State Environmental Conservation Department
(ECD), Sabah Malaysia

Water effluent from pig farms in Sabah - a preliminary investigation of key environmental issues

ECD-CAB Background

March 2001

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1 Recognised environmental impacts

In parallel with continued population growth and the increasingly dynamic nature of global markets, world trends over the last twenty years have seen the replacement of the traditional family sized farm by industrial livestock farms.

Pollution caused by nutrients and organic material

Large livestock farms would normally compose of sheds containing several hundred to several thousand pigs in cramped conditions. The sheer number of animals and the impermeable nature of shed floors mean that faeces and urine accumulate and need to be washed out, usually into open air lagoons where it is stored until it can be pumped out to irrigate fields, or in the Malaysian context, considered clean enough to be discharged into a river system. But the scale of these larger farms is such that enormous quantities of excess manure pose increasing threats to aquatic systems including drinking water and fisheries.

A mature pig produces three times the waste a person does. In general the current practices to dispose of this waste are largely ineffective. Unlike human sewage, which is treated and disinfected, livestock waste is collected in open-air pits called waste lagoons, where it is minimally treated and in some countries, then sprayed on to neighbouring agriculture land as manure. Managing so much livestock waste using this method may pose serious environmental threats to people and the environment.

Manure production as excreted in kg/animal/day for mature pigs of an average weight of 150 kg, would amount to approximately 21.1 kg/animal/day of solid material and 15.9 litres/animal/day of liquids (Table 1.1). Although this figure is high, it is interesting to note that when compared with larger herbivorous mammals such as dairy cattle (65 kg/animal/day solid waste and 62 litres/animal/day liquid waste), the loss values are comparatively low. Environmental problems associated with pig farming are compounded by the scale and location of operations.

Table 1.1 Nutrient production as excreted by mature pig

Element	kg/animal/day
Total Nitrogen	0.033
Phosphorous P_2O5	0.026
Potassium K_2O	0.026

Where intensive pig farming does occur, pollution from *nutrients* contained in animal manure, namely phosphorous and nitrogen is one of the most serious problems, leading to excess algae growth, robbing water of oxygen which may in turn lead to mass fish kills (See Annex A – Nitrogen and Phosphorous).

Analysis of raw wastewater taken during routine cleaning and bathing of the pigs in Melaka, Malaysia (1980), showed a wide variation in the results, which was explained by the different amounts of water used (Table 1.2).

Table 1.2 Characteristics of washing effluent from pig-sties

Parameters	Analysis results
BOD (3 days, 30^{o}C) mg/L	1,900 to 21, 600
COD, mg/L	4,800 to 39,000
Total solids, mg/L	3,690 to 22,300
Suspended solids, mg/L	636 to 15,900
Ammonical Nitrogen, mg/L	75 to 950
Total Nitrogen, mg/L	370 to 2,080
Organic N (excluding NH_3) mg/L	140 to 1,370
Phosphate, mg/L	160 to 1,600

In the same survey of pig farms, approximately 68 per cent of the farms had constructed retaining ponds for the pig wastes. However, these ponds were considered too small and thus over-loaded and non-functional. It was stated that the ponds also attracted the breeding of flies, with only a few of farmers utilising the wastes as manure for their vegetable farms.

The presence of large amounts of partially decomposed *organic material* within the faeces, apart from causing immediate health risks to downstream water users, also provides a readily available food source for bacteria, which in turn also uses up available oxygen (See Annex A – Biological Oxygen Demand and Chemical Oxygen Demand).

The reasons for the poor planning, design and upkeep of the lagoon systems could be attributed to a number of reasons:

- Lack of available land to build suitably sized lagoons
- Overstocking of livestock
- Lack of awareness
- Lack of finance
- Lack of interest.

In general the pollution pathways are through waste spills from flooded lagoons or deliberating flushing of wastes directly into the river system, leaking waste lagoons and run-off from fields where waste is sprayed. Leaking lagoons may also contaminate groundwater.

Other threats to human health

Odour pollution. Aside from the unpleasant odour commonly associated with intensive livestock rearing operations, air pollution in the form of ammonia nitrogen can cause respiratory illness in neighbours living up to two miles away.

Bacteria. Pathogens (disease causing organisms).

Antibiotic resistance. When large numbers of livestock are confined to small areas, the constant use of antibiotics is required in their feed to prevent disease. Some scientists believe that this practice encourages the development of germs that are resistant to antibiotics in humans.

Heavy metals. Pig feed is fortified with heavy metals (Cu, Zn) most of which end up in the waste, ultimately becoming concentrated in the solid sludge which accumulates in the waste lagoon

2 Case study from pig farms in Sabah

The study was concerned with investigating the effectiveness of the aerobic/anaerobic lagoon systems, the remediation of livestock effluent and to determine the ambient water quality downstream of these facilities. The impacts of concern were divided as follows:

- Potential eutrophication issues – nutrient enrichment caused by excess nitrogen and phosphorous in the aquatic system
- Increased biological and chemical oxygen demand (BOD and COD), the result of increased volumes of organic mater entering the system
- Other water quality issues associated with effluent discharge i.e. increased suspended solids and changes in pH.

A reconnaissance survey of effluent quality from pig farms was carried out on 10 August, 2000. Five farms in the District of Tuaran were selected.

2.1 Results

Table 2.1 Summary of sampling results

Farm	Station	Locality	Results					
			pH	TSS (mg/L)	NH_3 (mg/L)	TN (mg/L)	C.O.D. (mg/L)	B.O.D (mg/L)
1	JW-01	Shed outlet	7.1	788	186	329	2924	644
	JW-02	Lagoon 1	6.8	1543	299	325	4466	690
	JW-03	Lagoon 2	6.9	4727	374	481	2114	386
	JW-04	Lagoon 3	7.1	1884	435	491	771	248
	JW-05	Lagoon 4	7.4	232	371	391	1482	294
	JW-06	Lagoon 5	7.6	282	325	344	356	166
	JW-07	Sg Mangkaladai	6.5	4	8	27	1008	193
	JW-08	Lagoon 1A	7.2	333	191	205	2351	386
	JW-09	Lagoon 2A	8.6	288	375	448	1719	589
2	S-W01	Final lagoon	7.3	1065	413	467	2727	175
	S-W02	Final outlet	7.4	685	409	448	909	221
3	H-W01	Lagoon	6.3	230	5	81	1284	534
	H-W02	Road drain	6.4	349	126	169	356	156
4	C-W01	Lagoon	6.3	1203	336	436	1284	621
	C-W02	Shed outlet	6.7	31	3	12	356	368
5	K-W01	Lagoon	6.8	166	172	203	138	69

2.1.1 Farm 1

Farm 1 had possessed the most complete lagoon system. Samples were taken in a progressive sequence from the point where effluent leaves the rearing shed, following a series settling of lagoons, until the discharge point into Sg Mangkaladai.

pH

pH exhibits no particular trend except that the stream waters are slightly less basic, which can probably be accounted for by a greater buffering capacity in the stream water and other ambient water quality properties. It should be noted that the pH value greatly determines which of the ammonical nitrogen forms will predominate. Toxic ammonia occurs at a pH of 7.0 and over and ammonium at a pH of less than 7.0.

Suspended solids

The trend for suspended solids show an initial increase from 788 mg/L at the point leaving the shed, to a high of 4727 mg/L at lagoon 3. This may be explained by dilution from water used during the washing process from the shed. The suspended solids concentration then falls quickly to 282 mg/L at the penultimate pond and 4 mg/L in Sg Mangkaladai.

Ammonical nitrogen

Ammonical nitrogen would appear to follow a similar pattern to that of suspended solids in that concentrations rise from 186 mg/L at the shed outlet until 435 mg/L in lagoon 3. Concentrations then fall from 371 mg/L in lagoon 4 to only 8 mg/L in Sg Mangkaladai. Ammonical nitrogen concentrations at 8 mg/L is sufficient to impact ecological processes of the receiving waters.

Total nitrogen

As with ammonical nitrogen there is a difference in the concentration of total nitrogen from 491 mg/L in lagoon 3 to 27 mg/L in Sg. Mangkaladai, which is high enough to impact ecological processes in the receiving waters.

Ammonical nitrogen constitutes a significant proportion of total nitrogen. However, little more can be said on this unless more details are known on the actual process taking place within the lagoon. Ammonium can be a direct product from animal urine alone (the nitrogen in urine exists principally as urea which is hydrolysed rather rapidly by the enzyme urease to ammonium carbonate). Ammonia in this form would decline with metabolic uptake by plant and algal growth. However, ammonium and ammonia can become readily available by the breakdown of organic nitrogen compounds. Organic nitrogenous substances decay in stages in the presence of oxygen, a process called oxidative breakdown. It produces various nitrogen compounds as follows:

Organic nitrogen compounds – ammonia and ammonium – nitrite – nitrate

Toxic ammonia and non-toxic ammonium are produced in the first two stage of the nitrogen cycle. The pH value greatly determines which of the two will predominate. Ammonia occurs at a pH of 7.0 and over and ammonium at a pH of less than 7.0. The nitrogen cycle cannot occur without oxygen. If the supply is poor i.e. high BOD and COD, organic compounds decay more slowly and more toxic interim products i.e. ammonia and nitrite accumulate. The increased ration of ammonical nitrogen to total nitrogen would suggest that nitrogenous substances are being broken down, at least indicating that the lagoons are still functioning.

However, under anaerobic conditions, which presumably exist at the bottom of these lagoons, nitrates and nitrites are both reduced by a process called denitrification. Presumably nitrates are reduced to nitrites and then reduction of nitrites occurs. Reduction of nitrites is carried all the way to ammonia by a few bacteria, but most of them carry the reduction to nitrogen gas, which normally would escape to the atmosphere. However, if a layer of sludge caps the surface of the lagoon, as some of the plates suggest (Plate 3), this would allow the accumulation of sufficient nitrogen gas to further buoy the sludge and allow further accumulation of gas.

COD and BOD

Chemical oxygen demand also follows a trend of increasing after the first outlet, again probably explainable by dilution from the washing process. Concentrations then decline, but maintain a high degree of variation. The Sg Mangkaladai ambient water quality value of 1008 mg/L is considerably higher than that of the last lagoon (344 mg/L) suggesting that there is an additional source of organic matter upstream of the outlet. The same trend is exhibited but to a lesser extent in the biological oxygen demand values.

At the same farm there is a shorter series of three smaller ponds draining from the rearing shed. Sample JW-09 draining directly from the rearing shed has a pH of 8.6, sufficient to convert large amounts of ammonium to toxic ammonia. Otherwise the general trend as described above remains the same. But as the series of ponds is shorter, COD and BOD remain high in J-W08. However, as the final discharge was not sampled, the efficiency of this shorter series of ponds is unknown.

2.1.2 Farm 2

This farm is a smaller operation with a series of 5 small lagoons before effluent drains into a large collecting lagoon. Samples were only collected from the final lagoon and the final discharge point into the collecting lagoon. The same general results as for location 1 are observed, except that the level of pollution at the final discharge point is higher, suggesting a less efficient treatment system.

2.1.3 Farm 3

Farm 3 is a small operation housing only two collecting lagoons before the final discharge of effluent. The lagoons are arranged in parallel and not series. A sample was taken from the lagoon and also the point of discharge into the drain. Although generally the level of pollution was lower, probably due to lower numbers of livestock, the water being discharged into the road drain remained highly polluted.

2.1.4 Farm 4

Farm 4 is another small operation with a series of 4 lagoons, the last being the collection point for final discharge. This locality had the lowest concentrations being discharged from the rearing shed: suspended solids (31 mg/L), ammonical (3 mg/L) and total nitrogen (12 mg/L). However, this is probably attributable to low numbers of animals or dilution. The concentration of elements found in the collecting lagoons would suggest that they are overloaded and heavily polluted.

2.1.5 Farm 5

This last farm has three rearing sheds with a final outflow into a series of two lagoons. The final rearing shed also had an overflow system that could drain directly into Sg Bawang. A single sample was taken from the first lagoon. This locality had the lowest COD and BOD values although other pollutants remained high.

2.2 Discussion

It should be recognised that the sampling programme was necessarily limited in farm type, geographical and temporal extent and therefore important influencing factors and phenomena may have been missed. For example, the rinsing and cleaning regime of the sheds and the fate of effluent during rain events. Data on the number of animals being housed was furthermore unavailable.

From the data presented it is clear that the effluent leaving all drainage points remains heavily polluted for all elements except pH. Of particular note are the high concentrations of ammonical and total nitrogen.

It would appear that all of the lagoon systems are overloaded, with the possible exception of location 1. The others lagoons are probably overloaded due to a combination of being undersized and poor maintenance. The lagoon system at locality 1 would appear to partly mitigate the effluent pollution problem, however, it is probably lack of maintenance that prevents the system from reaching full potential.

It is interesting to note that BOD, which is often used as an indicator of overall pollution or environmental quality, although still below acceptable standards, does not reflect the overall severity of the water quality problem, particularly with regard to nitrogen compounds, and although not reported here, probably phosphate as well. This is so for Location 5 where COD and BOD values are 138 and 69 respectively, which are the lowest for all the samples, including the ambient water quality for Sg Mangkaladai, but the ammonical and total nitrogen values remain extremely high. This could in part be explained if the lagoon had not recently received organic material and the existing organics were being broken down into nitrogen compounds.

Aquatic Environmental problems associates with livestock problems may be summarized as follows:

- Water pollution (N&P) leading to eutrophication
- Water pollution (BOD, COD) leading to reduction of oxygen and general degradation of aquatic environments.

There are therefore two separate aquatic environmental problems associated with the effluent. First, the extremely high values of nitrogen compounds will promote eutrophication. Second, the high BOD and COD concentrations will also deplete oxygen levels and generally degrade the aquatic habitat. Although there is an association between high nutrient loads and high BOD concentrations, in that the bacteria that will break-down the organic material will also require nutrients to fuel metabolic processes, it is recommended that BOD alone should not be used alone as an environmental indicator.

2.3 Recommendations for further sampling

In order to better understand the environmental processes and management issues, which in turn will help formulate guidelines, standards or legislation, the following issues require further investigation.

- Survey and establish the environmental problems down stream (if any)
- Sample for heavy metals in lagoon sludge
- Sample effluent from different waste treatment types. Only aerobic/anaerobic lagoons were sampled during this survey. Such lagoons are probably the default process adopted due to the low start up and maintenance costs, however, unless they are well managed and maintained, are probably the least efficient. It would be expected that more technologically advanced, treatments such as aerated lagoons, oxidation ditches and activated sludge methods are more efficient
- It is probable that rain would cause lagoons to overflow and flush out during moderate to high rain events. Even though there is a greater potential for dilution, the environmental consequences of such events need to be examined – to determine whether or not lagoons should be covered
- Pathogens and other possible human health pollutants were not sampled for
- Odour related impacts were not sampled for.

3 Management and development options

Strategic issues

Some environmental protection agencies suggest that since most of the environmental problems are associated with the management of waste in poorly managed lagoon systems, the phasing-out of the lagoons should be a basic component of an effective programme to protect the environment. This would require two strategies; (i) the conversion/elimination of lagoons at existing livestock operations, and (ii) the development and approval of environmentally protective waste management systems for any new and expanding operations.

However, before lagoons can be phased-out, a process to expedite the identification and testing of alternative replacement technologies that can achieve the required effluent standards must be undertaken. Economics are certainly an important consideration in determining whether a particular technology can be used on a commercial scale.

For existing and continuing lagoons it has been suggested that an annual monitoring programme be developed for heavy metal concentrations in lagoon sludge, in conjunction with developing concentration standards for lagoons to determine when remediation and/or closure should be required.

Technical issues

Waste handling and treatment technologies, which *reduce the volume of water*, should be pursued. *Rainfall* should be excluded from any vessel containing high concentrations of waste. Open air lagoons, although cheap are problematic and should be covered with a material capable of collecting emitted gases, whilst excluding or controlling rainfall. As an intermediate step, bio-covers – floating materials such as straw – should be required. While bio-covers are unable to exclude rain, they are inexpensive, hold the potential to reduce ammonia emissions, provide some level of odour and insect control and could be installed quickly.

The suitability of *dry composting techniques* should be investigated, as these techniques are amongst the most promising treatments available. It is evident that environment pressures will make composting more common as a method of waste disposal in the future. Today the process in not thoroughly understood but it is gaining popularity with many farmers.

The use of *aeration* of effluent could be used. It has been shown that aeration for 20 hours reduced BOD from 2500 mg/L to 9 mg/L in an aeration tank.

Some countries implement a *zoning guideline* for the individual operations. For example Prince Edward Island, Canada, commencing April 1, 2000, require that river reserves must be established at sites with intensive livestock operations. Intensive livestock operations, including associated buildings, manure storage facilities, exercise yards and concentrated feeding areas cannot be constructed within 90 meters of a watercourse or wetland. With respect to existing livestock operations the slope of the land determines the distance between the intensive livestock operation and a watercourse ranging from 20m, when the slope is 9 per cent or less up to 30 m for any slope greater than this. For the same operations waste or contaminated runoff from livestock operations cannot be discharged to any watercourse or natural wetland – the wastes must be contained in a watertight holding facility.

Regulation issues

In attempts to address the environmental impact from agricultural sources, many countries have taken measures of legislation and guidelines. Approaches around the world vary. The ultimate sanction is the banning of pigs in, for example, Singapore. Most countries, however, adopt less harsh procedures. These procedures can be divided into two categories, legislation and guidelines.

In *Malaysia*, one of the industries identified as causing serious water pollution is the pig industry. In 1984, the National Agricultural Policy of Malaysia proclaimed that pig farming should be carried out in suitably sited areas incorporated with waste treatment facilities. If the existing farms were unable to meet the requirements of the government policy, they would be required to move to designated 'Pig Farm Areas' in which pollution control measures would be mandatory. Farms which have a land constraint or which do not have the economy of scale for building waste treatment plants should have an option for collective waste treatment where waste waters from several nearby farms are treated in a centralized treatment facility.

Evaluation parameters for monitoring the pig farming industry have been set for Malaysia (Table 3.1).

Table 3.1. Environmental quality (sewage and industrial effluents) regulations, 1979

Parameter limits of effluent other than of standard A or B	
Parameter	Limit
BOD at 20^{O}C	400 mg/L
COD	1000 mg/L
Suspended solids	400 mg/L
PH	5.0 – 9.0

In Peninsular Malaysia, *Johor and Perak* are intending to stop pig farming and a centralised pig farming area in Negri Sembilan has been proposed.

Sarawak has committed to developing three centralized pig farming areas for the resettlement of existing pig farms. However, millions of ringgit would be needed to acquire the land and to later develop infrastructure such as a centralized waste treatment system. There are an estimated 2,340 farms in Sarawak with an estimated animal population of 500,000. The industry generates estimated revenue of RM 60 million a year. In Sarawak, farms having more than 100 animals are required to obtain licenses to operate under the Natural Resources and Environment (Control of Livestock Pollution) Rules. Farm operators must build at least two oxidation ponds of appropriate size and depth depending on their animal population and should be prepared to treat pig wastes within four months after the issue of licences. These are interim measures before the farms are relocated to the special areas.

The Natural Resources Environment Board, Sarawak, Control of Livestock Pollution Rules (1996) have gazetted the following standards for the permitted discharge of treated waste (Table 3.2 & 3..3)

Table 3. 2 Proposed effluent standard for existing farms (units in mg/litre)

Parameter	Phase 1	Phase 2	Phase 3
BOD	1300	250	50
COD	2500	1000	500
TSS	1500	300	100

The BOD concentration without treatment in an existing farm shall not exceed 3,000 mg/L.

The license shall be given a one-year grace period as from the commencement date of these rules to install the waste treatment system. Upon installation of the waste treatment system, the period of achieving the permitted discharge shall be as follows, using the BOD concentration as the target

- Phase 1: 3,000 to 1,300 mg/L before 2 years
- Phase 2: 1,300 to 250 mg/L before 2 years
- Phase 3: 250 to 50 mg/L before 2 years or as determined by the board.

For new farms, that is to say a farm established after the date of commencement of the rules a licensee of a new livestock farm shall be permitted to achieve the limit of concentration of permitted discharge of treated waste of three phases (Table 3.3).

Table 3.3 Proposed effluent standard for new farms (units in mg/litre)

Parameter	Phase 1	Phase 2	Phase 3
BOD	500	250	50
COD	2500	1000	500
TSS	1500	300	100

In the case of a new farm, the treatment system shall be installed upon the establishment thereof. The period of achieving the permitted discharge shall be as follows, using the BOD concentration as the target

- Phase 1: 500 mg/L upon establishment of the farm
- Phase 2: 250 mg/L before 2 years
- Phase 3: 50 mg/L before 2 years or as determined by the board.

For comparison the effluent standards for animal husbandry in *Taiwan* are included (Table 3.4.).

Table 3.4 The effluent standard for animal husbandry - Taiwan

Parameter		Limit
PH		6 – 9
BOD	mg/L	80
TSS	mg/L	150
COD	mg/L	250
NH_3N	mg/L	10
P	mg/L	4

Considerations on regulation

Given the wide range of treatment processes and stages of effluent production, if Sabah is to consider developing standards, clear guidelines *as to where and when to measure* should be given.

Given the nature and potential environmental impact of nutrient enrichment upon receiving waters it is recommended that a standard *include reference to at least one of the nitrogen compounds if not both.*

If standards are to be developed and adopted, the application and *maintenance of these regulations* need to be reviewed from time to time to ensure that they compliment the environmental objectives.

In the long term a commission should adopt meaningful standards to eliminate or significantly reduce the release of *odour and ammonia* from livestock sheds, lagoons and other outbuildings.

Before legislation and standards are proposed, it is recommended that *the environmental issues be clearly identified alongside the ability of present farmers to implement mitigation measures*. Certain lower cost mitigation measures might be recommended for immediate implementation, for example the installation of roofing to prevent lagoons from flooding. Examples from around the world suggest that there are considerable difficulties in using legislation to control the environmental problems associated with livestock farming, most of the problems arise due to the high costs associated with the processing techniques that can suitably treat the waste to a sufficiently high standard.

Appendix A. Water quality

Nitrogen

Nitrogen (N) is essential for all life processes in plants and lack of N often limits plant growth The animal husbandry sector is inefficient in N use and is a major source of N loss.

The World Health Organisation recommends that drinking water should not contain more than 50 mg NO_3/L (Nitrate). Nitrogen occurs in several forms, including dissolved molecular nitrogen, ammonia/ammonium, nitrate, nitrite and numerous organic forms. Sources of nitrogen include: atmospheric inputs (precipitation and fallout); biological fixation, inputs by groundwater and manmade influences such as the effluent from sewage, and runoff from agricultural and residential areas. Since nitrogen compounds are important macronutrients in aquatic systems, they are important to monitor in system productivity and eutrophication assessment. High nitrate concentrations in wastewater effluents or from agricultural runoff can affect primary productivity and community structure. In the USA for example, most states have criteria for nitrate, nitrite and other nutrients, which are dependent upon the degree of protection being afforded to the water. An example is the Everglades National Park which has a maximum nitrate standard of 0.7 mg/L and nitrite standard of 0.04 mg/L. Waters with significant nitrate and nitrite concentrations are probably heavily polluted and possibly biologically unacceptable.

However, at levels well below this there are environmental consequences as a result of nitrogen entering the environment in quantities well above limiting factors, the most important of which is eutrophication and the subsequent loss of biodiversity in water and land ecosystems.

Phosphorous

Phosphorous in nature exists mainly as phosphate but in water may occur in several forms, including soluble reactive phosphate and total phosphorous. Phosphates in wastes are the primary sources of excess amounts of nutrients in water. Artificially nutrient-enriched waters quite often are biologically altered creating problems with algal blooms - stimulated growth of algal blooms, stimulated growth of aquatic weeds and the local extinction of fish species. Phosphate deficiencies retard plant growth and therefore additional contribution of P to ecosystems also contributes toward eutrophication. The State of California has established a mean annual concentration for soluble phosphorous, in Lake Tahoe, a very clean lake, at 0.007 mg/L, while mean annual concentrations for soluble phosphorous in other state waters in California are as high as 0.100 mg/L. It is probably appropriate to adopt a phosphorus standard for both soluble reactive phosphate and total phosphorous in waters of critical concern.

Organic matter

Various parameters are used as a measure of the organic strength of wastewater. Most of the common methods are based on the amount of oxygen required to convert the oxidizable material to stable end products. Since the oxygen used is proportional to the oxidizable material present, it serves as a relative measure of wastewater strength. Two methods used most frequently to determine the oxygen requirements of wastewater are the COD and BOD tests. The COD or chemical oxygen demand of the wastewater is the measured amount of oxygen needed to chemically oxidize the organics present. BOD is the measured amount of oxygen required by acclimated microorganisms to biologically degrade the organic matter in wastewater. BOD is the most important parameter in water pollution control and is used as a measure of organic pollution, as a basis for estimating the oxygen needed for biological processes and as an indicator of process performance

Biological Oxygen Demand (BOD)

BOD is usually defined as the amount of oxygen required by bacteria while stabilizing decomposable organic matter under aerobic condition and is widely used to determine the pollution strength of domestic and industrial waters. The term ‘decomposable’ may be interpreted as meaning the organic matter can serve as food for the bacteria. Therefore requires other nutrients such as nitrogen and phosphorous, which are usually in plentiful supply in most wastewaters.

The BOD test is one of the most important in stream pollution control activities and is of prime importance in regulatory work and in studies designed to evaluate the purification capacity of receiving waters. BOD is the only test applied that gives a measure of the amount of biologically oxidizable organic matter present that can be used to determine the rates at which oxidation will occur. BOD is therefore the major criterion used in stream pollution control where organic loading must be restricted to maintain desired dissolved oxygen levels.

BOD determination does not reveal the concentration of a specific substance but it does measure the effect of a combination of substances and conditions. BOD is not a pollutant itself and causes no direct harm. Only by lowering the dissolved oxygen content to levels that are threatening to fish life and other beneficial uses does BOD exert a potentially harmful effect. Standards for effluent discharge will vary depending upon the condition of the receiving water. In a slow moving stream, a 5-day BOD of 5 mg/l may be enough to produce deoxygenation, which results in anaerobic conditions. On the other hand a rapid mountain stream may have the capacity to assimilate an effluent with a BOD of 50 mg/l without appreciable depletion of dissolved oxygen. The input of natural organic matter i.e. leaf fall also exerts an increase in the BOD of the receiving water.

The laboratory test for BOD is determined by incubating the sample in a dark bottle for 5 days at 20^{o}C. It should be noted that most surface waters in Sabah range in temperature between 25-35^{o}C, depending upon locality and conditions.

Chemical Oxygen Demand (COD)

During the determination of COD, organic matter is converted to carbon dioxide and water regardless of the ability of the substances to be broken down by normal biological processes. As a result, COD values are greater than BOD and may be much greater when significant amounts of biologically resistant material is present e.g. wood pulping wastes because of their high lignin content. Therefore one of the chief limitations of the COD test is its inability to differentiate between biologically oxidizable matter and biologically inert organic matter. In addition is does not provide any evidence of the rate at which the biologically active material would be stabilized under conditions that exist in nature. However, the major advantage of the COD test is the short time required for evaluation. The determination can be made in about 3 hours rather than the 5 days required for BOD. For this reason it is sometimes used as a substitute for the BOD test. COD data can often be interpreted in terms of BOD values after sufficient experience has been accumulated to establish reliable correlation factors. The test is widely used in the operation of industrial treatment facilities because of the speed with which results can be obtained – allowing measures to be taken to correct errors on the day they occur.

pH

pH is a measure of hydrogen ion activity in a water sample. As it can directly or indirectly affect the concentration or activity of other constituents present, pH is an important description of the chemical and biological systems of natural waters. The permissible range of pH for fish depends upon many other factors such as temperature, dissolved oxygen and the content of various anions and cations. A pH range of 6.5-9.0 with no change greater than 0.5 units outside the natural seasonal maximum or minimum is protective of freshwater, aquatic life and is considered harmless to fish. However, due to photosynthesis, large diurnal pH changes can occur as a natural condition, particularly in shallow biologically active tropical waters. Here the pH can vary from 9.5 during the day to 7.3 just before dawn. The pH of undisturbed swamp forest waters may well fall below pH 4.

Suspended solids

Suspended solids in natural waters are composed of eroded silt, organic detritus and plankton. However, human activity alters and increases these constituents. Apart from the possible toxic effects attributable to substances leached out by water, suspended solids may kill fish and shellfish by causing abrasive injuries, clogging the gills and respiratory passages of various aquatic species, killing eggs and destroying spawning beds. Further and more indirectly, suspended solids can be harmful when they screen out light or trap bacteria and detritus on the bottom, resulting in oxygen depletion.

Turbidity

Turbidity is attributable to suspended and colloidal matter that can cloud water and diminish light penetration. Turbidity is defined as an expression of the optical property that causes light to be scattered and absorbed rather than transmitted in straight lines through the sample. The degree of turbidity is not equal to the concentration of suspended solids; rather it is an expression of just one effect of suspended solids the characteristics of water. Turbidity is measured in units known as nephelometric turbidity units (NTU). Turbidities as high as 200 units should be tolerable to fish. Waters with turbidities of 3000 units are considered dangerous to fish when maintained over a 10-day period (USA).

Micro-organisms

Wherever there is suitable food, sufficient moisture and an appropriate temperature, micro-organisms will thrive. Sewage provides and ideal environment for a vast array of microbes, primarily bacteria, plus some viruses and protozoa.

Coliform bacteria (Faecal and total)

The relationship between polluted water and disease has been firmly established. Protection of public health, the original purpose of pollution control, continues to be the primary objective in many areas. The use of biological indicator organisms in defining water quality has become a common practice. They are used to identify environmental changes, to quantify pollution levels and to study, under controlled laboratory conditions, phenomena, which could occur in the natural environment. Microbial indicators have been used to determine water's safety for drinking, swimming and shellfish harvesting. Coliform bacteria are considered to be the primary indicators of faecal contamination and as such are some of the most frequently applied indicators of water quality. Drinking water standards are based on total coliform bacteria with a general recommended limit of 2000 coliforms/100ml while drinking water must be free from coliform organisms at the time of consumption. Normally this is accomplished by disinfection.

Standards for faecal coliform are more variable. Recreational waters generally range from a geometric mean of 100 to 1000 organisms per 100 ml

Appendix B. Effluent and water quality requirements

Many countries have effluent and ambient water quality requirements that vary depending upon the characteristics of the wastewater and whether the receiving waters will be used for water supply, recreation, and irrigation or industrial purposes. The effluent requirements apply generally to municipal wastewater where at least 85 per cent removal of organic matter is provided. The criteria for stream quality pertain to receiving waters that are either suitable with filtration as a raw water supply or acceptable for swimming

Table 4.1 Example effluent and water quality requirements

Parameter	Wastewater effluent	Stream quality
Canadian objectives		
BOD	15 mg/L max	4 mg/L max
SS	15 mg/L max	
DO	2 mg/L min	4 mg/L min
Total coliforms		5,000/100 mL max
Faecal coliforms	200/100 mL max	500/100 mL max
United States Standards (Typical)		
BOD	30 mg/L max	4 mg/L max
SS	30 mg/L max	
DO		4 mg/L min
Total coliforms		5,000/100 mL max
Faecal coliforms	200/100 mL max	500/100 mL max
Japanese standards		
BOD	20 mg/L max	2 mg/L max
SS	70 mg/L max	25 mg/L max
DO		7.5 mg/L min
Total coliforms		5,000/100 mL max
Faecal coliforms	30/100 mL max	1000/100 mL max