerable volume of wastewater generated. Individual septic tank and soakaway arrangements often satisfy the immediate requirements, but long term implications; the environmental impact; or the efficiency and effectiveness of the systems are not given much consideration. The Water Decade objectives were mainly based on reducing health and social problems, but with improvements in personal hygiene standards and the increasing emphasis on protecting the environment, providing a wastewater treatment system must be looked upon as a valuable investment for the future.

With a suitable sewerage system conveying wastewater to a central location, an efficient and effective process of treating the waste to meet high environmental standards can be conveniently provided at an affordable cost. There are many sewage / wastewater treatment systems available but Waste Stabilization Pond (WSP) systems seem to be the most common system widely recommended for developing countries. The WSP system is indeed an effective and a very economical means of treating wastewater. They are not systems only reserved for poor nations with hot climates; many western European countries with widely varying temperature conditions use them very successfully with over 4,000 systems operating in France and Germany alone (Mara,Mills,Pearson & Alabaster 1992). However, it must be noted that WSPs' in Europe generally serve small rural communities with populations of less than 2,000; and are tucked away in remote locations. While a WSP system in a developing country generally serves the high income groups who are concentrated in a rapidly developing urban area. WSP or Grass Plot systems are not always feasible or desirable in every situation, and often other conventional systems similar to those employed in developed countries provide the only viable alternative. Indeed, such systems have been in operation in a somewhat smaller scale in many countries for some time.

The paper aims to focus attention on general principles concerning wastewater treatment by briefly describing the philosophy and basis of wastewater treatment works design, as practised in UK. It also discusses the operation of three types of treatment plants that could be adopted in developing countries at an affordable cost. It is not the intention of this paper to evaluate or compare WSP or other low cost systems with Biological and Activated Sludge treatment processes described, but merely to indicate the adaptability and simplicity of systems that could be employed to derive the maximum benefits.

Basis of design - standards and monitoring

The responsibility for treatment and disposal of wastewater falls on the 10 privatised water companies in England and Wales and the Regional Councils in Scotland. The Department of Environment(DoE) and the Office of Fair-trading for Water(OFWAT) act as the Governments regulatory bodies. The National Rivers Authority (NRA), which functions under the DoE, is the body responsible for setting and monitoring effluent discharge standards for wastewater treatment works(WWTW) in the UK. In the past a single standard of 30 mg/l Suspended Solids(SS) & 20 mg/l Biochemical Oxygen Demand(BOD) was applied as a general rule where the receiving watercourse provided a 8 to 1 dilution at all times. Single standards are still applied in many European countries, but the UK now bases its consent standards on environmental quality standards. The quality required in the watercourse, depending on the use it is put to is defined. This is known as the "River Quality Objective"(RQO), on the basis of this and the dilution available, the discharge standard known as the "Objective Standard" is set. These standards are presently being further tightened with the introduction of new EC Directives which are implemented by means of UK legislation.

Wastewater treatment works are designed to a 95 percentile standard. Compliance with such a standard requires that effluent samples achieve or better the required standard for at least 95% of the time. In assessing 95 percentile compliance, the probability of failure when a small number of samples is used must be taken into account. This is done by the use of a "look-up" table which is based on results of a survey of actual number of samples taken. The table sets out various bands of samples, taken over a twelve month period, and the number that could fail while still allowing compliance to be met; as indicated in Table 1.(SWA 1987 / WTI 1994)

Estimation of flows

The design of the treatment processes requires the estimation of design flows. The base flow adopted in estimating flows, whether for sewers or treatment works is Dry Weather Flow (DWF), which is defined as the daily flow achieved by 7 dry days followed by 7 days with less than 0.25mm / d of rainfall or 14 days with less than 1mm / d of rainfall. In practice this is difficult to achieve and the DWF is estimated by;

DWF = PG + I + E (m3 / d), where P = Population, G = flow rate per capita, I = Infiltration, E = Industrial / cesspool Effluent

As dry weather flow is rarely achieved, the Average DWF (ADWF = 1.25DWF) is used as the design flow to calculate pollutant loads given the concentration of pollutants received at the treatment works. The works are designed to accept the average daily and peak loads as well as flows which arise from rainfall. The maximum storm flow received at a treatment works is calculated by a formula known as Formula 'A'. This sets the minimum level at which the wastewater is sufficiently diluted by rainwater so as to avoid pollution of the receiving watercourse when overflowed from the sewer.

Formula 'A' = DWF + 1.36P + 2E (m3 / d)

The maximum rate of flow accepted for settlement and biological treatment at a wastewater works is defined as the Flow to Full Treatment(FFT) and it is this flow that is used to design hydraulic processes. FFT represents the economical and practical cut-off for treatment; the difference between Formula'A' and FFT is stored on-site or in the sewerage system until the rate of flows return to ADWF. Flows above FFT will be overflowed if storm flows last for longer than a set period of time (usually 2 hours). Overflow is normally from settlement tanks(Storm Tanks).

Generally **FFT => 3DWF = 3PG + I + 3E or 4DWF = 4PG + I + 4E.**

Estimation of loads

Estimation of design loads for biological process design is difficult because domestic loads vary greatly from one country to another for various reasons, such as the use of domestic waste disposal units and differences in personal hygiene practices. Domestic load figures used for European and other developed countries are given in table 2. (W.T.I.1994).

Design philosophy

The general concept of design is to establish the combination of unit processes in the right sequence such that each may; operate at optimum efficiency, produce the required product, achieve the lowest capital and operating cost, and maximise the return of the capital invested. The design comprises of three main steps in the form of; Process design, Functional design and Detailed design; in selecting a suitable sequence of unit processes, estimation of capacities and the structural design of units (including selection of M & E plant); respectively.(W.T.I.1994)

Classification

Unit treatment processes are classified with respect to the effluent quality they are expected to produce. Preliminary treatment consists of screening and grit removal facilities and provides the minimum level of treatment necessary. Primary treatment is however the simplest form of treatment and is often considered satisfactory for ocean disposal of effluent. It comprises simple gravity sedimentation, preceded by preliminary treatment. The effluent from primary treatment would usually satisfy a 200:100(BOD:SS) consent standard on a 95 %ile basis.

Table 1.

Samples Taken in an Year	Max Failures Permitted
4 - 7	1
8 - 16	2
17 - 28	3
29 - 40	4 etc

Table 2.

Pollutant	Load g/head.day
BOD	60
SS	75
COD	155
Amm.N	8

Secondary treatment is typically aimed at further removing the non-settleable, largely organic matter to produce an effluent suitable for discharge to inland watercourses. Effluent from secondary treatment would usually satisfy a 20:30(BOD:SS) consent standard. Where effluent of a higher quality, such as 15:25(BOD:SS) or better is required, tertiary treatment is added. Disinfection processes are often included in this classification. Removal of nutrients (Nitrate & Phosphate) is sometimes classified as tertiary treatment, but more correctly is advanced wastewater treatment(AWT). Sludge treatment reduces the quantity of sludge generated by primary and secondary treatment, rendering them less offensive and suitable for disposal.

Selection of processes

There are many factors that need to be considered in the selection and design of the unit processes. They include; the Applicability of the Process, Influent Characteristics, Climatic Constraints, Environmental Impact, Resource, Energy & Operating Requirements, Reliability, Land Availability, Costs, etc. In addition consideration must also be given to Planning Requirements, Health and Safety of the works staff and surrounding population, potential problems due to Noise, Odours, Leakages, etc.(W.T.I.1994)

Limpsfield and Oxted wastewater treatment works - general

Limpsfield & Oxted WWTW is a Biological Filter treatment works serving a population of approximately 15,000. It is a type of works that would ideally suit a developing country situation with a small but rapidly growing urban population. The works is designed for a 4DWF full treatment flow of 136 l/s and a Formula'A' flow of 303 l/s; to achieve a final effluent consent standard of 15:20:5 (BOD:SS:Amm.N) in Summer and 20:30(BOD:SS) standard in Winter. Brief details of the works are given in table 3, and is followed by a short description on the operation of the works. (S.W.A.1987).

Operation - preliminary and primary treatment

A large diameter gravity sewer brings the wastewater to the works. All flow in excess of the Formula 'A' is screened and discharged to the river via the land treatment area; bypassing the treatment works. The forward flow carries the screenings to the inlet works where two screw pumps lift it up to be treated through the works process units. The flow passes through a Pista Grit Trap and two fine screens which operate on a duty/standby arrangement. The screenings are removed and conveyed through a screw conveyor system with the de-watered and compacted screenings bagged in plastic bags and deposited in a skip, until they are removed for disposal at a landfill site.

Table 3.

Process	Details of Process Units
Preliminary Treatment	12mm Mechanically raked screen, 3.4m dia Pista Grit Trap, 6mm Automatic fine screens with screenings removal and handling plant, Flow measurement Flumes. (Q = 490m3/h)
Primary Sedimentation	1 No 11m dia circular tank with Surface Area = 400m2, Volume = 1080m3 Surface Loading Rate = 1.2m3/m2/h Retention Time = 2.2hr @ 3DWF.
Biological Plant	8 No 11m dia circular filter with Dosing Siphons, Volume = 6,400m3, Hydraulic Loading Rate = 0.55m3/m3/d Biological Load;Rate = 0.09kgBOD/m3/d
Secondary Sedimentation	2 No 9m dia circular tanks, with Surface Area = 540m2, Volume = 1450m3 Surface Loading Rate = 0.9m3/m2/h Retention Time = 3.0hr @ 3DWF.
Storm Treatment	1 No 11m dia storage tank with capacity of V = 1080m3.(Req;Capacity=1050m3 @ 70 l/head)
Tertiary Treatment	"Stratasand" Sand Filter plant for Q = 165 l/s Standby Microstrainer plant for Q = 116 l/s.
Sludge Treatment	Thickening & Consolidation Plant with 2 No 5m dia Holding(Day) Tanks with Mixers, 1 No 5m dia Picket Fence Thickener, 1 No 12m dia Primary Digester, V = 750m3 1 No 12m dia Secondary Digester

Figure 1. Schematic diagram of Limpsfield & Oxted W.W.T.W.

Figure 2. Schematic diagram of Lamberhurst W.W.T.W.

Flow to the primary treatment process is conveyed through two channels having flow measuring facilities. One channel is dedicated to carrying the FFT and is controlled by an actuated penstock. The other channel carries the storm flow which is separated from the main flow at a point immediately downstream of the screens. The flow is discharged to one of the two settlement tanks which operate either as a Primary Settlement Tank(PST) when receiving treatment flows or a Storm Storage Tank(SST) when receiving storm flows. The duties of the tanks can be changed as and when required. Flow from the PST is discharged to the secondary treatment process, while any overflow from the SST is discharged to the river through the land treatment area.

Secondary treatment

The percolating filters which provides secondary treatment; are fed through dosing syphons and rotating distributors. The effluent from the filters gravitate to the Humus Tanks, where facilities are available for recirculating the flow if required. The effluent from the humus tanks is discharged to the tertiary treatment process; while the humus sludge is returned to the inlet through the works pumping station. The works pumping station also referred to as the Return Works Liquors(RWL) pumping station; serves to discharge any effluent requiring further treatment to the works inlet and in most other instances is separate from the humus return pumping station.

Tertiary treatment

Effluent from the humus tanks passes through “Copasacs”; a disposable fine mesh plastic bag, before entering the Tertiary Treatment feed pumping station. The “Stratasand” sand filter Tertiary Treatment Plant(TTP); operates as a continuous gravity filter, with the reject / washwater from the TTP discharged to the RWL pumping station for return to the inlet. Final Effluent(FE) is returned to the old microstrainer chamber; which is maintained as a standby tertiary treatment facility, prior to discharge to the river. At the microstrainer chamber, FE is drawn by the washwater pumps which provides the high pressure water system required for cleaning plant and other works units.

Sludge treatment

The works has a sludge consolidation plant for thickening and stabilizing the works generated sludge as well as sludge imported from nearby works. Works co-settled sludge is pumped directly to the works sludge(day) tank. The imported sludge passes through a “Rotamat” sludge screening plant prior to being pumped to the other holding tank. Sludge from both tanks is then fed to a continuous “Picket Fence” thickener. It is then transferred to the primary and secondary digesters where the sludge is digested anaerobically. The works sludge, if necessary, can be pumped directly to the digesters, bypassing the day tank and thickener. The stabilized liquid sludge is finally tankered away for disposal as necessary.

Lamberhurst wastewater treatment works - general

Lamberhurst WWTW is a small treatment works with an Oxidation Ditch plant serving a population of approximately 1,000. The flow to the works consists mainly of domestic wastewater but also receives effluent from an abattoir with a high COD concentration. The works is designed to treat a 3DWF full treatment flow of 12 l / s and a Formula'A' flow of 26 l / s to achieve a consent standard of 40;60(BOD;SS). Activated Sludge plants similar to this could be adopted in developing countries, where waste from a small concentrated population in highly sensitive areas has to be treated to a relatively high standard. This plant does not consist of any primary settlement facilities. It has a major draw-back in requiring an un-interrupted power supply. The simple storm treatment facility provided at this scheme is of particular interest and value to many potential situations in developing countries.

Operation - Storm treatment

Flow to the treatment plant is pumped from a nearby pumping station. Upstream of the pumping station is a storm treatment facility, which controls the forward flow to formula 'A', and overflows the excess to the nearby river. The "Storm King and Hydrobrake Overflow Control System" provides storm treatment facilities to comply with specified requirements. It has no moving parts or electrical devices and operates on the principle of dynamic separation. It is a passive system which only comes into operation under storm conditions and the solids retained within the system are returned to the forward flow to treatment. It is a very cheap and a versatile system which sits in a manhole chamber below ground level and requires very little attention once installed. Brief details of this works are given in table 4.

Sandwich Bay wastewater treatment works - general

The economies of developing countries often depend on the tourist industry where the "unspoilt beaches" are the main attraction to the western tourist. If the beaches are to remain as a major tourist attraction, then urgent action must be taken to preserve that unique "unspoilt" status. Any wastewater that is discharged to sea must be treated to a high standard; not only for the sake of the tourists, but also to prevent any health risks it could otherwise pose to the indigenous population of the country.

The Sandwich Bay scheme is one such scheme that envisages improving the quality of a number of "Designated Bathing Beaches" in Kent. It is designed to replace existing facilities that discharge wastewater through sea outfalls from three coastal towns. Three new pumping stations are being constructed to facilitate the discharge of foul flow to a new treatment plant providing secondary treatment for a total population of 100,000. At the pumping stations; excess storm flow is discharged through short sea outfalls after preliminary treatment. Brief details of this scheme are given in table 5, followed by a description on the operation of Deal pumping station.

Deal Pumping Station

The new pumping facility at Deal replaces the existing arrangement of discharging wastewater through a tidal storage tank and short outfall to sea. The town of Deal has a combined sewerage system and improvements to prevent flooding and attenuate storm flows to comply with the 1.5 spills per bathing season criteria are presently under way. The pumping station is designed so that wastewater(3DWF) flows directly to the wastewater chamber for discharge to the WWTW. Flows in excess of 3DWF are retained in the sewerage system in storage tunnels. To

Table 4.

Process	Details of Process Units
Preliminary Treatment	"Storm King" storm overflow system providing 12mm screenings, Macerator pump at inlet. (Q = 43m3/h)
Aeration Plant	38x10x1.4 m deep 1 lane Oxidation Ditch with surface area = 350m2, Operating MLSS = 3000mg/l Sludge Load;Rate(F/M Ratio) =0.09 Activated Sludge Return Rate = 1:1 Retention time = 24 hr @ DWF
Secondary Sedimentation	1 No 7x7x6.5 m deep Pyramidal tank with Surface Area = 52m2, Volume = 140 m3, Surface Loading Rate = 1.2m3/m2/h Retention Time = 3.3hr @ 3DWF
Storm Treatment	1 No 7x7x6.5 m Storage tank with capacity V = 140m3 (Required = 70m3 @ 70 l/head)
Sludge Treatment	1 No 3.5 dia Batch Thickening tank, 1 No Shallow Sludge holding tank

Table 5.

Treatment Works	Details Of Facilities Provided
Weatherlees Hill WWTW.	Inlet works with 3No 6mm Automatic screens,8m dia Detritor and Flume channel. 4 No 30m dia PAST s',4 No 30m dia FST s', 4 No 15x45x5 m deep Aeration Tanks, Intermediate,FE,RWL,SAS,RAS & PE P.Stn;s
Deal Pumping Station	Wastewater PS to discharge 280l/s to WWTW through a 500mm dia, 11.9km Rising Main. Storm PS to discharge 2100l/s to sea, through a 1200mm dia, 1.1km Transfer Main & outfall.
Ramsgate Pumping Station	Wastewater PS to discharge 435l/s to WWTW through a 600mm dia, 6.2km Rising Main. Storm PS to discharge 1800l/s to sea through a 2.4x2.1m, 550m long Box Culvert & a 900mm dia, 150m long Outfall.
Sandwich Pumping Station	Wastewater PS to discharge 150l/s to WWTW through a 400mm dia, 6.4km Rising Main. Storm PS to discharge 700l/s to river through a 600mm dia, 520m long outfall.

comply with the NRA requirements only exceptionally high storm flows are overflowed to the storm chamber, where it is screened prior to discharge to the sea. The outfall is designed to provide a minimum 2m cover to the outlet at low water level. Screenings from the storm chamber are returned to the wastewater chamber for discharge to the WWTW.

Discussion and conclusions

Significant progress has been made in implementing water supply schemes in many developing countries in the past, but little interest has been shown in dealing with the wastewater it generates. The treatment and disposal of wastewater particularly in urban areas is just as important as the supply of potable water for a number of reasons. Temporary solutions, affordable and attractive as they may be at present, must not be seriously considered when selecting wastewater treatment systems. They could have a significant and costly bearing in the future. Many lessons are there to be learned from the developed world, particularly when contemplating solutions seen to be affordable in the short term. It is vital that developing countries urgently set up controlling bodies to monitor and enforce set standards. They should also concentrate on adopting a uniform policy for designing and operating wastewater treatment facilities, similar to those indicated. The level of technology now available in most developing countries is far more than that required to operate and maintain the types of plants discussed in this paper. The cost of implementing such schemes are relatively small when weighed against the value of benefits that can be secured for the future. The ability of the population concerned to afford safe and adequate facilities is also insignificant when compared with their ability to afford luxurious material comforts.

With the assistance and experiences of the developed nations, particularly those that are in the process of enhancing their existing treatment plants at an enormous cost, the developing countries have the opportunity to take the necessary precautions to protect the somewhat "unspoilt" nature of their environments in a safe and cost effective manner. It is an opportunity that must not be wasted however daunting a task it may seem with the economic constraints they could face.

References

Carter.R,Tyrell.S.F and Howsam.P. Lessons Learned From UN Water
Decade,IWEM Journal of 7.12.93.

Mara.D.D,Mills.S.W,Pearson.H.W,Alabaster.G.P, Waste Stabilization Ponds: A Viable Alternative for Small Community Treatment Systems, IWEM Journal of 6.2.92

Southern Water Authority, Manual of Sewage Treatment 1987.

Water Training International, Process Design of Sewage Treatment Works 1994.