7 DEWATS components & design principles

DEWATS can be constructed and operated successfully almost anywhere because they rely on natural wastewater-treatment processes, without special equipment, chemicals, or energy supply. This chapter explains the treatment processes and how they apply to different DEWATS components, in order to guide the reader in appropriate technical selection and design.

The chapter is sub-divided into the following sections:

- basics of wastewater treatment
- parameters for wastewater-treatment design
- DEWATS – technical components
- dimensioning of DEWATS

7.1 Basics of wastewater treatment

7.1.1 Definitions: pollution & treatment

Pollution is the undesirable state of the environment being contaminated with substances, which disturb the natural balance of nature and can lead to health consequences for flora, fauna and humans.

Although domestic wastewater is mainly organic, the high concentration of the substances has a polluting effect on open-water bodies, groundwater or soil, due to the oxygen-draining chemical and bio-chemical reactions that result.

Pathogens, including helminth eggs, protozoal cysts, bacteria and viruses, are responsible for innumerable cases of disease and death in the world.

Phosphorus and nitrogen are essential nutrients for plant growth. Their introduction to water bodies can generate great algae populations, which limit the amount of sunlight that can shine into the water, thereby leading to excessive oxygen consumption within the water body until other aquatic life-forms can no longer survive. Furthermore, nitrogen is poisonous to fish in the form of ammonia gases and may also become poisonous to other life-forms, including humans, in the form of nitrite.

Most heavy metals are toxic or carcinogenic. They harm the aquatic life of the receiving water and affect humans through the food chain.

Treatment consists of a wide range of procedures that relieve the negative effect of the pollutants, by removing or changing harmful substances into a harmless or less-harmful state. DEWATS treatment depends on natural bio-chemical and physical processes including:

- degradation of organic matter until the point at which chemical or biological reactions stop (stabilisation)
- physical separation and removal of solids from liquids
- removal or transformation of toxic or otherwise-dangerous substances (for example, heavy metals or phosphorous), which are likely to distort sustainable biological cycles, even after stabilisation of the organic matter

7.1.2 Biological treatment

Stabilisation occurs through degradation of organic substances via chemical processes, which are biologically mediated (bio-chemical processes). The processes are the result of the metabolism by micro-organisms, in which complex and high-energy molecules are transformed into simpler, low-energy molecules. Metabolism is the break-down of organic matter (from feed to faeces) to gain energy for life, in this case for the life of micro-organisms, which store and release the gained energy in the form of ATP (adenosine triphosphate). A few chemical reactions happen without the help of micro-organisms. Most of the micro-organisms involved are biologically classified either as bacteria or as archaea. In the past, archae were viewed as an unusual group of bacteria (archaebacteria). Due to their different evolutionary history, they are now classified as a separate domain. That is why "methanobacteria" according current classification are no longer bacteria but archae. In order to avoid confusion, the generic term "micro-organisms" is used.

In the main, wastewater treatment is the degradation of organic compounds, and subsequent oxidisation of carbon (C) to carbon dioxide (CO_2), nitrogen (N) to nitrate (NO_3), phosphorus (P) to phosphate (PO_4) and sulphur (S) to sulphate (SO_4). Hydrogen (H) is also oxidised to water (H_2O). In anaerobic processes, some of the sulphur is formed into hydrogen sulphide (H_2S), producing the typical "rotten-egg smell". The largest amount of oxygen (O) is required for burning carbon ("wet combustion").

The process of oxidation happens aerobically with free dissolved oxygen (DO) present in water, or anaerobically without oxygen from outside the degrading molecules. Anoxic oxidation takes place when oxygen is taken from other organic substances such as nitrate or sulphate.
Facultative processes include aerobic, anoxic and anaerobic conditions, which prevail at the same time at various parts of the same vessel or at the same place after each other. In anoxic respiration and anaerobic fermentation, as there is no free oxygen available, all oxygen must come from within the substrates. Anaerobic treatment is never as complete as aerobic treatment because there is not enough oxygen available within the substrate itself. The chemical reactions under aerobic, anoxic and anaerobic conditions are illustrated by the decomposition of glucose:

Decomposition via aerobic respiration: $C_6H_{12}O_6 + 6O_2 = CO_2 + 6H_2O$

Decomposition via anoxic respiration: $C_6H_{12}O_6 + 4NO_3 = 6CO_2+6H_2O+2N_2$

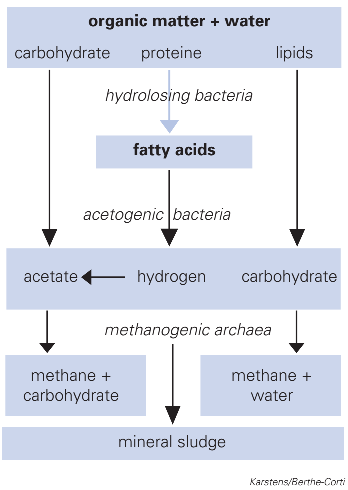
Decomposition via anaerobic fermentation: $C_6H_{12}O_6 = 3CH_4+3CO_2$

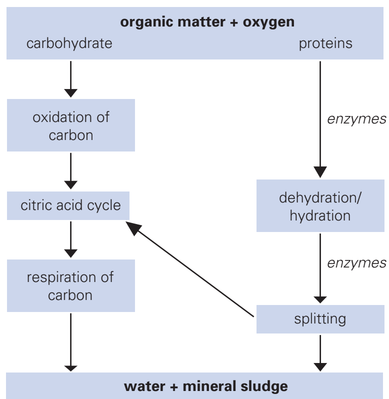
Micro-organisms need nutrients to grow. Any living cell consists of C, H, O, N, P and S atoms. Consequently, any biological degradation demands N, P and S atoms beside C, H and O. Trace elements are also needed to form specific enzymes. Enzymes are specialised molecules, which act as a kind of “key” to “open-up” complex molecules for further degradation.

Carbohydrates and fats (lipids) are composed of C, O and H atoms and cannot be fermented in pure form (Lipids are “ester” of alcohol and fatty acids; an ester is a composition that occurs when water separates off). Proteins are composed of several amino acids. Each amino acid is composed of a COOH-group and a NH_3-group plus P, S, Mg or other necessary trace elements. Thus, proteins contain all the necessary elements and, consequently, can be fermented alone. A favourable proportion between C, N, P and S (varying around a range of 50:4:1:1) is a pre-condition for optimum treatment.

7.1.3 Aerobic – anaerobic

Aerobic decomposition takes place when dissolved oxygen is present in water. Composting is also an aerobic process. Anoxic digestion occurs when dissolved oxygen is not available, but bacteria get oxygen for energy "combustion" by breaking it away from other, mostly organic substances present in wastewater, predominantly from nitric oxides. Anaerobic digestion breaks up molecules composed of oxygen and carbon to ferment them to carbohydrates.





The aerobic process is very diverse; the above diagram has been almost unacceptably simplified.
However, it shows that carbohydrates and proteins undergo different steps of decomposition. It also shows the importance of enzymes for breaking up proteins.

Picture 7_1: The anaerobic process in principle

Picture 7_2: The aerobic process in principle

The aerobic process happens much faster than anaerobic digestion and therefore dominates when free oxygen is available. The high rate at which decomposition takes place is caused by the shorter reproduction cycles of aerobic bacteria as compared to anaerobic micro-organisms. The latter leave some of the energy unused, which is released in the form of biogas. Aerobic micro-organisms use a larger portion of the pollution load (about 50% of the COD) for production of their own bacterial mass compared to anaerobic ones (only about 5% of the COD). That is why anaerobic processes produce 90% less sludge compared with aerobic ones. For the same reason, anaerobic sludge is less slimy than aerobic sludge and is easier to drain and dry.

Aerobic treatment is highly efficient when there is enough oxygen available. However, compact aerobic treatment tanks need external oxygen, which must artificially be supplied by blowing or via surface agitation. Such technical input consumes technical energy.

The anaerobic treatment process proceeds at a lower rate. It benefits from a higher digestion temperature. Therefore, it is well suitable for DEWATS in tropical and subtropical countries. Ambient temperatures between 15° and 40°C are sufficient. Anaerobic digestion (fermentation) releases biogas ($CH_4 + CO_2$), which can be used as a fuel (see section 6.6.3, page 129).

7.1.4 Physical treatment processes

Wastewater treatment relies on the separation of solids, both before and after stabilisation. Even dissolved particles are decomposed into the three main fractions: water, gases and solids, of which the solids have to be removed. The choice of method for solid removal depends on the size and specific weight of the suspended solids.

Screening

Screening of larger solids is the foremost step in conventional treatment plants. In DEWATS, screening is not advisable because screens require cleaning at very short intervals, i.e. daily or weekly, which demands a safe storage and treatment space in the immediate vicinity for the removed screenings. A blocked screen is an obstacle that plugs the entrance of the plant. DEWATS should allow for the full amount of wastewater to pass through the plant without obstructions. If this fails, it may happen – and, in fact, happens quite often – that the operator "organises" a trouble-free by-pass, which pollutes the environment, as if the treatment plant did not exist. For this reason it is recommended to avoid screens and, instead, provide sufficient additional space to accommodate larger solids within the first sedimentation chamber.

Sedimentation

Separation of solids happens primarily by gravity, predominantly through sedimentation. Coarse and heavy particles settle within a few minutes or hours, while smaller and lighter particles may need days and weeks to finally sink to the bottom. Small particles may cling together, forming larger flocs that also sink quickly. Such flocculation happens when there is enough time and little to no turbulence; stirring hinders quick sedimentation. Sedimentation is slow in highly viscose substrate.

Sedimentation of sand and other discrete particles works best in vessels with a relatively large area. These vessels may be shallow, since depths of more than 50cm have no influence on the sedimentation process in the case of discrete particles.

Table 10:
Settling velocities of coarse particles (m/h).

Suspended sludge particles have settling properties different from coarse particles.
Source: K.+K. Imhoff, p. 126

grain size in mm	1	0.5	0.2	0.1	0.05	0.01	0.005
quartz sand	502	258	82	24	6.1	0.3	0.06
coal	152	76	26	7.6	1.5	0.08	0.015
SS in domestic wastewater	120	60	15	3	0.75	0.03	0.008

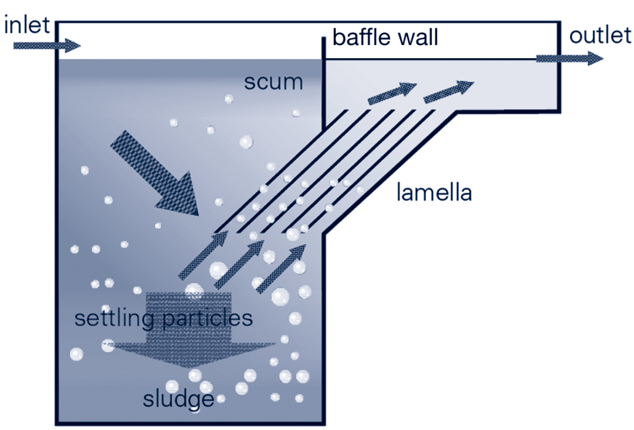
This is different for finer coagulant particles, where sedimentation increases with basin depth. This is because settling particles meet suspended particles to form flocs which continue to grow larger and settle faster on their way to the bottom. A slow and non-turbulent flow – still and undisturbed water – supports "natural" coagulation for sedimentation.

Settled particles accumulate at the bottom. In the case of wastewater, any sediment also contains organic substances, which begin to decompose. This decomposition, which occurs in any sludge sedimentation basin and, to a lesser extent, in grit chambers, results in the formation of carbon dioxide, methane and other gases. These gases are trapped in sludge particles of the vessel which then float to the top when the numbers of gas molecules increase. This process not only causes turbulence; it also ruins the success of the sedimentation that has taken place. The Imhoff tank, through its baffles, prevents such gas-driven particles from surging and spoiling the effluent. The UASB process deliberately utilises this balance of sedimentation (= downstream velocity) and up-flow of sludge particles (= upstream velocity).

After decomposition and the release of gases, the stabilised (mineralised) sludge settles permanently at the bottom, where it accumulates and occupies tank volume. It must be removed at regular intervals. Since many pathogens, especially helminths, also settle well, sedimentation plays an important role in the hygienic safety of domestic or husbandry wastewater treatment.

Flotation

Flotation is the predominant method for fat, grease and oil removal. In conventional wastewater treatment the process is also used to remove small particles by injecting fine air bubbles to the bottom of the tank.

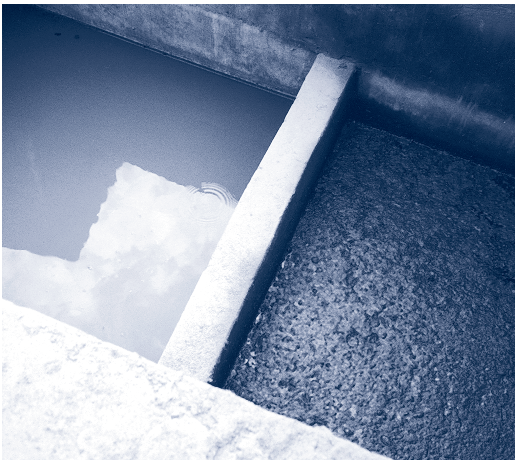


Picture 7_3: Principle of lamella solids separator to improve sedimentation – lamella may be made of plastic sheets, concrete slabs or PVC pipes

Most fatty matter can be identified by simple observation tests, similar to settleable solids. If fats, which are detected by laboratory analysis, are not separated by floatation, they present themselves as colloids, which can only be removed after pre-treatment (e.g. after acidification).

Unwanted flotation occurs in septic tanks and other anaerobic systems, where floating layers of scum may form. Accumulating scum can be removed manually, or can be left purposely to "seal" the surface of anaerobic ponds, preventing bad odour.

Flotation and sedimentation can be improved by installing slanted lamella sheets or several layers of slanting pipes. These surfaces artificially increase the separation of solids from liquids by facilitating floc and gas accumulation.



Picture 7_4: Baffle wall retaining scum, inlet is at the right side, water flows underneath the downflow baffle into the compartment at the left side

Filtration

Filtration is necessary for the removal of suspended solids, which do not "self-flocculate", settle or float within a reasonable time. Most filters have a double function: while forming a physical obstacle for smaller solid particles, they also provide a fixed surface on which treatment micro-organisms can grow. Both organic growth of micro-organisms and accumulated solids can lead to the clogging of the filter. Physical filters retain solids which accumulate, unless they are removed. Coarse filters, where physical filtration occurs primarily with the help of micro-organisms, can be cleaned by back-flushing. In this way, micro-organisms and suspended solids are flushed away simultaneously as, for example, is typically done with trickling filters. Upstream filters may be back-flushed. The filter media of sand and finer gravel filters must be removed, cleaned and replaced after several years of use.

Needless to say, filters with smaller grain size provide more efficient particle removal. On the other hand, effective filtration requires the retention of many solids and, therefore, leads to faster clogging. The permeability and durability of filters is always reciprocal to its treatment efficiency. Filter material of round and almost equal grain size is more efficient and renders longer service than filters of mixed grain sizes.

Aerobic filters produce more sludge than anaerobic filters and, consequently, block faster. However, they also have a self-cleaning effect when given sufficient resting time, as the aerobic bacteria in the sludge practise a kind of "cannibalism" (autolysis) when the nutrient supply stops.

Sludge accumulation

Sedimentation and filtration lead to sludge accumulation at the bottom of vessels. With time, the sludge compacts; consequently, older sludge occupies less volume than fresh sludge. Sludge-removal intervals are, therefore, important design criteria. The sludge must be handled and treated adaquately (see section 11.3).

7.1.5 Elimination of pollutants

Elimination of nitrogen

Nitrogen removal occurs in two steps: nitrification followed by denitrification, which results in pure nitrogen diffusing into the atmosphere.

Nitrification is oxidation. Nitrate is the most stable form of nitrogen and its presence indicates complete oxidation. Denitrification is reduction, or the separation of that very oxygen from the oxidised nitrogen. The pure gaseous nitrogen that remains is insoluble in water and, therefore, evaporates easily. Nitrogen escaping from the denitrification process may cause floating foam or scum, similar to the effect seen from the gas release by settled anaerobic sludge. Since nitrogen is the major compound of air it is ecologically harmless.

During nitrification NH_3 (ammonia) is oxidised by two special groups of bacteria – nitrosoma convert ammonia to nitrite (NO_2) and nitrobacter convert nitrite to NO_3 (nitrate). Since nitrobacter grow slowly, a higher sludge age and, thereby, longer retention time is needed for oxidation of nitrogen (= nitrification) than is required for oxidation of carbon (see section 8.1.1 "Control parameters", page 159).

Denitrification occurs faster than nitrification, as several groups of bacteria are able to utilise nitrate oxygen under anoxic conditions (absence of free oxygen). Incomplete denitrification may lead to formation of the poisonous nitrite (NO_2), instead of nitrate (NO_3).

This happens because the time left for the bacteria to consume all the oxygen is not enough or because there is not enough organic material left to absorb the NO_3-oxygen. Some non-DEWATS treatment processes recycle nutritious sludge to prevent such nutrient deficiency. A certain amount of nitrate in the effluent could also be a source of oxygen for the receiving water. In DEWATS, nitrate removal usually does not receive special attention, in that additional technical measures are not taken.

Elimination of phosphorus

Micro-organisms cannot transform phosphorus into a form in which it loses its fertiliser quality permanently. Phosphorus compounds remain potential phosphate suppliers. This implies that no appropriate biological process, either aerobic or anaerobic can remove phosphorus from wastewater. Phosphorus removal from water "normally" takes place by removal of bacteria mass (active sludge) or by removal of phosphate fixing solids via sedimentation or flocculation. Iron chloride, aluminium sulphate or lime fixes phosphates, a fact that can be utilised by selecting suitable soils in ground filters. However, the removal of phosphorus in root zone filters has not proven to be as efficient and sustainable as expected by the pioneers of these systems.

Elimination of toxic substances

Heavy-metal compounds occuring in bigger molecular structures may settle easily. Their removal is not difficult. Heavy-metal contaminated sludge must be handled accordingly and disposed of safely, at proper landfill sites. Heavy-metals occuring in the form of dissolved ions do not settle at all. Along with other soluble toxic substances, they are difficult to remove. There are numerous ways of eliminating or transforming toxins into non-toxic matter, which cannot be described here. You should consult more specialised literature.

Table 11: Noxious Substances Units (NSU) according to German federal wastwater charges act
Mercury is the most dangerous substance on the list.
Source: Imhoff, 1990

noxious substance group	1 NSU is eqal to
oxidisable matter	50kgCOD
phosphorous	3kgP
nitrogen	25kgN
organic fixed halogenes	2kgAOX
mercury	20gHg
cadmium	100gCd
chromium	500gCr
nickel	500gNi
lead	500gPb
copper	1,000gCu
dilution factor for fish toxicity	3,000m^3

High salt content inhibits biological treatment and is very difficult to remove. In the case of saline water used for domestic or industrial purposes, for example, the water remains saline even after treatment. So it should not be used for irrigation and should not be allowed to enter the groundwater table or receiving rivers that carry too little water.

Removal of pathogens

Even after treatment, wastewater should be handled carefully. Underground filtration and large pond systems are relatively efficient in pathogen removal, but not necessarily to the extent that wastewater can be called safe for bathing – let alone drinking. However, reuse for irrigation is safe under certain conditions (see section 11.4).

Helminth eggs and protozoa accumulate in sediment sludge, so are largely retained inside the treatment system, where they stay alive for several weeks. Most micro-organisms and viruses bound to the sludge die more quickly. Pathogens, which are not caught in the sludge and remain suspended in the effluent, are hardly affected. This is especially true in high-rate reactors, like filters or activated-sludge tanks. These bacteria and viruses exit the plant alive, although the risk of virus infection from wastewater has proven to be low.

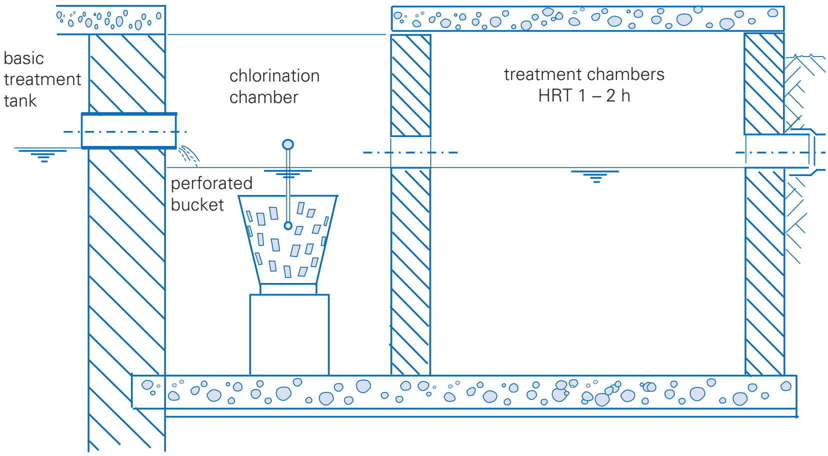
type of infection, type of wastewater	country	dose of chlorine g/m^3	contact time h	total rest chloride mg/l
intestinal pathogens	China		> 1.0	5
tubercular pathogens	China		> 1.5	7
raw wastewater	Germany	10 - 30	0.25	traces
post treatment	India	3		
post treatment	Germany	2	0.25	traces
odour control	Germany	4	0.25	traces

Table 12: Comparing the use of chlorine for different requirements at various places. Different sources

Exposure to UV rays has a substantial hygienic effect, in addition to sedimentation, predation and die-off in a hostile environment. The highest rate of pathogen removal can be expected from shallow ponds with long retention times, for example three ponds in series with HRT of 8 to 10 days each. Constructed wetlands with their multifunctional bacterial life in the root zones can also be very effective. However, it is the handling after treatment, that ensures hygienic standards.

Using chlorination to kill pathogens in wastewater is only advisable for hospitals in the case of epidemics and similar circumstances. It may also be applied in slaughterhouse treatment plants, which are only a short distance from a domestic water source. Permanent chlorination is never advisable, as it has adverse effects on the environment: Water is made unsuitable for aquatic life, and chlorine can react with organic matter to produce dangerous chemicals.

Bleaching powder (chlorinated lime) containing approximately 25% free chlorine is the most common source of chlorine. Granular HTH (high test hyperchlorite) containing 60 to 70% Cl is available on the market under different brand names. Since chlorination should not be a permanent practice, a chamber for batch supply, followed by a contact tank of 0.5 – 1h HRT will be sufficient (picture 7_5).



Picture 7_5: Post-treatment chlorination carried out in a batch chamber for small scale applications. The bucket is filled with bleaching powder, which is dissolves automatically. This plant is acceptable for emergency disinfection of effluent from rural hospitals only because controlled dosing is not possible.

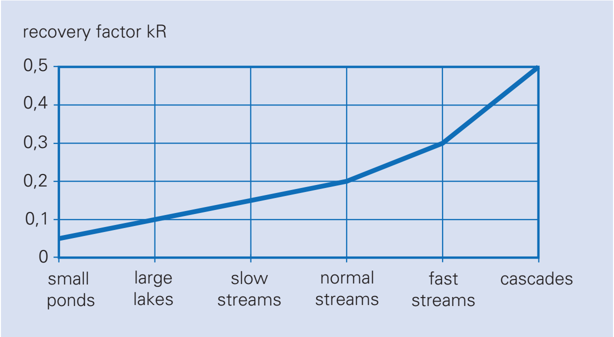
7.1.6 Ecology and self-purification in nature

An understanding of the self-purification ability of the natural environment helps in designing DEWATS intelligently. On the one hand, only harmless wastewater should be discharged; on the other hand, nature may be incorporated into the design for the completion of the treatment processes.

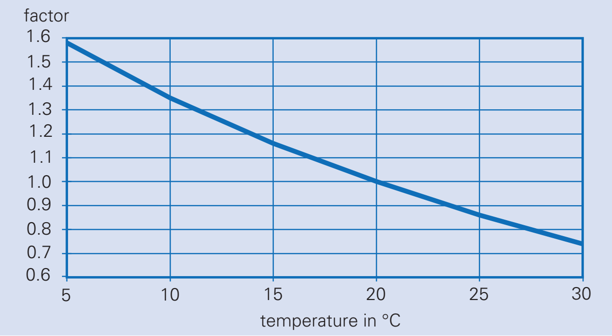
Surface water

The biological self-purification effect of surface waters depends on the climate, weather and on the relative pollution load in the water. The presence of free oxygen is a precondition for the self-purification process. The higher the temperature, the higher the rate at which the degrading bacteria, which are responsible for purification, multiply. At the same time, the intake of oxygen via surface increases, but oxygen solubility drops with increasing temperature. Rain and wind increase the oxygen-intake capacity. Consequently, acceptable pollution loads or wastewater volumes must be dimensioned according to the season with the least favourable conditions

(for example, winter or summer in temperate zones, dry season in the tropics).
It is difficult to reanimate water once the self-purification effect has stopped as from then on, it enters the anaerobic stage.
Extreme seasonal changes make it difficult to maintain the self-purification effect of water throughout the year. However, nature has a way of helping itself, as in the case of lakes and rivers that dry out in long dry seasons when the remains of organic matter compost and are fully mineralised before the next rains come.



Picture 7_6:
Ability of surface waters to recover oxygen after pollution. Turbulence increases oxygen intake and reduces time for recovery (Garg, p. 220)



Picture 7_7: Oxygen intake of natural waters via surface contact. Relative concentration of dissolved oxygen decreases with increasing temperature.

Minerals retain their fertilising quality even after drying. This is why it is better to bring sludge at the bottom of dried lakes, canals or rivers to the fields before it is washed away into the receiving water by the first heavy rains and its rich nutrient value is lost. However, the content of toxic matter in sludge should be observed.

The most important source of oxygen for natural water in an ecosystem is oxygen from the air, which dissolves in water via surface contact. Floating fat, grease or oil films restrict oxygen transmission from the air and, moreover, require additional oxygen for their decomposition.

The nutrients contained in wastewater increase algae growth. In a healthy ecosystem, algae produce oxygen during the day and consume part of this oxygen at night. If the algae population were to become unduly dense, sunlight would not be able to penetrate the dark-green water. As a result, the algae would consume oxygen during the day as well – and the supply of free oxygen that is needed for aquatic life would decrease.

The degree of pollution and, particular, in the content of dissolved oxygen (DO), can be gauged by the variety of plant and animal species found in the water. The colour of the water of rivers and lakes is yet another indicator of the quality of the water. Green or green-brownish water is indicative of high nutrient supply due to algae; a reddish-rosy colour indicates facultative algae and a severe lack of free oxygen; black is often indicative of complete anaerobic conditions of suspended matter.

Nitrogen in the form of nitrate (NO_3) is the main polluting nutrient. In the form of ammonia (NH_3, toxic to fish) it is also a major, oxygen-consuming toxic substance, therfore nitrogen should be kept away from living waters; notwithstanding that nitrate may also function as an oxygen donor in certain instances.

The next most-important polluting nutrient is phosphorus, which is mainly present in the form of hydrogen phosphate (H_2PO_4). Since phosphorus is often the limiting factor for the utilisation of other nutrients, its presence in surface waters is dangerous, as even in small doses it may lead to an oversupply of nutrients (eutrophication). Nitrogen that is normally plentiful needs 10% of phosphorus to be assimilated by plants. That means phosphorus activates ten times as much nitrogen and, therefore may be considered the most polluting element to any receiving water. At the same time, it is this property that makes wastewater rich in phosphate an excellent fertiliser when used for irrigation in agriculture.

Picture 7_8: DEWATS at a hotel in Cochin, India; large-size ponds are used for post-treatment

Phosphorus accumulates in closed ecosystems, for example in lakes. Unlike nitrogen that can be eliminated as N_2 or N_2O_2 etc., phosphorus remains potentially active in the residue of dead plants, which have previously incorporated it. For example, phosphate fixed by iron salts can be set free under anaerobic conditions in the bottom sludge, where it is available for new plant growth. It is for this reason that continuous supply of phosphate into lakes is prohibited. While this may seem less dangerous for flowing waters, it must be realised that all rivers end somewhere, at which point phosphorus will accumulate.

While chlorine may be used for disinfecting effluents from hospitals and slaughter-houses, it must be remembered that chlorine also disinfects the receiving waters, thereby reducing their self-purification ability. Moreover, they form chlorinated compounds being potentially carcinogenic.

It is self-evident that toxic substances should not enter any living water. Most toxic substances become harmless in the short term, particularly if they are sufficiently diluted. However, most toxic materials are taken in by plants and living creatures and, in the long run, accumulate in the aquatic lifecycle. Fish from such waters become unsuitable for human consumption and heavy metals accumulate in the bottom sludge of receiving waters, where they remain as a time-bomb for the future.

Groundwater

Groundwater was once rainwater. It is the most important source of water for domestic use, irrigation and other purposes. The supply of groundwater is not infinite. To be sustainable, it must be recharged. Rather than simply draining used water into rivers that carry it to the sea, it would be better to purify this water and use it to recharge the groundwater.

Organic pollution of groundwater happens in cases where wastewater enters underground water-streams directly. A crack-free, 3m-thick soil layer above groundwater is sufficient to prevent organic pollution. Pollution by mineralised matters is possible, however, as salts like nitrate and phosphate are soluble in water and cannot be eliminated by physical filtration when passing through soil or sand layers. Some pathogens may also reach the groundwater despite soil filtration. Viruses can be dangerous, due to their infectious potential, irrespective of their absolute number.

Nitrate is readily soluble in water. So it is easily leached out from soil into groundwater, especially in sandy soil during periods when vegetation is low (for example, winter in cold climates). Groundwater, therefore, will always contain a certain amount of nitrate (mostly above 10mg/l).

Nitrate (NO_3) in itself is rather harmless. For example, in the European Union, drinkingwater may legally contain nitrate up to 25mg/l. It is, however, latently dangerous, as nitrate is capable of changing to nitrite (NO_2) under certain biological or chemical circumstances. This process can even occur inside human blood, where nitrite attaches itself to haemoglobin, reducing the capacity of the haemoglobin to "transport" oxygen – leading to suffocation. Nitrite poses the greatest risk to babies, who have a greater tendency to form nitrite. For this reason, water used for the production of baby food must always contain less than 10mg/l NO_3.

Soil

Pollution can render soils useless for agricultural production. For example, the pH may drop as a result of incomplete anaerobic digestion of organic matter. This is particularly common in clay or loamy soils, where oxygen supply is insufficient due to the physical closure of pores in the soil by suspended solids from wastewater irrigation. Furthermore, soil pollution poses a threat because of washout effects that harm surface- and groundwater alike. Mineral salts in small doses do not pose a problem for wastewater treatment. Using saline wastewater for irrigation over a long period of time, however, may cause complete and irreversible salination of the topsoil. Clay and loamy soils with slow downward percolation are the most affected, as water evaporates from the top layers, leaving the salt behind.

On the other hand, sandy soils may benefit from irrigation with wastewater even when the organic load is high, provided that oxygen can be supplied to deeper soil layers. Well-treated wastewater, containing mineralised nitrogen, phosphorus and other trace elements, can improve soil conditions and is environmentally safe, as long as the application of nutrients is balanced with its in-take by plants. Applying of treated wastewater throughout the year, regardless of demand, may have adverse effects. Nutrients will be leached out into water bodies at times when plant growth is negligible, with the result that nutrients are not available to the plants when needed.