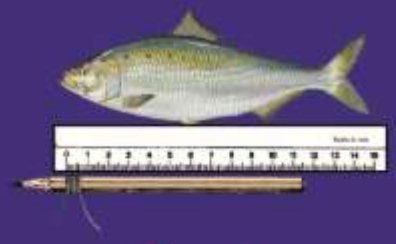
FISHERIES ENGINEERING TECHNIQUES IORCHOR SIMON IORER

FISHERIES ENGINEERING TECHNIQUES



IORCHOR SIMON IORER

DEDICATION

This book is dedicated to my mother, Mama Avese Iorchor for laying my educational career

Acknowledgements

I wish to acknowledge all the authors whom their text and articles have been cited in this book. I appreciate the contributions of my colleagues Mr. Sham Richard A and Mr. Igbudu Godwin A. Who also contributed some chapters to this book

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I am most grateful to my wife Joy and all my children for their inspirations and spiritual motivation during my hours of tiredness. Above all, I thank god for the wisdom given to me.

PREFACE

The diminishing returns from capture fisheries (wild fishing) is now a global concern as many factors like overfishing, natural disasters, insecurity (piracy, insurgency banditry and other skirmishes)as well chemical agricultural practices are interplaying to deplete the natural resources. In order to increase production from the wild we require higher technological adaptation for both fishing and strengthening of the wild stock. To also complement for the capture fisheries productivity, aquaculture must be given higher considerations by all concerned like fish producers, consumers and distributors.

Fish processing and preservations must be seen as a bridge between exploitation and conservation because purposeful preservation and processing will minimize food fish wastage and reduce the rate of exploitation of the wild fish stock. It will also enhance aquaculture production by adding value, extending distribution and increasing returns for the products. The above stated reasons may have given rise to the enthusiasm in aquaculture production such that many individuals and organizations have developed interest and are delving into aquaculture fish production as well as many students taking to fisheries studies. The major problem with the tertiary education students/graduates of fisheries is the easy translation of theoretical class work to real practical application on the field. Practicing farmers are always in search of relevant literatures that will answer their farm needed questions, update their knowledge and to assist in managing established projects.

This book attempts to simplify the technical aspects of capture and culture fisheries, identified and explained fishing equipment and tools. It also makes easy the understanding to start the construction of fish farmers and related facilities, stock and manage such farms with practically developed simple approaches. It reveals preservation and processing methods to guide fish producers towards the knowledge of managing and adding value to their products.

Much of what is in the book is based on my scholarly knowledge and the practical experience as a fisheries consultant for many years in the field. I encourage users to take advantage of the information provided and improve on fish production.

Above all, constructive criticism of the book is requested from the readers to enhance better production in the subsequent editions. Thank you for choosing to read the book.

FORWARD

It is with great pleasure that I write a forward for a strong contribution to knowledge in the area of "Fisheries Engineering Techniques."The dearth of books in this area of Fisheries Science is one of the motivating factors that lead to the production of the book. The book is divided into three sections namely Introduction to fishing gears and craft, equipment and tools for culture fisheries while the last section comprise of engineering inputs in fish processing, preservation and storage technology. The twenty one chapters of the book is written in standard English with adequate illustrations. The book will be useful to both beginners and professionals, It is a valuable asset especially for those on the field. I strongly recommend this book for all of those who wish to know more about fishing gears, craft, vessels and fish culture equipment.

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CHAPTER 19

FISH AS RAW MATERIALS

In the world of food preservation/ processing industry, foods are usually classified as less perishable, moderately perishable and highly perishable in order to understand their perishable nature. Cereals, nuts and grains are included in less perishable and more stable category, vegetables as moderately perishable and aquatic foods as highly perishable food items. Aquatic foods are less stable because of their high moisture content and availability of nutrients for the growth of microorganisms. Ambient temperature plays a crucial role to alter the stability of a product as they have low tolerance to ambient temperature, while moderately perishable items like fruits and vegetables have increased tolerance and non perishable items are least affected.

Properties of Fish Products

In order for us to use fish properly and process it very well, we need to know their properties like body structure, the size and weight ratio of their different body parts and organs. The physical properties and chemical composition and the properties of proteins, fats, vitamins and other substances contained in fish are equally important to the fish processor .

The causes, types and pattern of fish spoilage also should also be known so that the processor will determine the best method of preservation and processing to employ.

Most fishes have a symmetrical shape which may be divided into three main parts; head, body and tail. All these part pairs imperceptibly into another. The fish body is made up of several fins, the surface if the body and tail system is covered with elastic skin, which for some fishes it serve as the seat of the scales while in other it is naked.

Beneath the skin are the muscles, which constitute the flesh of the fish supported on a bony or cartilaginous skeleton. The body cavity holds the viscera (internal organs). The body flesh of the fish is made up of three groups of striated muscles which include those of the head, body and fins. The bulk of the muscles and the body have somatic muscles on either side of the vertebrate column and consist of four longitudinal two dorsal and two ventral muscles separated from one another by strong connective tissues.

Both muscles are separated laterally by fine partitions of connective tissues called the myoseptal into a number of segments, many text have discussed fish and their physical, chemical and biological properties with the view to throw more light on how to handle and prevent fish before final processing/ preservation. The skin of fish carries with it, bacterial load from the point of catching, the body tissues are fragile and the skeletal system is complex with simple blood circulatory system. The chemical composition of.....

Fish Spoilage and Causative factors

Fish spoilage may be defined as the contamination of fish products which results in the undesirable change in the colour, texture, flavour, odour and appearance, it is also referred to as putrefaction. Spoilage and freshness are the two qualities that have to be clearly defined. A fresh product is defined as the one whose original characters remain unchanged. Spoilage therefore is the indication of post harvest change. This change may be graded as the change from absolute freshness to limits of acceptability to unacceptability. Spoilage is usually accompanied by change in the product's physical characteristics like colour, odour, texture, colour of eyes, colour of gills and softness of the muscle are some of the characteristics that may be observed in spoiled fish. Spoilage is caused by the action of enzymes, bacteria and chemicals present in the fish. The major factors that contribute to spoilage of fish include; High moisture content, High fat content, High protein content, Weak muscle tissue, Ambient temperature and Unhygienic handling

Process of spoilage

Fish is highly nutritive and tasty because of its constituents. The main components of fish are water, protein and fat. The spoilage of fish is a complicated process brought about by actions of enzymes, bacteria and chemical constituents. The spoilage process starts immediately after the death of fish. The process involves three stages; (i) Rigor mortis (ii) Autolysis and (iii) Bacterial invasion that finally lead to putrefaction

Enzyme action

The Rigor mortis is a physical effect on the muscle tissue of fish caused by chemical changes following the death. In live fish, its movements are controlled by chemical signals which cause the eythmic contraction (stiffing) and relaxation of the muscles. This produces swimming action. After the death, the normal circulatory system breaks down and chemical

signals leak into the muscle causing them to stiffen. This process is known as Rigor Mortis. In other words, in live fish the glycogen present in the muscle is converted to carbon dioxide and water after supply of oxygen to the cells. When the fish dies, the blood circulation stops and the supply of oxygen is prevented. The enzymes present in the muscle convert glycogen into lactic acid. The pH of the fish muscle falls. The formation of the lactic acid continues till the supply of glycogen is completely used up.

After the completion of rigor mortis, muscle stiffness gradually decreases and become soft and accompanied by increase in pH, ending up in softening of muscle. This is followed by breakdown of proteins by enzymes. This process is called as autolysis which is the internal breakdown of the structure of the protein and fats due to a complex series of reactions by enzymes. Autolysis of protein starts immediately after rigor and creates favourable conditions for the growth of bacteria. Another important action of the enzymes is that it affects the flavour of fish. The components responsible for the taste and flavour of the fish are changed by the enzymatic action. An example is the progressive, degradation of Adonesin Triphosphate (ATP to AMP and Hypoxanthine. Hypoxanthine is produced by the breakdown of ATP which is a main component of fish muscle nucleotide. The accumulation of Hypoxanthine imparts a bitter taste in the fish muscle accompanied by loss of fresh fish flavour. Thus the estimation of Hypoxanthine content in fish indicates the degree of freshness. Enzymatic action also causes decomposition in the fish known as belly bursting. The belly bursting is caused by the action of digestive enzymes present in the gut of the fish.The black spot formation in fish is also caused by the action of the enzymes in the amino acid. The black colour is due to the formation of Melanin (Black Pigment) by the action of enzyme tyrosinase on tyrosin. Black spots presents a poor appearance and therefore, are not acceptable.

Action of the Bacteria

The freshly caught fish will be almost free from bacteria but the surface slime, gills and intestine may contain considerable load of bacteria. When the fish is dead, these bacteria start attacking the flesh causing spoilage and produce undesirable compounds. The nature and type of bacteria present in a fish depends upon the water from where it is caught and methods used for handling of the fish after its catch. The important changes brought out by the action of the bacteria in fish are as follows.

i) **Reduction of TMAO to TMA**

Marine fish contains a small percentage of odourless TMAO which is reduced to an offensive smelling TMA by the action of bacteria.

ii) **Breakdown of Amino Acids and formation of Primary Amines**

The bacterial action on amino acids present in the fish muscle leads to formation of primary amines. Examples are formation of histamine from histidine, arginine from glutamic acid etc. This bacterial action may cause food poisoning in extreme cases.

iii) **Breakdown in Urea**

The high concentration of urea in the flesh of some fishes is degraded to ammonia by the microorganisms. The formation of ammonia is accompanied by an offensive odour.

Apart from the bacteria load in the environment from which the fish is caught, bacteria exist everywhere and will continue to act on the fish products before, during and after preservation. In microbiology, and based on bacteria actions in different environments and at varying temperature conditions, it is classified into mesophilic and thermophilic bacteria. Mesophilic bacteria are only active at chilled and cold temperatures, and its action is slowed and completely retarded at extreme cold temperature levels (from -0ºC to -40ºC) where the water molecules become iced block and form crystals. Thermophilic bacteria operate and remain active at high temperatures and its action is only slowed down and can be completely killed at extreme high temperature levels (from 200ºC to 300ºC). Bacteria will still invade preserved/processed products which are exposed during storage so storage conditions still remain an important aspect of fish processing and preservation. ... One major way of reducing the effect of bacteria on stored products is to prescribe limited storage time (storage duration) for preserved/processed fish products....

Chemical Action

The most common chemical action which causes spoilage is the oxidative rancidity in fatty fishes. The levels of peroxide value and free fatty acid content are both a measure of oxidative rancidity and are considered an index of quality of fatty fishes. The spoilage in fish is accompanied by the change in physical characteristic. Changes in colour, texture, odour,

colour of eyes, colour of gills, softness of muscle, belly bursting are some of the characteristics of spoiled fish.

CHAPTER 20

HANDLING RAW FISH AND QUALITY ASSESSMENTS

Fish Handling

Fish handling refers to the ways and manner in which a particular fish caught is treated from the point of catch, how it is maintained and transported to the point of processing or preparation for human consumption. Handling is an important and critical aspect in the fish processing industry as it determines, prevents, reduce or even retard the spoilage of the fish raw products prior to preservation/processing. Handling is critical because once the raw products becomes contaminated the effects crossover to the processed products. Proper handling is important because the quality of raw materials used determine the quality of the end product. That is if good quality fishes are used definitely the quality of fish obtained from processing will be of best quality.

The main cause of spoilage is bacteria so to prevent the spoilage or to maintain the quality of fish it should be handled properly by handling the fish quickly, carefully, clean and keeping it cool in the following ways;

1. Handling the fish quickly

   Do not leave the fish for long, the time for handling the fish should be reduced to the barest minimum and sorting should be done fast enough to reduce its exposure to the sun and other bateria
2. Handling of fish carefully
   - Avoid throwing or trampling of the fish to prevent damage to the flesh because by so doing it is more exposed to bacteria also prevent the fish from braising against itself
   - Do not force the shape to damage during and after rigor mortis because it will alter the texture and reduce value.
3. Keeping the fish clean
   - All surfaces coming in contact with fish should be clean e.g. the basket, table and even the boat should be kept clean at the end of each operation.
   - Ice should not be re-used because it has already being contaminated.
   - Fish with swollen belly should be isolated and treated separately.

- Wash the body of the fish to remove the traces of blood with chlorinated water to remove dirt.
- The fish should not be kept on ordinary ground floors
- The fish handler also has to be clean.

4. Keeping the fish cool, temperature is the main factor that controls the rate at which bacterial grow so employ the use of ice water since icing is the most preferable method in the field. The higher the temperature the faster the fish get bad.

Importance of personal hygiene

A fish processing industry is part of food industry and there are laws which must be obeyed or kept, their main aim is to prevent food poisoning. Causes of food poisoning include micro organism such as bacteria and are found everywhere like from the air we breath, on the skin and gut of fish as well as eyes, mouth, gills. Our hair, ears, handkerchiefs, spot or pimples contain bacteria. Fish handlers and those working in the processing plants need to observe strict personal hygiene through;

- Regular baths
- Washing of hands after visiting toilets or handling rubbish
- Changing of under cloth keeping them clean
- Processing plant should be covered from excess atmospheric air because it contains *staphylococcus aurous*
- Smoking around a food handling plant, nail painting, use of wristwatches, finger and ear rings and necklaces should be avoided because they can easily hide bacterial.

Methods of Fish Handling

Sorting; separation based on certain criterions like species, sizes and freshness should be done fast to reduce the exposure of fish to the sun and reduce the rate of spoilage. Avoid trolling or trampling of the fish to prevent damage to the flesh and wash fish with clean chlorinated water to remove the bacteria slime on fish and debris, it should be washed thoroughly if gathered.

Gutting; this simply means the removal of the viscera (internal organs in belly and gills). It has to be done in a manner that the edible portion is not affected. The significance of gutting is to avoid quick spoilage, to remove enzymes and bacteria whish are which are the major

sources of spoilage. Clean and dirt free environment should be used and the process must be done very fast and the breaking of belly walls should be avoided

Bleeding; this is the removal of blood from fish by cutting the tail, species like shark and tuna are injected through the blood stream to ease the removal of blood. Other fishes are bled to whiten the flesh.

Filleting; is cutting the fish in smaller units parallel to the back bone in sizes that allows for easy processing or for direct selling.

Marketable Products of Raw Food Fish

Finfish, or parts of finfish other fisheries resources, are typically presented physically for marketing in one of the following forms;

Whole fish; this is the fish that originally came from the water, with no physical processing it may be displayed in the market with all the wanted and unwanted parts.

Drawn fish is a whole fish which has been eviscerated that is all its internal organs removed has been removed

Dressed fish; fish that has been scaled and eviscerated, and is ready to cook it may be dressed to specific sizes to fit into pan or ports in such cases, the head is removed.

Filleted Fish; the "fleshy sides of the fish, cut lengthwise from the fish along the backbone. They are usually boneless, although in some fish small bones called “pins” may be present; skin may be present on one side

Fish steaks; large dressed fish can be cut into cross section slices, usually with a cross section of the backbone

Fish Sticks; are pieces of fish cut from blocks of frozen fillets into portions, they may be available in fried form ready to eat or frozen raw, coated with batter and breaded, ready to be cooked

Fish Cakes; are prepared from flaked fish, potatoes, and seasonings, and shaped into cakes, coated with batter, breaded, and then packaged and frozen, ready-to-be-cooked

Fish Roe; fish eggs or egg filled ovary having a grainy texture is removed and placed for sale

Trash Fish; these include fish or fish parts that is unfit for human consumption and may not be accepted or does not meet marketing standards. Head, internal organs, fins and by-catches

of finfish and other fisheries resources are the major products that may be presented for sale especially to animal feed mill operators.

All the above products may be purchased for further processing or may be preserved for distribution and the manner and methods in which they were handled may determine the quality of final processed products.

Fish Quality Assessment (Reviewed)

Except for a fishing vessel that has processing/preservation equipment on board, generally fish caught from water are not processed nor conditioned for preservation immediately, this may be due to the distances of fishing grounds, quantity to catch at a time and the quantity to be taken to the processing plant or market. It may take hours for the fishers to get the products to the point of collection during which so many changes may occur on the products before, during and even after handling therefore, the assessment of the products quality before purchase for both consumption and preservation is very important.

Quality is usually referred to as the aesthetic appearance and freshness or degree of spoilage which the fish has undergone. It may also involve safety aspects such as being free from harmful bacteria, parasites or chemicals. It is important to remember that "quality" implies different things to different people and is a term which must be defined in association with an individual product type. For example, it is often thought that the best quality is found in fish which are consumed within the first few hours post mortem. However, very fresh fish which are in rigor mortis are difficult to fillet and skin and are often unsuitable for smoking. Thus, for the processor, slightly older fish which have passed through the rigor process are more desirable.

The eating quality of fish is one of the important attributes that influence the acceptability of fish as food to the consumer. Price, appearance, availability and perceived nutritional value are important also, but if the fish is not good to eat the customer will not buy it again. The quality of fish begins to deteriorate quite soon after capture, and so it is essential that everything possible be done at all stages in the handling of fish to slow down such deterioration. It is important, then, to be able to *measure* the eating quality of fish at all stages.

Methods of measuring quality can be described as sensory or non-sensory. Sensory methods use the senses directly, principally those of taste, smell and sight, in much the same way as the ultimate consumer will. Microbiological methods can give information on the state of spoilage, but are applied much more in assessing hygiene, safety and conformance with standards. Methods for evaluating fresh fish quality may be conveniently divided into three categories and these may include:

Physical Methods also referred to as subjective or Sensory method

Physical methods; The method uses physical equipment (either as analog or digital) to assess the fish products, during the last 50 years many schemes have been developed for sensory analysis of **raw fish.** The first modern and detailed method was developed by the Torry Research Station (Shewan *et al.*, 1953). The Torrymeter is a device that is placed vertically and provides a digital reading of the fish quality whether it is aged or fresh. From the digital readings or value of the **torrymete**r, the freshness of fish can be estimated. It has values of 1-10, and a low value indicates the presence of a high number of the microbial population. 10 is the highest value for the freshly caught fish, and below 3 is the value of spoiled fish. The value of 6 on torrymeter is acceptable for consumption.

Subjective and sensory method

Sensory evaluation is defined as the scientific discipline used to evoke, measure, analyze and interpret reactions to characteristics of food as perceived through the senses of sight, smell, taste, touch and hearing, it is also subject to the individual's perception and judgement. In sensory analysis appearance, odour, flavour and texture are evaluated using the human senses. Scientifically, the process can be divided into three steps. Detection of a stimulus by the human sense organs, evaluation and interpretation by a mental process, and then the response of the assessorto the stimuli.

The Organoleptic qualities of the fish are directly assessed by the customer or consumer by looking at the physical organs of the raw fish. This test includes the quality assessment of fish by observing;

i) The eyes should be clear and vibrant. If there is any discoloration around the eyes and cloudiness in the eyes then it indicates that the fish is not fresh.
ii) The gills should be red- pink in colour and not scattered

iii)

iv) The skin should shiny not slimy and the surface of the fish should be clear, and there must not be any discoloration.

v) One can check the quality of the fish by touching the flesh and scales of the fish, if the scales are peeling the the fish is not fresh, the flesh should be tight, elastic, but not slimy.

vi) We can also check the quality of the fish by the sense of smell: The smell of fish should be neutral and fresh. There should not be fishy, sour and ammonia likes smell.

The sensory observations are summarized to a table which is also known as Quality Index Method. The Quality Index Method (QIM) was originally developed by the Tasmanian Food Research unit (Bremner *et al.,* 1985) for individual species like cod, herring and sardines and is suitable many commercially important species of the marine and fresh waters in Africa

Table.....Quality Index Score Guide

Index	Quality parameter	Character	Score (Fresh /marineawater)
1	General appearance	Skin	0 Bright, shining 1 Bright 2 Dull
		Bloodspot on gill cover	0 None 1 Small, 10-30% 2 Big, 30-50% 3 Very big, 50-100%
		Stiffness	0 Stiff, in *rigor mortis* 1 Elastic 2 Firm 3 Soft
		Belly	0 Firm 1 Soft 2 Belly burst
		Smell	0 Fresh, seaweed/metallic 1 Neutral 2 Musty/sour 3 Stale meat/rancid
2	Eyes	Clarity	0 Clear 1 Cloudy
		Shape	0 Normal 1 Plain 2 Sunken
3	Gills	Colour	0 Characteristic, red 1 Faded, discoloured
		Smell	0 Fresh, seaweed/metallic 1 Neutral 2 Sweaty/slightly rancid 3 Sour stink/stale, rancid
Sum of scores			(min. 0 and max. 20)

QIM is based on the significant sensory parameters for raw fish when using many parameters and a score system from 0 to 4 demerit points (Jonsdottir, 1992). QIM is using a practical rating system, in which the fish is inspected and the fitting demerit point is recorded. The scores for all the characteristics are then summed to give an overall sensory score, the so-called quality index. QIM gives scores of zero for very fresh fish while increasingly larger totals result as fish deteriorate. The description of evaluation of each parameter is written in a guideline. For example, 0 demerit point for the appearance of the skin on a fish means very bright skin only experienced in freshly caught herring. The appearance of the skin in a later state of decay turns less bright and dull and gives 2 demerit points. Most of the parameters chosen are equal to many other schemes. After the literal description, the scores are ranked for each description for all the parameters, giving scores 0-1, 0-2, 0-3 or 0-4. Parameters with less importance are given lower scores. The individual scores never exceed 4, so no parameter can excessively unbalance the score. It is advised that QIM be developed for every commercially important species based on their individual differences.

Most sensory characteristics can only be measured meaningfully by humans. However, advances are being made in the development of instruments that can measure individual quality changes. Instruments capable of measuring parameters included in the sensory profile are the Instron, Bohlin Rheometer for measuring texture and other rheologic properties. Microscopic methods combined with image analysis are used to assess structural changes and "the artificial nose" to evaluate odour profile (Nanto et al., 1993).

CHEMICAL METHOD

Biochemical analysis includes the following methods

Proximate testing: it is a prevalent method, in which the fish components like moisture, protein, lipid, etc. are regularly checked from the time of fish harvesting. This method does not give a satisfactory assessment and thus not accepted.

Hypoxanthine value: after the death of fish, break down of an **ATP** (Adenosine Triphosphate) into ADP, AMP, and IMP and finally into **hypoxanthine** occurs. The value of hypoxanthine increase during the storage of fish. Hypoxanthine value gives an estimate for the freshness of fish. A fish is considered to be spoiled when the hypoxanthine value reaches **7 – 8 micromoles/g**

Trimethylamine (TMA) value: fish contains a considerable amount of trimethyline oxide (**TMAO**), but when it gets spoiled, the TMAO reduces into TMA. The value of TMA with level of **1.5mg/100g** indicates that the fish is moderately spoilt.

Ammonia production: the production of ammonia indicates that there is an extent of spoilage.

Peroxidas value:it helps in measurement of **oxygen rancidity**. Peroxidase value less than 10 indicates the good quality of fish but value more than 20 indicates rancidity.

Thiobarbituaric value (TBA): it also helps to determine the oxygen rancidity. TBA values lees than 2, is accepted by the consumer.

Biological method

It includes total plate count method (TPC), which is use on the quality assessment of fish by giving an estimate of bacterial presence. In this method first, grinding the fish and then dilute the sample by following serial dilution. Prepare media for the growth of microorganisms present in the fish, where we can use both ordinary and selective media.

For the enumeration of microorganisms in marine fish, agar media is used whereas for he processed fish, try pone glucose beef extract agar media is used. Other than this, selective media SS agar can be used for the detection of collator bacteria (E. coil, Shigella, etc.) in the fish.

After media preparation, perform pouring method and incubate the plates for 24 hours at 35 – 37^0C. Count the number of bacteria per plate, by multiplying with the dilution factor. Total plate count method thus gives a count for the bacterial population present in the fish, which can be pathogenic and non – pathogenic. Hence, total plate count does not determine the edibility of the fish

CHAPTER 21

FISH PRESERVATION AND PROCESSING

Fish is a highly perishable food which needs proper handling and preservation to keep it in good condition for considerable length of time (to have a long shelf life) and also retain its desirable quality in appearance and nutritional value. The major concern of fish processing is to prevent fish from deteriorating. The best and most obvious method for preserving the quality of fish is to keep them alive until they are ready for cooking and eating but the major challenge with this method is the means, mode and duration of transportation for the required quantity, distance, storage time and above all, the cost benefit of such transport means.

The words, 'Preservation and Processing' are often used freely and interchangeably whenever it comes to this topic however, they differ according to their procedures and the end products obtained. It is important to note that;

i. Preservation is aimed at keeping the product in its original form/state from the point of harvest to the point of preparation for consumption either by humans or other animals

ii. Processing though with the same aim as preservation but due to the methods and procedure the product is transformed from its original form/ state to an irreversible by-product.

The major differences are that (a) Most preserved food items do not require labelling for its identity so anybody seen it will identify it as fish if it was preserved as fish but processed food items require labelling for its identity for example, a flour, powder or cake must be labelled as fish flour, fish powder or fish cake for one to know.

(b) Processing is an irreversible change action while there is no significant product change in preservation.

The common aim of both preservation and processing is to prolong the shelf life of products with the main objective of maintaining their nutritional value for the end products and to present it to the consumers in a wholesome state therefore any method of both preservation and processing that denatures or reduces the nutritional value of its end products is unethical and unacceptable.

Preservation of food including fish products dates back to the existence of humanity and prior to the advent of high level technology, it was practiced in many ways and methods and

according to the level of technology and local creativity of the people involved but modern technology has brought about improvements and many better ways of fish preservation.

Value Addition

There is an increasing demand for ready to eat fish products, or products that do not need much preparation like steaming, grilling, roasting and half done salad. All these require minimum value addition to the fish products for maximum profit.

Generally there are four major ways of preserving dead fish products, these includes but not limited to chemical and physical bacterial control, Dehydration, Lowering and raising of the product's temperature.

Chemical and physical Bacterial Control

Control of bacterial load on the fish body may be done by adding acids, and oxygen deprivation by vacuum packaging and removal of microbial loads through microwave heating or ionizing irradiation, Microbial growth and proliferation can be inhibited by a technique called biopreservation. Biopreservation is achieved by adding antimicrobials or by increasing the acidity of the fish muscle. Most bacteria stop multiplying when the pH is less than 4.5. Acidity is increased by fermentation, marination or by directly adding acids (acetic, citric, lactic) to fish products. Lactic acid bacteria produce the antimicrobial nisin which further enhances preservation. Other preservatives include nitrites, sulphites, sorbates, benzoates and essential oils.

Spoilage bacteria and lipid oxidation usually need oxygen, so reducing the oxygen around fish can increase shelf life. This is done by controlling or modifying the atmosphere around the fish, or by vacuum packaging. Controlled or modified atmospheres have specific combinations of oxygen, carbon dioxide and nitrogen, and the method is often combined with refrigeration for more effective fish preservation.

Heat or ionizing irradiation can be used to kill the bacteria that cause decomposition. Heat is applied by cooking, blanching or microwave heating in a manner that pasteurizes or sterilizes fish products. Cooking or pasteurizing does not completely inactivate microorganisms and may need to be followed with refrigeration to preserve fish products and increase their shelf life. Sterilised products are stable at ambient temperatures up to 40 °C, but to ensure they remain sterilized they need packaging in metal cans or retortable pouches before the heat treatment. Two or more of these techniques are often combined to improve preservation and reduce unwanted side effects such as the denaturation of nutrients by severe heat treatments.

Common combinations are salting/drying, salting/marinating, salting/smoking, drying/smoking, pasteurization/refrigeration and controlled atmosphere/refrigeration

Dehydration is the removal of moisture from the fish body where the product is first frozen and then placed in high vacuum cabinet or chamber the water is then removed from the frozen product. Vacuums lower than 1.0 mm as the upper limit of pressure, result from the fact that the vapour of pressure in water over ice is about 1 mm at $^{-}0°$ C. The advantage of freeze-dried products lie in the increased quality of the product with respect to flavor retention, and the fact that the rehydration characteristics are far better than those of many conventionally dried products.

Lowering of temperature; the many ways of lowering temperature include; keeping the products in cool place, chilling by placing ice block to melt on it, refrigeration, quick freezing and cold storage.

Raising the temperature to control water activity; includes methods like parboiling, cooking, sun-drying, smoke-drying, oven-drying, toasting and canning.

Usually more than one of these methods is used in combination before, during and after preservation because when chilled or frozen fish products are transported by road, rail, sea or air, the cold chain must be maintained. This requires insulated containers or transport vehicles and adequate refrigeration. Modern shipping containers can combine refrigeration with a controlled atmosphere. The chilled products may then be smoke-dried etc.

Fish products may be processed into fish oils (hair relaxers, body cream, balm and medicines), flours (baking and flavouring), bones and scales may be used to produce ishing glass for jewelleries, by-products may serve as raw materials for the leather industries. None-edible parts of the fish (fins, bones and the viscera) may be processed into animal feeds and bio-fertilizers.

Fish Processing Equipment

There are so many preservation and processing equipment, systems and tools across the world the new technology evolving new ones to suit modern preservation methods. Processing methods are mostly based on consumer choice that may be determined locally, regionally and internationally. It is therefore not easy to specify or set standards for processing /preservation equipment and methods and as such cannot be described in this book. The book only highlights and guides its readers on the common methods of

preserving/processing fish, the most hygienic and easiest ways of handling fish before, during and after preservation

Processed Fish Quality and Consumer Safety (Reviewed)

Any method and equipment employed in fish processing /preservation, has to recognize and consider seriously the health and safety of the product's consumers. It is therefore pertinent to note that wholesome fish products produced in the most hygienic ways and conditions are given to unsuspecting consumers at all times. Processing plants, the personnel, environmental conditions, Preservatives, packaging materials, storage and distribution vans and other holding materials are special concerns of all stake holders in fish preservation, processing and storage industry. It therefore requires and is approached internationally.

The International Organization for Standardisation (ISO), is the worldwide federation of national standards bodies. ISO defines *quality* as "the totality of features and characteristics of a product or service that bear on its ability to satisfy stated or implied needs."(ISO 8402). The quality of fish and fish products depends on safe and hygienic practices. Outbreaks of fish-borne illnesses are reduced if appropriate practices are followed when handling, manufacturing, refrigerating and transporting fish and fish products. Ensuring standards of quality and safety are high also minimizes the post-harvest losses.

The fishing industry must ensure that their fish handling, processing and transportation facilities meet requisite standards. Adequate training of both industry and control authority staff must be provided by support institutions, and channels for feedback from consumers established. Ensuring high standards for quality and safety is good economics, minimizing losses that result from spoilage, damage to trade and from illness among consumers.

Fish processing highly involves very strict controls and measurements in order to ensure that all processing stages have been carried out hygienically. Thus, all fish processing companies are highly recommended to join a certain type of food safety system. One of the certifications that are commonly known is the Hazard Analysis Critical Control Points (HACCP).

Although fish quality is not as determinant as fish safety, it has a direct impact on market price. Accurate assessment and prediction of fish quality are of main importance to set prices, increase competitiveness, resolve conflicts of interest and prevent food wastage due to

conservative product shelf-life estimations. In past years, research in food science and technology has focused on developing new methodologies to predict fish freshness.

HACCP is a system which identifies hazards and implements measures for their control. It was first developed in 1960 by NASA to ensure food safety for the manned space program. The main objectives of NASA were to prevent food safety problems and control food borne diseases. HACCP has been widely used by food industry since the late 1970 and now it is internationally recognized as the best system for ensuring food safety. It has now gained worldwide recognition as the most cost-effective and reliable system available. It is based on the identification of risks, minimizing those risks through the design and layout of the physical environment in which high standards of hygiene can be assured, sets measurable standards and establishes monitoring systems. HACCP also establishes procedures for verifying that the system is working effectively. HACCP is a sufficiently flexible system to be successfully applied at all critical stages (from harvesting of fish to reaching the consumer). For such a system to work successfully, all stakeholders must be cooperative which entails increasing the national capacity for introducing and maintaining HACCP measures. The system's control authority needs to design and implement the system, ensuring that monitoring and corrective measures are put in place.

HACCP is based on seven basic principles;

- Principle 1: Conduct a hazard analysis.
- Principle 2: After assessing all the processing steps, the Critical Control Point (CCP) is controlled. CCP are points which determine and control significant hazards in a food manufacturing process.
- Principle 3: Set up critical limits in order to ensure that the hazard identified is being controlled effectively.
- Principle 4: Establish a system so as to monitor the CCP.
- Principle 5: Establish corrective actions where the critical limit has not been met. Appropriate actions need to be taken which can be on a short or long-term basis. All records must be sustained accurately.
- Principle 6: Establish authentication procedures so as to confirm if the principles imposed by HACCP documents are being respected effectively and all records are being taken.
- Principle 7: Analyze if the HACCP plan are working effectively.

Hazard Analysis Critical Control Points (HACCP) is endorsed by the Food and Agricultural Organisation (FAO), World Health Organisation (WHO), the European Union (EU) and is implemented through Codex Alimentarius (a commission of the United Nations). It is adopted by the World Trade Organisation (WTO) and all countries of the United Nations (UN) enforce the HACCP standards through their individual control agencies for Drug and food administration.

CHAPTER 22
WASTE MANAGEMENT (REVIEWED)

Waste is a necessary by-product that must come out of any industrial activity, it should be recognised and be given special attention at the onset of the establishment of any industry, irrespective of its size and the magnitude of production. All fish production (capture and culture) and processing activities generate waste materials and if not properly handled may constitute nuisance to the environment, contaminate and sometimes become poison to consumable products and may become a major source of pollution. Waste produced during fisheries operations are of three categories and may include;

i) Biodegradable solids

ii) None biodegradable solids

iii) Liquids (water soluble and insoluble liquids).

Biodegradable solids may be waste materials of plant origin like spent or consumed fish feed, fish excreta that comes during pond de-silting and cleanings. Weeded herbs from the farm, dead fishes and other rodents, emptied bags, cartons and other disposables may become waste materials. Some biodegradable substances take a long time for complete degradation. A special waste disposal area should be created on the farm at the farm planning stage.

None biodegradable solids are materials of steel, metals rubber, nylon and other polyesters that may become waste due to worn out equipment, tools and utensils ,glass bottles, torne fishing nets and ropes including broken plastic pipes and containers. Special arrangements for their evacuation from the farm should be put in place to avoid fall backs into fish ponds. Wind may blow nylon and cellophane bags into pond and if unchecked some of them may have contained poisonous chemical that could kill fish or cause suffocation as fish may get entangled in it.

In fish processing solid wastes may include skin, viscera, fish heads and carcasses (fish bones). Solid waste can be recycled in fish meal plants or it can be treated as municipal waste.

Liquid wastes: include blood water and brine from drained storage tanks, and water discharges from washing and cleaning. This waste may need holding temporarily, and should be disposed of without damage to the environment. How liquid waste should be disposed

from fish processing operations depends on the content levels in the waste of solid and organic matter, as well as nitrogen and phosphorus content, and oil and grease content. It also depends on an assessment of parameters such acidity levels, temperature, odour, and biochemical oxygen demand and chemical oxygen demand. The magnitude of waste management issues depends on how much waste volume there is, the nature of the pollutants it carries, the rate at which it is discharged and the capacity of the receiving environment to assimilate the pollutants. Many countries dispose of such liquid wastes through their municipal sewage systems or directly into a waterway. The receiving water body should be able to degrade the organic and inorganic waste components in a way that does not damage the aquatic ecosystem

Treatments can be primary and secondary.

Primary treatments: use physical methods such as flotation, screening, and sedimentation to remove oil and grease and other suspended solids.

Secondary treatments: use biological and physicochemical means. Biological treatments use microorganisms to metabolise the organic polluting matter into energy and biomass. "These microorganisms can be aerobic or anaerobic. The most used aerobic processes are activated sludge system, aerated lagoons, trickling filters or bacterial beds and the rotating biological contractors. In anaerobic processes, the anaerobic microorganisms digest the organic matter in tanks to produce gases (mainly methane and CO2) and biomass. Anaerobic digesters are sometimes heated, using part of the methane produced, to maintain a temperature of 30 to 35°C. In the physicochemical treatments, also called coagulation-flocculation, a chemical substance is added to the effluent to reduce the surface charges responsible for particle repulsions in a colloidal suspension, thus reducing the forces that keep its particles apart. This reduction in charge causes flocculation (agglomeration) and particles of larger sizes are settled and clarified effluent is obtained. The sludge produced by primary and secondary treatments is further processed in digesting tanks through anaerobic processes or sprayed over land as a fertilizer. In the latter case, care must be exercised to ensure that the sludge is freed of its pathogens.

SECTION TWO

CHAPTER 11

AQUACULTURE ENGINEERING CONCEPT

A fish farm is the economic integration of more than two fish ponds into a production unit as it provides one with the opportunity of serial and alternate production of fish on continuous bases. Such a unit may support the production of more than one species of fish.

Aquaculture Engineering is the application of science in the design, planning, construction and maintenance of buildings, machines and other manufactured things especially those used in aquaculture. With the expansion of aquaculture in many countries, the importance and crucial role of engineering expertise in sound development work have come into sharper focus.

Poor selection of sites, defective designs and poor construction of facilities on farms often leads to the cause of failure of many aquaculture projects. Engineering planning, design and construction of dams, barrages, pumping stations and other structures is normally carried out with a high degree of efficiency, sometimes, however, the smaller structures, secondary channels used for aquaculture projects are badly made or omitted entirely from engineering plans. In many cases Engineers have frequently neglected these minor works, particularly those required at the farm level especially when they appear to be unnecessary in the core production of fish and to the contractors, they do not mean much profit and they are dispersed and difficult to supervise. It has been increasingly recognized that one of the major difficulties encountered in the implementation of aquaculture development projects is improper project preparation. Inadequate planning and poor preparation of projects documents has often caused the final construction cost of the project to be much higher than estimated.

Fish Culture Systems

There are so many culture systems in fisheries technology which may include; **cage, raceway, aquarium, plastic/metal tanks, tarpaulin bags, bottles and fish pond**. These systems may be made of several structures like earth material (sand and mud), Portland cement, glasses bamboos and wire mesh. The technology and sophistication of the facilities may depend on the purpose of culture, availability of equipment and scale of production,

sometimes limited knowledge of the personnel engaged may lead to poor utilization of resources. The main and best commercial production system is the fish pond.

A fish pond is a drainable body of water constructed for the purpose of raising fish with inlet and outlet for easy entry and out flow of water. A fish farm refers to a number of ponds intergraded economically into a production unit. Such a farm would have a hatchery, nursery, production/ holding ponds and would be properly secured. Fish farms are mostly located where the conditions permit, these may be the source of water, availability of landed space and other social factors. The level and structure of management depends on the number of facilities and their capacity for production of fish and other fisheries products, the overall activities that lead to farmed fish production is referred to as Aquaculture.

There are many kinds of fish ponds and these may be grouped into earthen and concrete ponds. Concrete ponds are chiefly made of Portland cement either as solid cast or vibrated hollow blocks or solid bricks. They may be established as permanent structures anywhere there is an adequate perennial source of water supply. Earthen pond may be the modification of any existing lake that could be manipulated to suit for culture of fish. A barrier could be created to obstruct a running water (spring or stream) and create dam, excavation of borrow ditches may be carried out to suit for fish culture as dugout or sunken pond. The major conditions for earthen ponds may include permanent, adequate and perennial source of water that is free from industrial effluents and other pollutants, high water retention capability of the soil involved and good gradient to allow gravitational flow (in and out) of operational water in the pond. Fertile soils may be an added advantage to pond fertility and nutrients availability. Race ways may be constructed in shallow river beds and screened to culture fishes, also levee barriers around coastal areas that overflow at high tides could be created to hold fish, these are referred to as tidal ponds because the main source of water inflow is at high tides.

Engineering Considerations

The success of a production system depends on its design and construction because a well-designed and soundly constructed system will easily respond to good operations and management. Pond designs vary from one level of management to the other, proper planning of the layout can cut down construction and production expenses. A modular plan of approach to the construction may be adopted to allow for future expansion. The development of intensive fish farming has given rise to horizontal construction techniques and re-

circulatory systems. Proper design of the various pond structures results in tremendous savings on the development costs without sacrificing the function of these irreversible land development process. Fish ponds and other important farm structures are usually presented together with mathematical equations relevant to sound designs, construction and operational utilization.

Approach to Fish Farm Design and Construction

Fish farm engineering can be approached in two broad perspectives viz: (a) design concept and (b) application of technology.

Design Concept

This is usually streamlined towards the desired objective or goal of the motivator, entrepreneur or user. It is also influenced by either the physical environmental factors or financial budget for the project and this implies that the design concept may be informed from the motivator's aesthetic inclination, financial position and above all, the social and political conditions of the environment in which the project is to be sited.

The basic design criteria must give considerations for the farm functions and operational methodologies to include;

(i) The Desired goal: The purpose or function for which the structure is going to serve will determine the scope or form of the project

(ii) Environment: It plays a key role in the overall design when durability and efficiency are to a large extent determined by weather variables. The structural components of the project should be capable of withstanding environmental stress and strain (wears and tears)

(iii) Financial element: The type of design envisaged is sometimes a function of the capital out lay available to the prospective investor.

(iv) Suitability of the model: The relevance of a particular device to the intended project can also determine the type of design choice and selection

(v) Availability of the material input: whether the right materials for the various components parts can be locally sourced is one pre requisite for the durability and efficiency coupled with the sincerity and honesty in the monetary application during construction.

There are matters patterning to aquaculture pond development that are best known to Aquaculture Engineers but there are simple mathematical tools that an investor can use to

technically evaluate the design and construction parameters. This will offer the investor assurance for long years of trouble-free fish production.

Application of Technology in Farm Design

The application of technology depends on the core knowledge of the Fisheries/Aquaculture specialist to combine his knowledge of fish biology and the techniques of facilities and equipment utilization (Biotechnical knowledge) to determine the structures and their positions, sizes, distances from one another and the best connectivity for easy operations and high production output (Basic Farm Layout). This is very important because the farm is home for the fish animal and its biological needs for optimum survival and rapid growth requirements must be met to achieve the desired goal for the project purpose. A costly well established farm project with utral-modern facilities and equipment that negates the biological requirements of the desired animal may easily fail.

Technological Requirements

The major requirements for the technologist to provide the basic fish farm layout include:

(i) Species of fish to be produced and target size.

(ii) Sequence of operations envisaged: production from hatching to market fish, or production of market fish alone.

(iii) Method of fry/fingerling production, production quantities envisaged, (iv) methods and possibilities of nutrient supply to the ponds, such as organic manure, duck farming, fertilizer application

(v) Methods for water supply, reuse, recirculation and final discharge of waste water with other effluents.

(vi) Feed production, distribution and feeding methods, (fish feed type, grain, pellets or wet feed.) and the type of feeders to use.

(vii) Transport management - method and means of intra-farm and inter farm transportation for personnel, items, feed, fish and other materials.

(vii) Buildings required for operation, social-cultural amenities, grain store, equipment shed, sales and offices, netloft and other repair workshops, housing and others.

(viii) Proper identification of farm equipment and other structures, their specific sizes, uses and suitable positions on the farm so that proper dimensions (length, width

and heights) of facilities like housing, roads, culverts, weirs and drainages will be considered at the design stage.

CHAPTER 12
SITE SELECTION FOR FISH FARM

Site selection is always a focal point for Aquaculture engineers and fisheries technologist once the desire for fish farming is expressed, but factors for farm establishment and the interests varies from one physical environment to another and from one individual to another. It sometimes looks and sounds funny when ill qualified and acclaimed skilled fisheries personnel are seeing carrying pictures of farms and making reference to other farm projects to convince investors and win contracts for their projects, these category of artisans may waste funds and cause irreparable damages as well as make irreversible land deformation mistakes and discourage such investors from fish farming.

Major Considerations in Farm Site Selection

It is already established that farms must be located where there is water and suitable soil structure but advanced technology has changed that perception as underground water at very high depths could be accessed through bore hole rigging and, concrete, plastic or tarpaulin tanks may be used as fish ponds without recourse to soil quality and available natural water source. Weather factors may be controlled by land excavation and building facilities (land gradient modification drainage, and housing).

Depending on the magnitude of the farm project (size and volume of production), the first approach should be Environmental Impact Assessment (E I A). This assessment is very useful even for small scale farms. One may easily confuse E I A for Feasibility studies and assessments but they vary greatly because while Feasibility focuses on the suitability/workability of the project from the engineering/ construction and the cost/benefits of the business perspective, the E I A considers the artificial deformation/ modification of the natural environment by the alteration of the physical land, weather factors and the social conditions, before the project, during construction and after establishment.

ENVIRONMENTAL IMPACT ASSESSMENT (E I A)

Environmental Impact Assessment (EIA) is a process of evaluating the likely environmental changes that proposed project or development will bring to an environment, taking into

account inter-related socio-economic, cultural and human-health impacts, both beneficial and adverse. Environmental Impact Assessment as a tool should be used to identify the environmental, social and economic impacts of a project prior to decision-making. It aims to predict environmental impacts at an early stage in project planning and design, find ways and means to reduce adverse impacts, shape projects to suit the local environment and present the predictions and options to decision-makers. By using EIA both environmental and economic benefits can be achieved, such as reduced cost and time of project implementation, avoid treatment/clean-up costs and impacts of laws and regulations after implementation.

Although there are internationally accepted environmental regulations as enshrined in the United Nations (UN) charter, many countries have specific environmental laws and regulations that are peculiar and they may vary or differ from one country to another but the overall objectives remain the same (protect human health, reduce social crisis, conserve the environment and encourage profit making)

A complete EIA team would comprise of Engineers and Technologists, Health personnel (human, veterinary and environmental), Legal professionals, Biologists, Sociologists and security experts. A good EIA team with sound knowledge and expertise will make credible recommendations and advise the decision makers about sitting of the fish farm project before a detailed feasibility assessment shall be carried out. The major details required during the assessment can be grouped into physical, human, socio-economic and legal/ political considerations.

Physical Environmental Impact; The assessment would reveal information about the physical land deformation/modification vis-vis erosion, hilling blockades, effect on vegetation and animal biology with subsequent effects of wind, temperature, sunshine, plant pollination, reduced or increased depths of water volume in streams and rivers, its adultrations/pollution and other factors from the climate change.

Human and Environmental Impact; Generally environmental changes bring about new health orientations like waste disposals, sanitation, communicable diseases and epidemics. Change of food habits are likely to occur among humans and other animals with consequent allegories, an in-depth EIA will help plan and prepare for such impacts ahead of time.

Socio-Economic Impacts; The aspects of social life such as religious customs, consumer preference, cultural values, norms and taboos, societal civilization and cultural dynamics may frustrate or promote the project. Considering the social factors, it is obvious that the objectives of producing fish in a culture system should be clearly spelt out while the acceptance or preference of the local community would be of prime interest in producing fish for local consumption, the acceptability of the target group to whom the fish are supplied, in some cases, even by export, is of major interest.

Political and Legal Considerations (During E I A)

Government acts, laws and guidelines for aquaculture projects established should be consulted properly to fit into the national plan for development of industry and agriculture This is specially, needed when aquaculture is a part of rural development programme, as indeed most such projects are. It should specially help in sharing infrastructural facilities of public water supply, transportation (road), power supply and communications and also in judicious sharing of inputs and recycling outputs. Partisan politics is another good factor for consideration because a very suitable site for a fish farm may be rejected by the motivator or entrepreneur, the key players in execution and or the host community based on political differences.

Legal aspects, such as security of landed property tenure, legal size limits with reference to the ponds/culture area, as well as the species under culture, and closed seasons should also be considered. Several countries already have certain regulations concerning these legal aspects, some of which are in force, much before aquaculture was thought of as an industry. In many cases these legal clauses cannot be easily modified, even though some attempts in this direction would be necessary, especially with reference to size-limits of fish species to be caught and closed seasons. Some legal regulations have been included to protect the species survival under intensive capture systems of wild stock. While this protection may be necessary for such cases here in aquaculture, capture from the wild fish of certain size, when the season for capture is closed legally, the fish can only be transferred to the culture ponds - either as brood fish or as fry or fingerlings in grow-out ponds. Maritime laws controlling coastal waters (in cases where sites are coastal) should be referred to, in some cases maritime areas through which navigational routes and certain other country priorities exist, cages, raceways and pens may not be allowed.

FEASIBILITY STUDIES/ ASSESSMENTS

It is the general reconnaissance/ assessment of a proposed site for any project of a business venture with the views to see how suitable the environment is for the proposed venture. The assessment usually covers the physical, social and the economic indices for the success or failure of the venture. This is usually carried out with three (3) major objectives;

(i) To understand the physical conditions obtainable in a given environment and how they could be modified or manipulated to suit for the project.

(ii) To determine the methods of construction and relative costs for establishing the project

(iii) Prospect the production costs and market price for the products and determine the benefits of the project.

A detailed feasibility for a fish farm project will be carried out under (a) Locational feasibility, (b) Biotechnical feasibility and (c) Economic feasibility

(a) **Locational feasibility** assess the detailed Physical environmental factors obtainable on the project site, the study will reveal details about ;

- **Good quality Water Supply** on perennial basis at the required volume, its cost of procurement and discharge.
- **Topography** is considered based on the gradient that will govern the location of ponds and other structures that will permit gravitational flow of water into and out of the farm ponds, very steep slopes are usually very difficult for ponds establishment but gentle slope of 0.3 -1.0 % gradient is ideal. The drainage pattern of the area is always observed as pond water flow must follow the same pattern.
- **The soil profile** is examined because it affects water quality, pond dykes for earthen ponds and even the construction methods for concrete ponds, spillways, canals and weirs. All buildings constructed have relationship with the soil formation of the area as the soil structure is observed and foundation based to carry the entire weight/density. Vegetation of the area usually influence cost of construction especially large trees and stumps are to be removed.
- **Weather Condition;** The geography of the area under consideration should be an important consideration as some areas are characterized by higher seasonal rain fall, such areas may be prone to flooding and heavy soil erosions. Desert and highland zones loose water by percolation, leeching, seepage and evaporation, these may affect operational production cost for the farm.
- **Accessibility** to the area under consideration is an important factor as the farm needs to be accessed at all seasons and under any weather condition at relatively low fares or fueling cost and in good time. The site should be in the vicinity of transportation routes, or where the access road can be constructed economically.

The Engineering and Technological knowledge of the experts carrying out the feasibility is critical at the feasibility study stage because they are required to obtain the correct information in the chronological steps for construction work and at the farm management stage. Certain information may be collected from survey offices, meteorological stations, security office and the local inhabitants. Positive analysis of the information obtained by the experts will have long lasting effects on the success of the farm operations.

(b) **Biotechnical feasibility** actually seek to reveal the required information that combine the biology of the fish species under consideration, the water chemistry and its physical parameters that determine the fish metabolic activities as they will fit in the pond environment. A sound preparation and configuration of the above biological techniques will make a successful farm venture. The required details here will determine (i) Food and feeding habit of the fish, (ii) Its growth (rate, growing time and maximum), (iii) Cohabitation with other species (iv) its reproduction in captivity, (v) optimum requirements for dissolved oxygen (DO), ammonia, nitrate, nitrite and (vi) other physical parameters like optimum temperature, water depth, light penetration, total density and turbidity.

The knowledge about all the above factors are the major considerations during the farm design that determine pond dimensioning (length, width, and depth), type and kind of pond, their positions among and to other structures as well as frequency of their attention. It will be the objective of the culturist to manipulate the species and the environment to obtain an optimum (if not maximum) yield, considering the economics of production. In the proximity of inhabited areas, considerations of public health and the necessity of guarding against poachers should be kept in mind. Fish farms need electrical power, so the possibility and cost of connection should be considered. Existing electric power lines should guard the positions of farm structures and facilities and if possible, must be excluded from the area envisaged for the fish farm.

(c) **Economic feasibility** Considers the socio-economic aspects such as infrastructure facilities for post-harvest treatment of product including marketing, manpower (labour quality and quantity), even if the fish produced is for local consumption (same state, province/country) or export outside the country. Similarly relative merits or demerits of the specific site, with reference to availability and cost of materials / equipment for farm construction and subsequent needs for renewals in the farm structures and also for the maintenance of the farm, e.g. supplies of feed stuffs and fertilizers, should also be considered. Human security and skilled operators are essential for operating major fish farms efficiently. An important consideration in site selection is, therefore, to provide an attractive environment and facilities for both professionals and other operators.

The experts involved at the feasibility stage should have a clear objective that the fish cultured must pay for all the costs incorporated and profit made, so beautification and aesthetics for the farm should be carefully employed and the economics of production should be based on the current economic indices. In each of the above factors considered, reference should be made to the fish species intended for culture with specific structural set-up.

Data Collection for Aquaculture Project Establishment

During feasibility assessments, detailed information (data) regarding the area and the people required to be the key players for the project is collected. Information required is usually based on the peculiarities of the venture under consideration and in this text the required information will be streamlined to the peculiarities of fisheries as business entity.

General Technical Data; these will include

(i) Data on existing water uses affected like irrigation, industrial and domestic uses
(ii) Data affecting water supply and drainage like source and if it is a river then the volume, velocity of flow and potentials for flooding and draught severity.
(iii) Future development plans for the area like estates, industry and further layout.
(iv) Data on other existing facilities and infrastructure like roads, railways, navigational route and other farm projects
(v) Property conditions and data like, type and kind of title ownership, its relationship with

the community and other existing set conditions for project execution and community relationship

Geodetical Data

Topographic surveys to the scale of 1:500 to 1:5000 and with contour lines of 20-25 cm vertical spacing are needed for the entire fish farm area, in order to permit designing complete pond drainage and earthwork volume estimates of the required accuracy. On any existing earth structures (embankments, canals, etc.) cross sections should be taken at 50-100 m spacing, with points spaced sufficiently close to each other to plot the actual terrain with ± 20 cm accuracy on the cross sections of 1:100 scale. Cross sections should be plotted at the sites of major structures (intakes, road crossings, etc.) Cross sections at not more than 500 m intervals and continuous profiles are needed on the connecting stream or canal extending for the distance affected by the fish farm (e.g. to the backwater limit).The topographic survey should be connected, especially as regards elevations, to the national survey network.

Hydrology and Meteorological Data

Hydrological data will include information for discharge, yield, floods and water elevations of existing water sources (rivers, irrigation channels, reservoirs and springs) restriction periods for water supply to the fish farm (for example, periods of the maintenance works in the irrigation channel). Meteorological data should include mean monthly temperature, mean monthly rainfall, mean monthly evaporation, mean monthly humidity, mean monthly sunshine, mean monthly wind speed and direction.

Where water is obtained from a natural stream, data must be acquired on the stages and flow rates to be anticipated at the diversion point in the periods of pond filling and for compensation of water losses. Water supply should be designed for a flow rate of 80 percent probability. In the case of ponds through which floods must be conveyed, or the dikes which are required to retain floods on the stream, the designer will require also data on designed flood levels and discharges. The probability of occurrence of the design flood is normally specified by the competent water agency. In the absence of such specification, the flood of 1 percent probability of occurrence (once in a hundred years) should be adopted as the design flood. In the case of minor ponds, where a dam failure would cause no other losses, a flood of say 3 percent probability might be adopted as the design flood. The retention capacity of upstream ponds is taken into account in estimating the design flood. Data on the peak values of monthly evaporation and rainfall are needed for estimating the water demand. Data on the monthly average and extreme temperatures are needed for selecting the species of fish for farming, for planning the necessary feed supply rates and for designing the holding and storage facilities of live fishes. The annual volume of sediment entering the ponds should be estimated. Data are needed on the direction and highest speed of wind prevailing in the area in order to design wave protection.

Geotechnical Data

The geotechnical explorations should be extended to the entire area for the fish farm, to provide data on the soil stratification in the pond area, under the dikes, along the canal traces and at the sites of structures. The data obtained by soil explorations should be suited to estimate: (i) seepage losses, (ii) under seepage conditions and the hazard of piping failure, (iii) stability of the soil for the dikes, (iv) the required degree of compaction (v) the allowable flow velocity in the supply canals, and (vi) the foundation of the structures.

Water Quality Data

The water supplied to the fish ponds must not contain pollutants and toxic substances detrimental to fish life. The composition of the feed water should be subject to quality analysis, including the following: oxygen content, pH value, total salts content, ammonia content, free CO_2 content, phenols, oil and tar content. The water quality analyses should be such as to enable prediction of the interactions between the soil and the feed water as they sometimes determine the turbidity levels.

CHAPTER 13

PREPARATION OF THE PROJECT PLAN DOCUMENT

(FEASIBILITY REPORT)

When all considerations have been made and data is fully collected about the area for fish farm project, one should envisage the structure and operations of all the farm components and produce a plan document, also known as feasibility report but since this particular aspect contains more technical information, it is better described as the Aquaculture Engineer's Technical report. It should be noted that the layout of the farm is governed by the combined requirements of operation and the particular site conditions. Project preparation usually referred to as outline plan is usually considered to include all those activities that lead to a final decision for the project implementation. This process includes the following stages:

Outline plan

An outline plan is generally used as a basis for the approval and financing of a project, this should provide for the technical feasibility of the project. The production calculations concerned as well as the design should be in sufficient details so that a reliable cost estimate including both the annual operational and production cost can be established. The principal parts of the outline plan consist of the following;

(i) Report
This should contain the most important information on the project proposal including a description of the site, soil characteristics determined by the reconnaissance soil survey, source of water and the results of the water analysis, meteorological features used for planning, operation plan with the necessary production calculations. Planning considers arrangement of the layout plan for the ponds, the location of the hatchery and the other buildings with the approach road to the project, arrangement for water supply and drainage of the ponds and the hatchery, the pond facilities, abstract of costs for capital, operational and production costs, economic analysis for benefits, and the proposed construction programme. Additionally, all the statements obtained and required for approval and implementation of the project must be presented usually in a list of annexures to the report.

(ii) General location map; this is generally an unsealed map showing the location of the project.

(iii) Plane table map; This should have scale that range from 1:2000 to 1:5000 depending the size of the project and showing the boundary lines and the proposed size of the project, the locations of the soil test pits with their elevations, the rough contour lines and water source and drainage possibilities.

(iv) Outline layout plan; This plan may be to a scale of 1:1000 to 1:5000 should include the arrangements of the ponds, the water supply and drainage systems as well as the location of the hatchery and other buildings including the proposed approach road and the power and telephone lines. All structures should have their specific dimensions clearly shown.

(v) Outline cross-sections of dikes and channels; all the typical cross-sections of the dikes and channels showing their measurements and slopes required for the cost estimate must be provided.

(vi) List of proposed buildings and equipment; a list of the proposed buildings with their plinth areas and the equipment needed for running the project should be given for the cost estimate.

(vii) Soil test laboratory results of the samples taken from the test pits for engineering and production purposes should be provided in tables which are used for planning dykes, canals, weirs culverts and others.

(viii) Cost estimate; Estimates of basic (civil works) cost must be calculated using unit rates judged to be applicable for the region of the project site and major quantities of each item shall be calculated from the drawings in just sufficient detail to serve the needs for proper estimation. Building costs should be estimated on plinth area. Earthwork costs are based as far as possible on a balance between cutting and filling. Estimates of cost are given for electricity supply, engineering (design of detailed plan and supervision of construction), equipment, land procurement and physical contingencies. Lastly, the operational costs and the production cost are provided under separate headings.

(ix) Implementation schedule

Based on the results of the reconnaissance investigations and quantity calculations, a bar-chart for the various activities required to complete the detailed plans and tender documents to procure the materials for construction should be prepared.

Outline Plan Review

After having approved the outline plan of the project, a review should be made of all data available and, if this is insufficient, action should be taken to rectify the deficiency. Any modifications of the proposed operating schedule and related water management and water requirement calculations for both the fish ponds and the hatchery have to be completed prior to commencing detailed implementation.

Topographic survey

The topographic survey which has to be carried out at the site selected for a project should be based on a convenient datum marked with a temporary bench mark (TBM) at the site. There are several methods used for topographic surveys. Depending upon the nature and size of the

land required for the project, the following methods are the most commonly applied for topographic surveying;

(i) Gridding
(ii) Plane tabling
(iii) Cross-section method with traverse survey
(iv) Radiating lines method with traverse survey
(v) Tachometry

Methods (i) and (ii) are ideal on relatively flat land, while methods (iii) and (iv) may also be used but are best suited to hilly terrain or use in a narrow, long valley. Tachiometry can be used in either case. The field work in tachiometry is rapid compared with the other methods and it is widely used, therefore, for contouring of any types of areas. With reasonable precautions, the results obtained can be of the same order of accuracy as, or better than, those obtainable by other methods. The following topographic maps and plans are generally needed for *a* project:

(i) Index or location map
(ii) Boundary map
(iii) Contour map
(iv) Cross and longitudinal sections
(v) Land map

Basic Principles of Fish Farm Layout

After selecting a suitable site for a fish farm, one of the major challenges for the Aquaculture engineer is to provide a master plan for all structures usually called 'layout'. This is very important and must be produced in details because the consultant who selected the site and provided the site plan may not be part of the construction team, as this may be tendered for contract and a different person may undertake the construction. It should also be borne in mind that the physical features of the located land area as influenced by the atmospheric weather conditions governs the entire layout.

Major Fish farms consist of many ponds performing different functions in fish production. Their relative positions, as well as their connection to the water supply and drainage facilities, power supply and transport roads, in fact the general arrangement of the fish farm, has a major influence on the operating costs. In deciding on the general arrangement, the following should be considered:

(a). The farm centre, consisting of operating buildings and living quarters, should have good internal road access.

(b) The facilities requiring frequent attendance, such as the hatchery, rearing and nursery ponds, holding ponds, power supply and water pumping stations should be as near as possible to the centre.

(c) Separate filling and drainage possibilities should be provided, if possible, for each pond.

(d) Transport of feed from the grain storage to the ponds and of the fish harvested to the holding ponds should involve short hauling distances.

(e) The holding ponds should be close to the common external cropping pits serving several ponds.

(f) The farm feed mill and other vibrating/ noisy engines and gadgets should have considerable distances from nursery and rearing ponds to avoid unnecessary threats and shocks to the growing fish

(g) Security fence; Walled or screened fence for securing the farm is important to check for both human and other animal poachers but surface drainage from run offs (outside and inside the farm) and from the ponds should be properly guided but not blocked entirely, the entire drainage design should follow the natural drainage pattern of the physical environment of the farm.

The foregoing principles can be realized best by an arrangement in which the operating buildings, the holding ponds and the water control structures are in the vicinity of the geometrical centre of the area. Wherever the terrain conditions permit, this type of arrangement should be adopted. General access to the farm must first connect the central area and should be followed with restricted access to production areas of the farm.

Power House

Special note must be taken about the location of the power house in a fish farm because the vibrations from power plants are not fish friendly as it create shocking threats, accidental overflows of lubricants and spills from leaky fuel storage tanks (especially underground tanks that such leakages are not quickly and easily noticed) has to drain far away from production ponds. Also during establishment of fish farm with earthen ponds as major production units, the distance from already existing fuel filling stations and the possibilities of new ones coming up must be determined. The location of power house/generator house can be best located at the lower terrain on the farm, there is always a temptation of situating a power house close to a borehole as the two are likely to be operated by same staff but this has to be avoided since submersible pumps function with power supplied through wire cables so the only additional cost may be the wire cables.

Dimensioning and timing

All structures constructed on the farm are meant for specific operations and purposes, their shapes, sizes and arrangements are based on the purpose for which each of the structure will be used. Dimensions of structures especially fish holding facilities are structured to suit optimum carrying capacities, maintain or regulate temperatures, allow for sufficient oxygen dissolution, keep water densities in relation to fish size and age, allow for sufficient sunlight to create the euphotic zone (litoral zone where photosynthesis will take place and enhance plant growth with oxygen supply). The pond service parts like the dyke crests may be dimensioned according to the size of the intended walk ways (motorable or padestran), weirs and canals will suit the volume of water to be transported and discharged, outlets and inlets will determine specific filling and empting times. Housing apartments should adequately accommodate required equipment with doors and passages that allow for free movement for humans and other material freight within the farm. Heights of buildings and their roof pitches are very important considerations because farm houses are most at times isolated from the urban settlements and are more prone to windstorm devastation, so they require proper carpentry designs. Pond depths and the water freeboard are important considerations because pond carrying capacities are determined based on the volume of water in the pond and not the entire pond size so a very deep pond with excess freeboard is a wasteful excavation/construction. Spillways, culverts, walk bridges and aprons should really serve for flood and erosion controls and not just decorations. Walking or motorable distances between and within operational structures should be timed to maintain optimal oxygen requirements of fish out of water as it is easier to move fish without water during sorting and other activities, correctly calculated empting times for fish ponds and other fish holding facilities will enable the manager and other operators schedule their operational activities with ease.

CHAPTER 14

FISH FARMS CONSTRUCTION AND SIZE STANDARDS

Fish Farm Size

A fish farm could be so large that it may run into hundreds of hectares and can be smaller than an acre depending on the level of establishment and, this could be described as small holding farm, medium size and commercial large farm. The major distinguishing characteristics is that a large commercial fish farm will have to be complete with a hatchery, feed mill and processing/preservation units that will make for outputs in commercial quantities at all seasons.

In general, the fish farm is an establishment which is composed of pond system and support facilities. The pond system usually consists of various compartments with specific uses such as nursery or fry pond, transition or holding stunting pond, production or rearing ponds and other features (catching, de-silting food-growing ponds, etc.). Also, apart of the pond systems there are other water control structures like gates, pipes or culverts and water supply or drainage canals. Each of these units should be properly located and fitted in the system in order to have ease in water management and manipulation of cultured stock.

On the other hand, support facilities consists of farm buildings, farm roads and road dikes, bridges, fish tanks, storage shed (for feed and equipment), chilling tanks, and other ancillary structures. Efficient organization of support facilities in relation to the pond system is of paramount significance in the overall developmental planning and operation of the farm.

Fish farms should be located at convenient distance from major rivers or stream, depending on a particular country's environmental regulations the recommended buffer zones of at least 100 m from the sea to the main perimeter dike and 20 m along river banks is spared for ecological consideration as well as physical protection against flooding and wave action.

Pond shapes, depths and Sizes

One most frequently asked question by intending fish culturists and farmers is, 'what is the standard size of a fish pond?' and 'how many fish can be put in what size of a pond'. Also many people including some fisheries personnel would try to categorize farms according to the number of ponds within such farms. It is important to note that;

1. There is no specific standard size or shape for a fish pond, rather fish holding structures are categorized into tanks and ponds based on size (length x width x depth). Small fish holding structures with shallow depths are referred to as tanks while wider and deeper structures are referred to as ponds.
2. Standard pond size is a relative term because it is a relationship of the species water requirements and the dynamic factors of the water chemistry, physics and the biological interplays of the animals and plant activities within the pond because fish under culture vary according to species, age, size and behavior as well as the resultant effects of its interaction with the physical environment.
3. Fish pond sizes may be determined by;
    i. Interest /financial strength of the entrepreneur/ motivator
    ii. Available space and environmental factors
    iii. Farm size and the production target
    iv. Production system and the operational methods
    v. The culture system and species under culture

Naturally, fish survives and grows in any structure that hold water, so it can grow and do well in any artificial structure that holds water with all factors at optimal levels for its metabolic activities. Pond size, be it a homestead or fish farm may be established based on the interest of the motivator and may depend on financial element but could sometimes be limited by the available space or earth surface topography and soil profile. The farm size may require for the establishment of large production ponds along with smaller units while small holding farms may be characterized by small ponds and tanks. The production system like, varied pond depths for natural fish breeding, re-circulatory systems and the production target may determine maximum utilization of space such that ponds may be established in various sizes and shapes. The culture and management systems may also influence the sizes of ponds to be established as mono or poly-cultured ponds under extensive or intensive management may require variation in space for differential fish stocking density.

Dimensions of a fish pond structure are based on the volume of water it can hold at one particular time and the volume determines the strength and type/ level of reinforcement to be included. They are also based on the species, size, age and number of fish a structure can hold at a given time. For small holding structures like homestead ponds, the available space influence the size of fish pond structure but it should be noted that;

i. Too shallow small structures may not permit for optimum fish growth as the small water volume in the structure may be too hot or too cold for the fish depending on the prevailing weather conditions.

ii. Very high depths may not be conducive for small fish and other bottom dwelling species because the excessive water density will be stressful for them to swim from bottom to the top and may be too heavy for their body when at the bottom

iii. Moderate size ponds are easier to manage, especially concrete ponds that are serviced by borehole because it takes relatively shorter time to fill and empty and attaining a commensurate water level will be easier than in wide or larger ponds.

iv. Very large ponds demand for more hands with higher labor to operate them.

Dimensioning of Fish Farm Structures

Dimensions of structures are established using measurements and the universally acceptable International Units of measurements (SI units) are the Meter (m) for linear measurements, Liter (l) for liquid substances and Gram (gm) for the mass of solid substances. A fisheries Engineer or Technologist must be well aquinted and knowledgeable with the above three units to be able to determine or establish dimensions for the entire farm and its structures because any space created on a farm should be meant to accommodate either as holding or passage for solid structures or liquids and should be specified for such purpose. Rooms, doors, gates, roads/walkways, ponds/tanks, pipes (inlet and outlets) sluice gates, monks, canals, weirs and culverts are the very important structures that must be taken into consideration before dimensioning. It should be borne in mind that all engineered equipment, plant (stationary and mobile), automobiles, materials and tools have been designed and constructed to specifications so a good knowledge and ideas of such could be of advantage.

Fish Ponds and Tanks

As earlier explained, the two major differences between a pond and tank are their sizes and uses, while a pond is used for rearing and outgrowing, a tank may be for temporary holding in view of sales, quarantine, transfer and or treatments. Water holding spaces are usually calculated in volume. For example;

A pond area of 1cubic meter (like sugar cube) is equal to 100cm x 100cm x 100cm
(L x W x Depth)
will hold 1000 liters of water

A pond / tank size of 5x5x1m = 25^2 will translate to 25,000 cubic liters of water

A homestead fish pond constructed of concrete materials that measures 8 x 4 x1.3m will have a total area of 41. 6m^2 and has capacity for 41,600 cubic liters, lager ponds will hold more water. Water holding structures range from Hatchery troughs to fry rearing tanks/basins, fingerling nursery/rearing tanks and production ponds.

Although the food and Agricultural Organization (FAO) has specified measurements for the above mentioned structures, their establishment may depend on the magnitude of investment and the production targets. One factor that remains very important is that all structures must be designed to empty completely and their gravitational filling and empting times (in hours or days) should be clearly known. Fish ponds with shorter filling and empting times (hours) are much easier and better for routing management.

Pond Features

These includes; the walls or dykes, the inlet, outlet and pond bottom. Sometimes other structures like the apron, berm, internal drains and harvest pits may be included

Pond walls, this is the entire embankment that hold water for the stocked fish, the wall may be a continuous ring for circular ponds, walls may be joined to form rectangular, square or any other shape of pond. Plastic and other metals may be used to construct ponds but the walls that are suit for discussion in this text are the concrete and earthen.

Concretes walls

are composite man made materials that consists of rationally chosen mixture of bound material such as lime or cement, well graded fine and coarse aggregates, water and admixtures to produce concrete with special properties. In concrete mix, cement and water form a paste or matrix which in addition to filling the voids of the fine aggregates, coats the surface of fine and coarse aggregates and binds them together. Concretes are classified on the following basis; (i.) Based on cementing material, concretes are classified as lime concrete, gypsum concrete and cement concrete. (ii) Based on perspective specifications: the cement concrete is specified on proportions of different ingredients example 1 (cement):1.5 (fine aggregate) :3(coarse aggregate). It is presumed that by adhering to such perspective specifications satisfactory performance may be achieved. The usual mixed proportions of cements concretes are given in table …. Below

Mix Proportions of cement concrete

Grade of concrete	M10	M15	M20	M25
Mix proportion	1: 3: 6	1: 2: 4	$1:1^{1}/_{2}:3$	1:1:2
Perspective characteristics strength	10	15	20	25

After Duggal (2012)

In the table above M refers to the mix, this type of concrete mix is also known as nominal mix. Conventional nominal mix proportions have limited significance since the quantity of fine aggregate is fixed irrespective of the cement content, water cements ratio and the maximum size of aggregate to be used. Grade M15 and M20 are suitable for water holding structures, M25 should be used at reinforcement columns while M10 may serve for none submerged superstructures

Earthen walls (dykes)

are the walls that make up for the earthen ponds, depending on the size of farm and the ponds arrangement, dykes may serve as primary (serving for a single pond), secondary (dividing two ponds) and tertiary dykes in which all the four walls take water on all sides. As already stated in chapter 11, earthen ponds must be established where the soil texture permits water logging. That is the soil types that can retain water, clay and loamy soils are most suitable, adequate soil test may be required in some places but where water is adequately available and there are traces of flooding it may only require the control/ regulation of water flow to keep fish so, excavations may be to deepen the pond ditches in order to hold fish but whichever earth material that may be used, there will be need for proper engineering and construction. The pond dykes should be designed to;

(i) Withstand internal erosion by shaping to slope on both sides (in and out) and depending on the kind of operation envisaged, the tops (crest) should be wide enough for the purpose of the pond operations i. e. some crests may allow of vehicular passage for operational vans and articulated machines and may still accommodate water supply canals and weirs, for smaller farms, it may just provide for tricycles and wheel barrows to ease harvesting haulage and feeding.

(ii) Withstand back-cuttings by the pond water especially when it holds large fishes, this could be achieved by adequate compaction and gentle slope of the dyke gradients especially inside the pond.

(iii) Prevent underground seepage between ponds, this can be achieved by providing a core trench within the dyke using heavy clay soil material

Dyke Protection

The dykes require effective protection against the destroying effects of waves. Even the surfaces of earth structures not exposed directly to pond water may often require protection against rain and wind erosion, depending on the prevailing climatic conditions.

Wave Action

The length and height of wind generated waves depend on wind speed, the fetch length and the depth of water. Of the large number of empirical wave height formulae, the one suggested by Dyakova is

$$\mathbf{h} = 0.0186\ W^{0.71}\ B^{0.24}\ H^{0.54}$$

Where **h** is the wave height in meters, W the wind speed in m/sec, B the fetch length in km and H the water depth in meters.

Biological Protection

Biological protection consists of establishing a vegetation cover as a means of controlling both wave action and erosion, provided that such vegetation can be planted and grown under the particular conditions, and is compatible with the requirements of fish production (none toxic materials). Information on the plants potentially applicable and their biological requirements in any particular area should best be obtained at the site. Experts in Horticulture and landscaping could be consulted for best plants and planting methods but for effective wave action control, the reed belt should be 4 m wide for the first 1000 m length of fetch, and should be increased by 2 m for every subsequent 1000m increment of fetch length. The density of the stand should be at least, 70 reeds/m^2 and each reed should have a diameter of not less than 8 mm above the water level.

The wave control reed belt is planted on the reed berm of the dike over the surface on which the reed is to be planted a topsoil or humus cover of at least 20 cm thickness should be spread, in which the reed is planted either by seeding, as a soil root mixture or as root or shoot cuttings. Except for propagation as shoot cuttings, reed planting operations are confined to the winter hibernation interval. The shoots should be planted at the time when the fresh shoots have developed 7 to 8 leaves.

Whichever method of reed propagation is adopted, the water demand of the growing plants must be satisfied. Without the possibility of irrigation, the result of reed planting will be

questionable. In the first period of growth, up to the appearance of 3 to 4 leaves, the soil should be saturated, but a permanent water cover is definitely undesirable.

On the slope surfaces and dike crests exposed to rain and wind erosion, a sound grass cover is often the most economical method of control. For grass planting the surfaces should be covered by at least 10 cm of topsoil, but this can occasionally be replaced by manure and fertilizers. The grass cover is established on properly prepared surfaces most expediently by seeding. The desirable seed mixture should be determined with due consideration to the soil type and climatic conditions. The grass cover must be mowed regularly and in dry climates provision must be made also for irrigation. Where irrigation is impracticable, the costs of grass seeding will be wasted.

Wave Control Linings

Where no biological protection is possible, the earth structures exposed to wave action must be protected by other types of lining. Guidance to designing such linings can be found in the notes on soils engineering.

Other Common Methods of Dyke Protection

Some of these methods may be carried out during and after pond construction
During construction, the filling of earth should be done in layers not exceeding 20 cm in height and consolidate each layer by watering and ramming for manual construction.
The earth work for the dykes should be thoroughly compacted so that even minor seepage can be checked.
If the fish farmer is economically sound, he can go for stone pitched dykes.

- A typical embankment is built with an outside slope of 1:1 and an inside slope of 1:2.
- A slope of 1:2 means that for every increase in 2m width there is a change of 1 m in height.
- Once the embankment is constructed, it is better to plant grass on it.
- The grass roots help to hold the wall together and prevent erosion of the soil.

Roadways and access paths

These needs to be constructed in most farm systems, to allow for everyday operations, to move materials and to collect harvested stock. Depending on the soil characteristics, the road or pathways may need to be reinforced, either by simple piling with a suitable earth material

CHAPTER 15
SPECIAL FISH POND FEATURES

Inlet

An inlet is one feature of the pond that allows or transport water from the supply source into the fish pond that is always placed or constructed on top of the dyke. It could be open sluice, pipe or canal. The water source could be; spring, diversion from a stream or river, portable water from a public line or a farm service borehole and house roof collection. For spring fed fish ponds, inlet may not be necessary especially when the water supply quantity is adequate. The size of any inlet will determine the velocity of water flow within it and, depending on the pressure from the source of supply, the velocity will in turn determine the filling time for a particular water holding structure (pond). It is very important to know the maximum volume of water that an established pond could hold at a standing time and also to understand the filling and empting time in hours for ease of operations therefore, any inlet adopted for a particular pond should have its dimensions known so there are established formulas that are used in calculating water volumes based on the factors of inlet width, length, head loss, velocity and discharge. The table below shows the symbols, dimensions and units used in calculating water hydrology in artificial structures

Table…….

Symbol	Description	Dimensions	Units
A	Area	L^2	m^2
B	Surface width of a channel	L	M
B	Bottom width of a channel	L	M
D	Diameter	L	M
D	Depth	L	M
G	Acceleration due to the force of gravity	L/T^2	m/sec^2
H	Total head; head over a crest	L	M
H	Head or water depth	L	M
h_l	Head loss	L	M
K	Permeability coefficient	L/T	m/sec
L	Length	L	M
$\mathcal{L}$	Length	L	M
N	Meaning's roughness coefficient	$T/L^{1/3}$	$sec/m^{1/3}$
P_w	Wetted perimeter	L	M
P r----	Allowable pressure held for siphon	L	M
P r---	Pressure	L	M
Q	Discharge	L^3/T	m^3/sec
Q	Unit discharge	L^3/T	m^3/sec
R	Hydraulic radius	L	M
R	Radius	L	M
S	Drawdown	L	M
V	Volume	L^3	m^3
V	Average velocity	L/T	m/sec
W	Weight	F	Kg

W	Unit weight of water; width of a structure	F/L;^{3}L	kg/m^3; m
r-----	Density of water	F/L^3	kg/m^3

After FAO 1984

The flow of water in pond structures is influenced by so many factors therefore, for one to understand the equations for designing inlet and outlets it is important to understand the General formulas for water flow in artificial structure (pond and other structures) so as to be able to calculate and design precisely the size of inlet or outlet that will fill and discharge water from a given pond on record time

1. Design formula for surface channel flow using manning's formula (chow 1959)

$$V = \frac{c}{n} R^{2x3} S^{1x2} \text{ m/sec}$$

Where V= average velocity/sec

R= $\frac{A}{P}$ Hydraulic radius

A = cross sectional area of channel (m^2)

P_W = wetted perimeter of the channel (m)

S = slope of the channel

N = roughness coefficient

2. Design formulas for submerged discharges

For $Q = c \times a \times b \sqrt{2g\ x\ h}$, m^3/sec

Where; c = ∅.4 = discharge coefficient

a = opening height of the gate, m

b = width of gate, m

h = Ho – H_2 = HEAD, M

Ho = upstream energy level, m

H_2 = downstream water depth, m

g = 9.81, m/sec^2

3. Formula for discharges influenced by downstream is

Q retarded = K. Q, m^3/sec

Where k = coefficient

Q = for discharge, m/sec

4. **Design formula for inlets**

$$Q = H \times A \sqrt{2gH} \text{ M}^3\text{/sec.}$$

Where; Q = discharge of the inlets, m^3/sec.

H = discharge coefficient

A = internal cross sectional area of pipe, m^2

g = 9.81 = acceleration due to gravity

H = head of upstream water surface over the center of the pipe

The discharge coefficient depends on the angle face of the pipe and it range from

∅ 0. 10 to 30. This could be determined by the designer

Some inlets may be submerged and as such are influenced by the density of the external cover (sand or water).

So it will be

$$Q = C \times B \times H^{3x2} \text{ L/sec.}$$

Where Q= designed discharge of inlets, L/sec.
B= width of the throat, cm
H = height of the designed full supply level in the feeder channel above the size level of the inlets
C = discharge coefficient
Coefficient ranges are for open tune
Like 6 – 10 cm = 0.0160
10 – 15 cm = 0.0164
15 nd above = 0.0166

Outlets

An outlet is one of the pond features that allows for discharge of unwanted or waste water from the pond. It may appear simple but it is complicated to construct because of the following reasons;

(i) It must allow for complete drainage of water and so, has to be positioned at the lowest level of the pond bottom

(ii) Fish must be prevented from flowing out with water during discharge especially the young and small ones

(iv) It must not be attached to wall (dyke) to avoid tampering with walls during operations and in cases of repairs and so it must pass under the wall

(v) Discharged water must not be allowed to settle close or behind the pond wall to avoid wetting the surrounding soil which may soften and lead to cracking and total collapse of the affected wall even if it is concrete

(vi) It must technically hold and maintain the desired pond water level at all times

(vii) It must be to accessed and operated at any time

Different kinds of outlet have been employed in fish ponds and these include the monk, underground pipe with valve, open weir or spillway and ordinary hole with cover. For spring fed ponds, water is mostly removed or drained with pumping machines. The adaptation of any of them depends on choice and situation as well as available technology, very large ponds may demand for more sophisticated outlet systems like the monk. Generally a volume of water held in stationary position will accumulate very high kinetic energy that will tend put intense pressure on the holding walls and will discharge at very high velocity if an opening is created through the walls, and the portion of that wall where the opening is created will receive enormous pressure as the entire internal flow of water will be directed towards the opening. It is therefore important to give high consideration during the choice of outlet on

an intending pond dimension, based on the velocity theories many formulas have been obtained for designing outlets

Design formulas for outlets

There are two major types of outlets; the open outlet (sluice) and the pipe outlet, these are applicable based on the size and the volume to be accumulated by the pond, note that a monk system is based on pipe outlet. Formulas given for intake can also be used for outlet with variation in the velocity of flow. The insertion of the stop logs (valve, board etc) into the outlet creates over- shot flow conditions and the discharge formula (neglecting the approach velocity), for over- shot flow is:

5. $Q = 1.84\ B \times H^{3/2}$, m^3/sec

Where B = internal width of the outlet monk, m
H =head, the difference between the pond water level and the stoplog crest , m

Emptying time for ponds or tanks is:

6.0 $T = 0.75 \quad \frac{A_1}{B_2} \quad (\sqrt{H1} - \sqrt{H2})$, sec

Where T = emptying time in seconds
A_1 = average across - sectional area of the pond or tank, m^2
B_2= cross sectional of the outlet m^2
H_1 = water depth in the pond at the beginning, m
H_2 = water depth in the pond at the end, m

If the pond is completely emptied H_2 will be = 0

Design formulas for culvert discharges

(A). Submerged discharge formulas (inlets)

The formulas given for pipe intake can be used, but the following entrance friction coefficient should be used to calculate the discharge coefficient C.

Values of entrance friction coefficients for culverts flowing full is as follows

Entrance condition	K_e
Sharp edged projecting entrance	0.9
Flush entrance, square edge	0.5
Well rounded entrance	0.08

(B). Un-submerged discharge formula is

7.0 $Q = v \times A_c$, m^3/sec

Where; Q = design discharge of the culvert, m^3/sec
$v = \frac{1}{n} R^{2/3} S^{1/2}$ = average velocity, m/sec
A_C = actual flow area of the culvert , m^2
n = roughness coefficient for concrete pipe = 0.012 for congregated metal pipe = 0.024
$R = \frac{A_C}{P_W}$ Hydraulic radius , m
P_W= Wetted perimeter of the culvert
S = slope of the culvert

Entrance head $H = (1+K_e) \frac{1}{N^2} \times S \times R^{4/3} + d_c$, m

Where H = head on entrance above the bottom of the culvert, m
d_C = water depth in the culvert, m

To solve entrance head equation it is necessary to try different values of d_C and corresponding values of R until a value is found that satisfies the equations the equation. If the head on a culvert is high, a value of d_C less than the culvert diameter will not satisfy equation. This means the flow is under pressure and discharge can be calculated by submerged discharge formula

8.0 Design formula for vertical falls

8.1 Discharge formulas

a. Free discharge for vertical fall with a trapezoidal cross – sectional area

$Q_1 = 1.60 \times A \sqrt{Ho - H1}$, m^3/sec

Where Q1 = design discharge of the vertical fall m^3 /sec
A_1 = contracted cross – sectional area of the flow, m^2
$H_o = \frac{H + v_o^2}{2g}$ = upstream energy level, m
H = upstream water depth in the channel, m
V_O = approach velocity, m/sec
H_1 = contracted depth = 0.92h , m
hc = critical depth, m

The critical depth can be obtained from the formulas

b. submerged discharge

$Q_2 = 1.60 \times A \sqrt{Ho - hs}$, m^3/sec
A = cross - sectional area of the flow, m^2
$h_S = H_2 - p$, m
H_2 = downstream water depth, m
P_S = height of sill over – down stream bed level = $1.14h_c$

c. length and depth of the basin

the length of the basin is given by empirical formula

$Lb = 5 (H \times h)^{1/2}$, m

Where H = upstream water depth, m
h= head, difference in upstream and downstream water surface level, m

The depth of the basin is

$d_b = 0.17 (H \times h)^{1/2}$ m

9.0 Design formulas for spillways

Recommended design floods for the spillways

3.6.1. Types of spill ways

1. Side channel spillways
1.1 side earthen channel spillway
1.2 side lined channel spillways
2. over fall spillways
3. Shaft spillways
3.1 . Circular crest
3.2 3.2. Standard crest
3.3 3.3. Flat crest

4. Siphon spillway

In case of the failure of the dam would create danger to human life or would cause great property damage, Q_O %has to be used to design the spillway.

3.6.3 Discharge formula s

3.6.3.1 Side earthen channel

A. Discharge over the crest

$Q = 1.55 \times h^{3/2}$, m^3 /sec

L = overflow crest length , m

Where h = water depth above the crest , m

Q= design discharge, m^3/sec

B. velocity in the earthen channel

Using manning 's formula (2.1):

$v = \frac{1}{n} \times R^{2/3} \times S^{1/2}$,m/sec

To prevent erosion in the earthen channel the calculated velocity should be less than the securing velocity of the material concerned as shown in table 3.

C. length of crest protection

$l = 2.4 \frac{v}{} h$, m

Where v = velocity of the designed discharge , m/sec

v = scouring velocity, m/sec

h^S = water depth above the crest , m

3.6.3.2 Side lined channel spill way

The side channel has to be lined when the valley side has such great gradient that the calculated velocity in the side channel is higher than the scouring velocity concerned .

3.6.3.3 over fall spillway

a. discharge over the crest

$Q = 1.7 \times L \times h^{3/2}$ m^2/sec

Where L = overflow crest length, m

h= water depth above the crest , m

Q= designed discharge , m

b. design formula s for th3e glacis and the stilling basin critical depth is from Equation

$$h_C = \sqrt[3]{\frac{q}{g}}$$

where $q = \frac{Q}{L}$ = discharge per unit width , m^3/sec

The velocity of the flow at the toe of the spill way may be computed by

$V_1 = 3\sqrt{p}\cos(60-\phi)$

Where $p = \frac{2g(p+h-h) + v_c^2}{3}$

$\cos 3\phi = \frac{e}{\sqrt{p^3 +}}$

e= g x q

p = the crest height above the stilling basin

and $h_1 = \frac{q}{v_1}$

the head loss among the glacis can be determined by the formula

$h_O = \frac{Q^2}{A^2 \text{ x } 4/3}$ n x l , m

Where n= roughness coefficient, $sec/m^{1/3}$

l= length of the glacis, m

The subcritical conjugate depth is defined by the formula

$h_2 = \frac{h1}{2}\left[\sqrt{1 + 8(hc)3 - 1}\right]$, m

h_1

The depth of the stilling basin is:

$d_S = h_2 - h_3$, m

The length of the stilling basin can be calculated by the formula

$l_{sb} = 0.45\ v_1 \cos\alpha\sqrt{ds} + 0.5h_1 + 3\ h_2$, m

3.6.3.4 shaft spillways

a. discharge over the crest

1. circular crest

$Q = 2 \text{ x } C \text{ x } r \text{ x } m \text{ x} \P \text{ x} h^{3/2}$, m^3 sec

Where C_1 = discharge coefficient

r = radius of the circular

h = water depth above the crest , m

2. standard crest

$Q = 2 \text{ x } C2 \text{ x } r \text{ x} \P \text{ x} h^{3/2}$, m^3/sec

3. flat crest

$Q = 3.2 \text{ x } r \text{ x} \P \text{ x} h^{3/2}$, $m^3 sec$

3.6.3.5 siphon spillway

$Q = C \text{ x } A\sqrt{2g\ ,h}$ m^3/sec

Where C = discharge coefficient

A = cross – sectional area of the throat , m

h = head, m

value of the discharge coefficient is determined by the formula

$c = \frac{1}{\sqrt{1 + \lambda\frac{1}{d} + \pounds\ k}}$

where λ = friction factor =0.03 (concrete pipe)

l = length of the siphon, m

d= diameter of the siphon, m

∑k = all local loss coefficient

In order to determine the approximate size if the siphon, the value of C can be considered as follows:

3.7. Design formula for siphons

3.7.1. Types of siphons

Diameter length discharge

	(mm)	(m)	(m^3/sec)
a. small mobile	25 – 120	<5	0.0000 – 0.015
b. medium, moveable	120 – 200	< 10	0.15 – 0.050
c. large, stabile	200 – 1200	< 100	0.050 – 3.10

3.7.2. Discharge of siphon

Calculating formulas

$$Q = C\,A\,\sqrt{2g\,H}\ ,\ M^3\ sec$$

Where C = discharge coefficient

A = cross – sectional area of the pipe , m^2

H = head , m

The discharge coefficient C can be calculated by the formula

$$C = \frac{1}{\sqrt{1 + \lambda\frac{l}{d} + \sum k}}$$

Where λ = friction factor =0.02 (steel pipe)

l = length of the siphon, m

d= diameter of the siphon, m

$\sum k$ = all local loss coefficients along the siphon

The allowable pressure head for siphon will be

$$\frac{p}{\lambda} = 0.9\,\frac{P_O}{\lambda} - \frac{P_V}{\lambda} - 1.0,\ m$$

Where

$\frac{P_O}{\lambda}$ = atmospheric pressure head at the location, m

Altitude in m	0	500	1000	1500	2000	3000
$\frac{P_O}{\lambda}$ in m	10.3	9.8	9.2	8.6	8.1	7.2

$\frac{P}{\lambda}$ = Vapour pressure of the water

Water temperature

^OC	10	20	30
$\frac{P_V}{\lambda}$ in m	0.123	0.24	0.43

The allowable section head of the siphon is:

$$H_S < \frac{P}{\lambda} - \frac{V^2}{2g} \sum h_{e\,1} \quad (3.37)$$

Where V = velocity in the pipe, m/sec

$\sum h_{12}$ = all the upstream head losses along the pipe, m

The maximum allowable downstream head of the siphon is:

$$H_T < \frac{P}{\lambda} \quad \frac{V^2}{2g} \sum h_{12} \quad (3.37)$$

where $\sum h_{12}$ = all the downstream head losses along the pipe , m

Depth of water above the entrance of the siphon

a. entrance with vertical axis

v (M/sec)	D (m)		h_O (m)
1.5	0.1 – 0.3	1D, but min .	o.3
1.5 – 2.5	0.3 – 2.5	1D	0.7
> 2.5	> 1.0	1.7 D	2.0

b. entrance with horizontal axis

$$h_O = 1.3 \left[\frac{v^2}{2g} + \frac{v\left(1+\sqrt{k_e}\right)^2}{2g}\right] \quad (3.38)$$

Where k_e = entrance loss coefficient

c. entrance with inclined axis

$$h_O = 1.3 \left[v2 + \frac{v\left(1+\sqrt{k_e}\right)^2}{2g}\right] + 2 d \sin \alpha \quad (3.39)$$

Where α = angle of the tilt in deg

The Monk

Monk is the major outlet in fish pond construction because the outlet pipe (s) is laid at the bottom and the protective base with a suspended internally grooved wall which supports the sluice boards is raised above the water level (same height with the dykes) and the pond water could be maintained at any desired level. One major advantage it has is that water can be removed from the pond without the operator touching the water, this is easily achieved by providing a simple walk bridge from the dyke to the top of the monk with a single strong plank.

Ideally, monks should be built in the early stages of the pond's construction, and set on a secure foundation so that the structure does not move. Critical design and construction aspects include attaching the exit pipe securely to the monk box, securing the pipe well through the pond bund, and preventing seepage around the pipe. In addition, the base of the pond around the monk and the sides of the bund may need to be strengthened with cobble or a light concrete cover or wooden piling, to protect them from erosion caused by water flow or harvesting activities. The foundations of the monk are typically at least 0.3 to 0.5 m wider than the monk area, usually made of lightly reinforced concrete on a bed of graded rock, or on simple wooden piles.

To control seepage and avoid possible local erosion, metal or concrete anti-seep collars should be firmly placed along the pipes, perpendicular to the line of the pipe (Fig. 8.18).

These should be at least 0.05 m wider than the pipe but preferably at least 50% greater than the pipe diameter, and more if the pond soils are loose and easily eroded. As the bund is built up around the pipe, soils should be well compacted around the collars and along the pipes. Once the whole pipe is covered, the rest of the bund may be built up, though care has to be taken in using machinery over the pipe area. Alternatively, the bund may be constructed normally, and then cut through to provide the route for the pipe. After placing the pipe, the soil removed from the bund should be replaced and well compacted. The success of this method depends on the type of soil and the care in construction.

Sluice gate structures built through the lower pond bund can also be used for drainage. These are much larger and more expensive than monks for an equivalent size, and so are less commonly used. However, for very large ponds which require a substantial drainage flow, they may be a practical solution, as large monks with very large pipes, or multiple pipes may be just as expensive. Sluices are also far more accessible for cleaning and repair.

For smaller ponds, a pipe outflow may be used to drain water. In its basic form, this is simply a pipe (typically 0.060.15 m diameter) run from the interior base of the pond, through the lower pond bund, with a cap or valve at the outer end.

As with the monk drain, the pipe should be fitted with one or more collars to restrict seepage. A common variant uses a 90 degree angle fitting on the outside, holding a vertical pipe extending up to the maximum intended level of the water inside the pond. This 'swinging arm' pipe can then be swivelled down to the required level, or dropped down completely to drain the pond. Both these systems need careful protection against leakage or accidental damage. Additional protection can be provided by connecting a vertical pipe on the inside of the pond. Sometimes, particularly for small ponds, outlet structures may not be used at all; in these cases either a small pump with a simple net screen is set up with its intake at a suitable drainage point, or the outer bund is simply cut through to let the pond drain down.

Where conventional outlets are used, a discharge channel takes the water to a level below the ponds. Immediately below the discharge pipe a brick, concrete or timber frame and board box can be constructed

to buffer the water impact force and prevent erosion in the discharge channel. In fish ponds, similar boxes may be placed inside the pond to collect fish during total harvesting (Bard et al. 1974; Huet 1986). However, placing these boxes outside the pond is better for freshwater prawn harvesting. Such boxes are typically 1.0-2.0 m wide x 1.53.0 m long, depending on the

size of the pond and the quantity of harvest stock to be held. The discharge channel, usually dug into the site soils, would normally be set at a 0.1 to 0.5% slope (i.e. 0.1-0.5 m per 100 m) along its length. Topographic study (section 8.1.2) should indicate the best route for waste disposal, commonly downstream of the water supply. Channels dug in open soil need constant maintenance to de-silt, remove vegetation and repair surface erosion. Underground pipes can also be used, if dimensioned according to the maximum system discharge, though provision should be made for access to flush out or scrape clean the pipe interior. Pipes of these dimensions, typically 1 m in diameter or more, can be expensive.

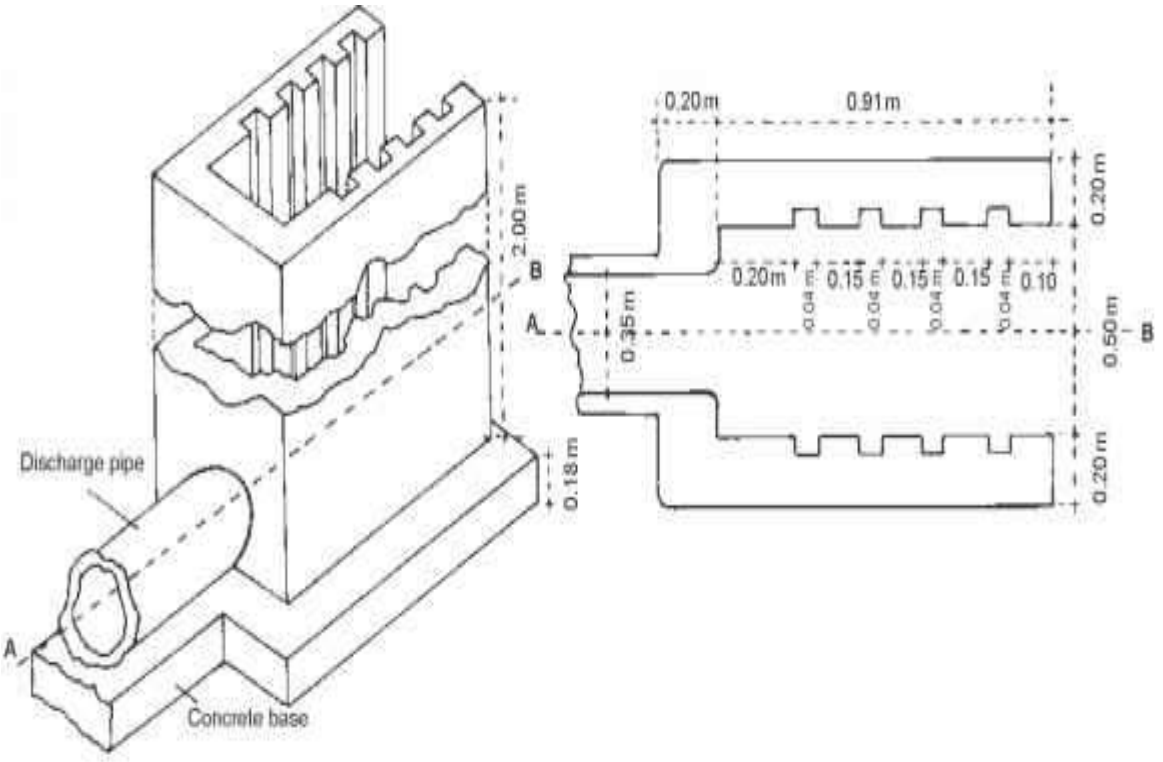


Fig. 8.17 Discharge pipe on concrete base.

CHAPTER 16
SERVICE STRUCTURES AND FEATURES IN FISH FARMS

A number of other technical features may be incorporated in a farm to support the pond systems, these may be for the production of other live foods for the fish, depending on the management approach, the intensity of production and local environmental conditions. Some of the more common elements may include;

Waste treatment

In some cases enriched water and waste solids may need to be treated to prevent adverse effects on receiving waters, or to permit some or all of the pond water to be reused at various stages, pumped back for the same ponds or drained into other systems downstream. Solids removal is the main form of treatment, usually based on sedimentation, in settling ponds.

Aeration

Aerators may be used to increase oxygen levels, and algal growth in the settling ponds may help to remove nutrients. Power supplies where aerators are to be used, electrically driven pumps operated, overhead lighting installed, or for various items of field equipment, a power supply network may be required. Cables may be laid below surface, with suitable protection, or run overhead using power lines, ensuring that they are not at risk from damage. Live cables dropping into water can be extremely dangerous, and external lines should be protected if possible with an earth leakage circuit breaker. Sockets should be of suitable external rating, or else placed in secure, waterproof housings.

Roadways and access paths

These need to be constructed in most farm systems, to allow for everyday operations, to move materials and to collect harvested stock. Depending on the soil characteristics, the road or pathways may need to be reinforced, either with simple piling, with a suitable depth of stones and cobbles or, in some cases, using a light concrete surface or a brick-lined road bed. Suitable drainage ditches will be needed to allow water to drain from the road surfaces. Simple bridges and culverts may also need to be constructed.

Feeder Canals

The feeder, or supply canals carry water from the intake to the individual ponds, and may be used occasionally as waterways for ferries. The feeder canals should be dimensioned to allow the various types of ponds to be filled within specific given time as estimated based water velocity and width of the canal

The longitudinal profile of the feeder canal should be designed to ensure a canal water level at least 0.1 m higher than the normal water level at the intakes to the individual ponds. In estimating the water level in the feeder canal, the backwater caused by the structures should normally be taken into consideration. Depending on the seepage losses anticipated from the feeder canal, some kind of lining, or other method of seepage control, may be necessary. The feeder canals are made with trapezoidal, or mixed, cross-sections. The bottom width and water depth are found from the hydraulic calculations. The dykes housing the feeder canals should have at least 2.0 m wide crests. The slope inclinations depend, just as in the case of the pond dikes, on the quality of soils, but should not be steeper than 1:1.5. The safety freeboard along the feeder canals should normally be 0.5 m, but can be reduced sometimes to 0.3 m over the terminal sections.

Drainage canals

The drainage canals serve to convey the water from the ponds to the recipient stream when the ponds are drained. The lowest water level in the canal at the outlet of the drain sluices should be at least 20 cm deeper than the lowest bottom elevation in the pond, or than the bottom of the harvesting pit. Where this is impossible to achieve, pumps should be considered to ensure complete drainage of the pond. The conveying capacity of the drainage canals should be estimated starting from the drainage times and periods mentioned for the various types of pond.

Drain Ditches

These ditches serve to drain any seepage from the ponds and the feeder canals, and the external runoff that is prevented by the pond dikes from draining towards the recipient stream and, thus, to protect the surrounding areas against the potential damages caused by such waters. The bottom of the ditch should nowhere be less than 0.3 m below the terrain level and the water should not be allowed to overflow, even when carrying the design discharge.

The drain ditch follows largely the trace of the extreme dike. The distance from the dyke depends on the soil conditions and stratification. The distance between the outer toe of the dyke slope and the edge of the drain ditch should not be less than 2.0 m.

Internal Pond Drains

The water from undrained depressions within the pond area is conveyed to the outlet sluice, from where the fish are carried to the cropping pit. The slope of these drains should be

steeper than 0.1 percent, while they should be cut deeper than 0.2 m. The minimal bottom width desirable is 3.0 m and the sides should be sloped at 1:3, or flatter. The earth excavated from these drains might possibly be used for constructing the dikes or for filling any depressions. Any material that cannot be used for such purposes should be deposited at a distance of not less than 5 m from the drain, so as not to interfere with draining the pond, and to prevent it from sliding back into the drains.

Spillways

Spillways are essential components for the safe operation of fish ponds formed by valley closure. These serve to pass the floods arriving at the ponds without damage, while preventing the water level in the ponds from sinking below the normal operating elevation and the fish from escaping from the pond system.

The spillways should be dimensioned to pass the design flood without damage. The structure must be capable of passing at least the 10 percent probability flood without any human interference. At higher flood discharges human control may be necessary at the closing mechanisms of the structure. A wide variety of spillway designs have been developed, of which a few simple types will be described.

Simple unlined spillways are earth canals arranged at the junction of the dam and the valley side and having a sill level corresponding to the normal operating water level in the pond. Normally, no fish screen is provided. For stabilizing the sill, a recessed beam of concrete or hand-placed rock may be advisable. The depth of flow over the spillway, or the highest allowable flow velocity must be determined with due regard to the local soil conditions so as to prevent scouring. The surface of the spillway may be protected against scouring by a grass cover, reinforced if necessary by rows of buried brushwork or hand-placed stone ribs.

Improved unlined spillways are similar in design to the foregoing but with fish screens between piers and lined for some distance upstream and downstream of the screen. The piers have cantilevers at the top, on which a service walkway is supported to permit cleaning the screen.

Reinforced concrete spillways with recessed sill have the sill elevation below the normal operating water level in the pond, which is maintained by means of stop-logs. The fish are prevented from escaping by a fish screen. To pass major floods, the stop-logs must be lifted clear of the water. For ease of handling the stop-logs, the spans between the piers should not be longer than 1.5 m. The sill should not be lower than 0.6 m below the normal pond level. The piers should carry a walkway or a footbridge.

Drop shaft spillways are normally combined with the outlet sluice. Where the subsoil offers good foundation conditions, such structures are capable of passing safely minor flood discharges. Behind the shaft of the monk sluice a drop shaft having a crest elevation at the normal pond level is also provided. The flood discharge is carried by the pipe of the sluice, so

that the pipe must be dimensioned for the design flood flow. At the downstream end of the pipe, an energy dissipator is needed. Cleaning of the fish screen around the crest of the drop shaft can be accomplished from the access bridge of the structure.

Fish Control Structures

At valley-dam fish ponds supplied by a perennial stream, measures must be taken to prevent fish from escaping from the upstream pond. A fish screen or electrical fish deterrent are possible solutions. The fish screen should extend at least up to the level if the 10 percent flood. The screen must be cleaned at the time of floods, so that a working platform must be provided for the operator. The mesh width of the screen or the spacing of the rack bars depend on the size of fish kept in the pond. In production ponds a bar spacing of 2 cm is sufficient.

Landscaping and site finishing

At the end of the pond construction stage, grass should be planted on the bund free-board slopes and crests to avoid erosion. Pieces of turf are preferable to seeding, and can be transplanted from other areas in the farm or from neighbouring areas. The topsoil, which was scraped and set aside before pond construction, can be used as soil cover where grass is to be planted. Other areas of the site may need to be moved and shaped to redistribute surplus soils, to improve site drainage, prevent erosion, ensure effective lines of sight for security purposes or improve the visual quality of the site. In some cases, the planting of shrubs and trees may be required for visual protection or shelter. Fencing and erection of windbreaks may be required for site security purposes. Finally, the site should be cleared up and made safe and secure

CHAPTER 17

MAKESHIFT PONDS AND OTHER CULTURE FACILITIES

Generally, there are many objectives of culturing fish and these may include;

(i) Economic gains i. e. commercial production

(ii) For ritual purposes

(iii) For aesthetic appeal

(iv) For game and recreational activities

(v) For research and academic studies

Depending on the purpose and scale of production many other artificial structures in addition to the pond are now used in culturing fish either as indoor or outdoor culture systems. The systems design and construction methods differ from one another as well as their operations and maintenance. This book will highlight them with their basic engineering concepts but reference shall be made to specific texts that treat or deal with them in more details

Aquariums

An **aquarium** (plural: *aquariums* or *aquaria*) is a vivarium of any size having at least one transparent side in which aquatic plants or animals are kept and displayed fish keepers use aquaria to keep fish, invertebrates, amphibians, aquatic reptiles such as turtles, and aquatic plants. An aquarium is a water-filled tank in which fish swim about. Small aquariums are kept in the home by hobbyists. There are larger public aquariums in many zoological gardens for tourist attraction. This kind of aquarium is a building with fish and other aquatic animals in large tanks. A large aquarium may have otters, turtles, dolphins, and other sea animals. Most aquarium tanks also have plants. Aquarium is typically constructed of glass or high-strength acrylic in various shapes. Concrete can also be used to build aquarium but the basic element for it is for one side to be transparent and permits for visual display.

Aquarium design Materials; Rectangular tanks are most satisfactory as they are less complex to construct and maintain so their development in recent years has taken many forms. The frame is usually of angle iron to provide the necessary strength and rigidity, although the smaller tanks can safely use pressed steel.

The common materials used for aquarium construction include; I super structure materials like cement bricks, transparent glass, cement sealant, wood, plastic or steel covers. Silicon gum is mostly used to join material when cement is not involved. Glasses are produced in varying thickness measured in millimeters (3mm, 4mm,5mm and 10mm) the choice thickness depend on the size and volume of water plus the organism it may hold.

Aquarium equipment

Composts; Aquarium compost is the gravel at the bottom of the tank in which plants can be grown. This is comprised of mixed gravel usually fairly light in color with varying size according individual choice.

Lighting; Lighting delays fishes to grow and to a best advantage it helps plant growth. Most aquarists prefer to provide artificial lighting that they can regulate rather than relying on daylight or ordinary room lighting. In any case, room lighting is useless for lighting an aquarium and a tank placed in strong sunlight will encourage algal growth, turning the water green.

Thermometers

The temperature of aquarium water is very important especially for tropical fishes. Too low a temperature makes fishes sluggish and more susceptible to disease but too high temperature decreases the oxygen content of water and the fishes will rise to the surface, gasping for air. It is important to use thermometer to tell if a large change temperature has occurred, so its always advisable to have a thermometer available.

Heaters

To maintain the required temperature in aquarium some of the heating is necessary.

Thermostats

It is necessary to control the temperature of the water within a range of 19 – 32 ^{0}C, depending upon the species of fishes concerned. Aquarium thermostats are operated by contraction and expansion of a bimetallic strip at the end of which they are electric contacts.

The manufacturer's instructions should be followed closely both in the wiring up and use of these thermostats. The temperature of any tank will always fluctuate a few degrees around the point set by the thermostats. This is a good thing as slightly varying temperature is better for the fishes than an exactly constant one. In their natural environmentally tropical fishes are subjected to diurnal variations.

Air pumps

Air pumps are used in the aquarium for two purposes: to force air into the tank and to work filtration systems. Aeration consists of forcing air by means of the pump through a small porous atone. (Diffuser). The stream of small bobbles formed agitates the surface of the tank allowing better exchange of carbon dioxide and oxygen. In a properly kept tank, not overstocked with fishes, there is usually no need for aeration.

In filtration systems the pomp pushes water through a filter which is either inside or outside the tank. The filter contains a filtration medium of charcoals, peat, nylon, wool plastic foam, etc, and particles passing through the medium are filtered off, keeping the water clear and freely circulating.

The dimensions of the aquarium have an important bearing on the number and health of the fishes it contains. During life like all animals fishes take in oxygen (0_2) and give out carbon dioxide (CO_2). This process is called respiration. Dissolved oxygen is extracted from the water, and carbon dioxide a waste products from the fish, is released from the fish and finally escape into the air. The amount of oxygen never becomes critical except under very unusual circumstances, but a high level of carbon dioxide can become poisonous to the fishes. This may happen when they are too many in the quota of carbon dioxide. As this cannot escape quickly enough it accumulates in the eater eventually killing the fishes.

Cage Culture

Fish can be cultured in cages. A cage or net pen is a system that confines the fish or shellfish in a mesh enclosure. By strict definition, a cage and a net pen differ based on their construction. A cage has a completely rigid frame (on all sides) and a net pen has a rigid frame only around the top. However, the terms “cage” and “net pen” are often used interchangeably. Marine cages are often called net pens, even though they have completely rigid frames, and vice versa. Structural differences have little effect on production practices or the environmental impact of these systems. Cage culture uses existing water resources (ponds, rivers, estuaries, open ocean, etc.) but confines the fish inside some type of mesh enclosure. The mesh retains the fish, making it easier to feed, observe and harvest them. The mesh also allows the water to pass freely between the fish and surrounding water resource, thus maintaining good water quality and removing wastes. Wood, steel and plastic materials are used in used in constructing cage frames which may be fitted with netting materials made of nylon, other fibres and alluminium. Floatation materials may be added to help suspend the

cage for very deep waters, sizes and designs depends on individual choice but all materials used must be nontoxic in water.

Recirculatory system

Recirculatory system is simply the recycling of used water in a production system.
Some of the reasons for recycling may be to.

i. Conserve and use water effectively in area of scarcity.
ii. To maximize the use of available space by deliberately overstocking ponds but ensuring that enough oxygen and fresh water is automated to create a logic condition.
iii. Water may be conditioned to a particular temperature depending on the prevailing whether factors to suit the optimum level for the cultured species.
iv. Used or waste waters may be factored and sediment collected for use as manual for plant cultivation.

There are two types of water recirculatory system: the simple and complex recirculatory system, the two systems differs based on their single pass system. In the former, the water flow rate,

The term "Recirculatory System" or "recycling system" is used for that type of cultivation unit in which the outflow of the rearing tanks or ponds partially or completely recirculated to them. Some other terms like "reconditioning system" and "reuse system" are also used to describe the same system.
There two general types of water recirculation system in fish production: the simple circulation system and the complex recirculation system. These systems differ from their single pass systems that is shown in figure 1a

Figure…….

where Q represent water flow rate require ensuring proper oxygen water supply for the rearing unit. And where Q= 1.0 is the flow rate that is required for a given population (w) in the rearing unit.
A simple recirculation system is one where the water supply for that system is needed to support a certain animal population is decreased by employing aeration and/or water treatment. Sometimes there is no treatment in this system at all.
In the complex recirculation system a high reduction in water supply can be achieved by employing a water treatment unit. Which besides employing re – aeration and mechanical

filtration, at least one biological treatment is used. In recently developed complex recirculatory systems, more internal by – pass water cycles can be found. These systems usually are semi closed or quasi closed system. The term closed system is used when the water is supplied only for filling and to replace evaporation. A common aquarium with a bottom sand – filter may be described as a closed system.

Designs for Recirculation Systems

Design for oxygen supply; in designing the oxygen supply, maintenance of the required oxygen concentration in the fish tanks and replacement of the consumed oxygen should be taken into account.

Assuming stabilized conditions, the balanced equation on oxygen concentration is as follows.

$$QC_{AO} - K_La\ (C_S - C_A)\ (C_{Aout} - C_A)\ Q_r - m_Aw = 0$$

Where; Q= supplemental water or make – up water (m^3/d)

Q_r = recycle water (m^3/d)

C_{AO} = oxygen concentration of inflow water (g/m^3)

C_A = oxygen concentration of the water in the fish tanks (g/m^3)

Presuming perfect mixing, this is equal to the oxygen concentration of the outflow water

C_{Aout} = oxygen concentration of water out flowing from the aerator placed in the recycled water.(g/m^3)

C_S = saturation oxygen concentration (g/m^3)

K_La = oxygen transfer coefficient of the aerator placed in the fish tank d

V = useful water volume of the fish tanks (m^3)

Design for Ammonia Removal; in designing ammonia removal, two main considerations should be taken into account:

i. The concentration if toxic nitrogen should not exceed lethal levels and
ii. The toxic nitrogen compounds should be removed or transformed to non – or less toxic materials. To accomplish these ends, a biological purification system which transforms the toxic nitrogen compounds to non – toxic forms should be installed into the recycling system.

Ammonia and organic nitrogen compounds are excreted by the fish in the process of metabolism. The nitrogen compounds are transformed into ammonia by herterophic micro organisms. Ammonia in turn is oxidized into nitrite and then to nitrate by nitrifying bacterial. Ammonia in its un – ionized form is highly toxic to fish. The biological filer installed therefore would provide sufficient surface area to allow for attachment of adequate quantities of nitrifying bacterial needed to convert ammonia into non – toxic or less toxic nitrogen compounds.

A part of ammonia excreted through the gills of fish and originating from the decomposition of an organic compound in water is transformed to ionized form as follows:

$$NH_3 \quad \rightleftarrows \quad NH_3 + NH_4 +$$

The ratio $$\frac{f = (NH_3 - N)}{(NH_3 - N) + (NH_4 \pm N)}$$

Depending on the temperature (^0C) and the pH value

If the allowable concentration of non – ionized ammonia (NH - N) is known, and the ratio f as found in the tables applied. The allowable total ammonia (NH_3 – N + $NH_4 \pm$ N) concentration (c_B) can be determined by the following equation:

$$CB = \frac{^{C}NH_3 - N}{f}$$

The designs for ammonia removal in recirculation is similar to that of oxygen supply, theoretical scheme has shown that under stable conditions, the following equation can derived:

$$CB_OQ - {}^{C}B^{Q} - C_{bout}t - C_B Q_r + m_A w = 0$$

Where: C_{BO} = total concentration of ammonia – nitrogen of the inflow water (g/m^3)

C_B = total concentration of ammonia – nitrogen of the water in the fish tanks (g/m3)

C_{Bout} = total ammonia – nitrogen concentration out flowing from the biological filter (g/m3)

m_B = specific ammonia – nitrogen excretion of fish per unit if time (g/kg/d).

Coefficient (2) and (8) can also be applied here, and the following can be introduced:

i. Efficiency of biological purification system (X_B)

$$XB = \frac{C_B - C_{bout}}{CB}$$

ii. Figure characterizing the ammonia contents of the inflow water (X_{BO}):

$$X_{BO} = \frac{C_B - C_{bout}}{CB}$$

Design of complex recirculation systems

The term “complex recirculation system “is used for that type of cultivation unit, in which a biological filter and an aerator are both installed. When the ammonia removal is desired equation

When oxygen is supplied, the quantity of oxygen needed for oxidation of ammonia to nitrite, then to nitrate, in the biological filter can be determined, using the following equation:

$$a\, Q_r C_B x_B = (C_{about} - CA)\, Qr$$

Where

a = the quantity of oxygen needed for oxidation of a unit quantity of NM3 – N to no3 – n. its value is 4.0….. 4.6.

While biological filters can be considered as aerators the efficiency of aeration can be calculated using the following equation:

$$x_{Al} = \frac{^{C}Aout - C_A}{^{C}S - {}^{C}A} = -\frac{a^{C}B^{X}B}{D}$$

Their efficiency, is negative, thus the negative sign showing oxygen consumption. Positive efficiency on the other hand is provided by aerators.

The resultant efficiency (x^A) of these aerators can be calculated by the following formulas:

$$x_A = x_{Al}\, x_{A2} + x_{A2}$$

Where

x_{Al} = efficiency of the biological filter as an aerator

x_{A2} = efficiency of aerator placed in the recirculation unit

To illustrate the above, determination of the different values are given below:

Basic data:

Temperature of flow and rearing water $\theta = 20^{O}C$

Concentration of hydrogen ions pH= 8

Saturation 0_2 concentration at $0 = 20^{O}C$ from a table

$Cs = 9.0 g/m^3$

Ratio of nitrogen forms at $0 = 20^{0}c$ and at PH = 8 (from a table)

$F = 0.04$

Required oxygen concentration in the fish tanks

$c_A = 4.0\ g/m^3$

Oxygen concentration in the flow water $C_{AO} = 8 g/m^3$

Allowable free ammonia concentration in the fish tank in ammonia nitrogen ($C_{NH3 - N}$) = $0.05 g/m^3$

Free ammonia concentration in the inflow water

$(CNH3 - N)\ 0 = 0.005\ g/m^3$

Specific ammonia excretion of fish $m_B = 1.125$ g/kg/d

Specific oxygen consumption of fish $m_A = 12$ g/kg /d

Colaspsible Tarpaulin Tanks for Culturing Fish

Tarpaulin is a piece of material which has been designed or treated to be water proof or water resistant. It may also be a large sheet made of heavy water proof material and is used to cover things to keep moisture or rain off. The flexible tanks made from these fabrics are foldable and can be transported even by a bicycle. The fabric tank is filled and stays up when the water is filled and collapses on draining the water. It is easy to shape it into any form to allow for maximum utilization of space which permits for homestead fish production. Tarpualin is made of chemicals like; polyethylene terephthalate (PET), cutin or plant cuticles through

polymerization such as polycarbonate and polybutrate. Depending on their chemical structures, polyesters may be thermoplastic or thermoset. Industrial polyester fibers, yarns and ropes are also used in tyre reinforcements, fibers for conveyor belts, safety belts, coated fabrics and plastic reinforcements with high energy absorption. All fibres and plastics are affected by continued exposure to higher temperatures and water immersion.

Hatchery Units

Race Ways

Steel metal/fibre tanks

CHAPTER 18
FISH STOCKING, MANIPULATIONS AND FEEDING

Pond Carrying Capacities

The carrying capacity of a fish holding facility (pond/tank) refers to the total biomass of fish (number, size and weight) the facility can conveniently hold at a time, this means that each single fish will have adequate space, enough oxygen and every other factor that will be at optimal for its continued growth during the rearing period.

Also during consideration of the number of fish to be put in a pond facility, calculation should be based only on the area of the facility covered by water and not the free board space. It should be noted that in human beings, people who do physical exercise keep fit and the younger that always do physical plays grow faster and stronger.

Fish also require free movement and exercise to grow faster and stronger so during fish stocking, enough space should be provided for the fish to move freely both vertically and horizontally and at considerable distances.

Many authors have provided fixed stocking densities for the growing fish, this may not be acceptable in all situations since it varies with an increase in size and weight, however a yardstick must be used in deciding how many fish that will be stocked in a given space but the following considerations must be made before a final decision for a particular stocking density should be adopted

(i) Farmer with single tank /pond and the one with alternative ponds.
(ii) Species of fish under consideration and whether, it is poly or mono culture system
(iii) Kind of facility; metal , plastic, glass, concrete, or earthen
(iv) Water supply and the routine management regime
(v) Culture and feeding system.

The above factors are important because a fish rearer with only one pond may not have the opportunity to sort and separate faster growing fishes so the space in the facility will keep reducing as the fishes grow bigger. Some species may attain maximum growth at small size that is less than 1000gm (1kg) while others can grow to 30kg/single fish. In a poly-cultured system that one species may serve as food for the other, priority may be given to the predator since it will be the economic return target

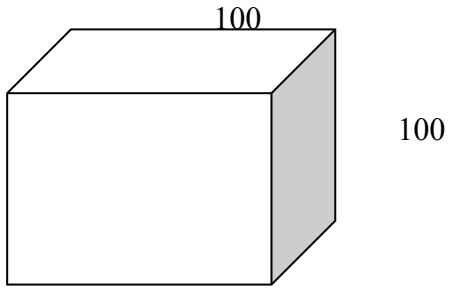
Biological decomposition and other anaerobic factors take place in earthen ponds with peculiar bacterial degradation but, minimum of it take place in concrete ponds. Biological

decomposition hardly take place in the other holding facilities, therefore a relatively highly populated earthen pond may permit the growth of a stock while a resultant stunted growth will occur in the other kind of facilities. Fish stocked under the condition of continued water flow through like the cages or re-circulatory systems may tend to have peculiar or specially considered stocking densities.

In extensive, semi- intensive and intensive culture systems, the stocking of fish may be considered based on food availability and feeding and feeding regime, growing time and the target profit maximization. Naturally, a small number of fish in a wide space with adequate water may tend to grow bigger with less feed application. It is not always surprising when a farmer under the pressure and stress of feeding a large stock may tend to ask vaguely 'who feed the bigger fishes in the wild' and they sometimes query the quality of their species stock against that of the rearer with a small number of fish.

In calculating carrying capacity/ stocking density;

take the water volume in cubic meters 100cm x 1oocm x 1oocm x 100cm



and consider the fish number in 1cubic m^3 then multiply by the total area of the pond,

for a example stocking density (@) 5fish/m^3 for a pond of 10 x5x 2m

will be 10 x 5 x 2 = 200m^3 x5fish = 500fish

so a pond size of 10 x 5 x 2 m water covered area will have currying capacity for 500 fish @average weight if 1kg (100gm).

Note that this calculation should be based on the size of adult fish of atleast 1kg, as the fish will continue to grow and occupy the available space.

Fish Feeding and Feed Application

Fish is normally fed according to its body weight and fish nutritionist after research findings over time, have established nutritional requirements for almost all culturable species of fish.

This book focuses on the rate of feed application in relation to the body weight of fish under culture. It should be noted that under normal conditions, younger children of humans need to

eat more quantity and nutritious food than adult because their growth is more rapid, the same occur in fishes. So the percentage weight of food in relation to the body weight of younger fishes is always higher than the adult fishes. Good quality feed should be fed to the fish at 7% 5% 3% to 2% of their body weight from the young to adult fishes. This is also dependent on species under culture and the obtainable water parameters at the time of feeding.

Feeding rate

The objective of aquaculture should be to produce the maximum weight of marketable fish from a given volume of water in the shortest time at least cost. Fish require energy for movement and all other metabolic activities. As aquatic animals, they are cold blooded and so do not need energy to maintain body temperature as they make use of the ambient water temperature and the optimal levels for best growth vary with species.

One important and interesting thing about the fish is that they eat more during warmer periods and the metabolic rate in small young fishes is higher than that of bigger adult fishes also, the young fishes grow faster in terms of percentage increase in weight per day, so young fishes require higher feeding ratio. At a certain body size in fish, growth rate start to decline rapidly, the optimum marketable size of a farmed fish normally occurs at this point except for special market requirements.

Based on the feeding habit of fish, they are grouped into herbivores, detritus feeder, carnivores and omnivores. In the calculation for fish feeding ratio, it should be noted that the ratios depend on the species feeding habit, age of fish and the weather conditions. Also for earthen ponds and, depending on the stock population, there is always available, the natural primary foods that exist due to the photosynthetic activities of plants this should however be ignored in intensive commercial production system during ratio calculation.

Under feeding can result in loss of production, overfeeding will cost wastage of expensive feed and it is a potential for water spoilage and contamination and is additionally a potential cause of water pollution, a condition resulting in loss of animas or requiring expensive corrective measures. Thus, both overfeeding and underfeeding have serious economic consequences which affect the viability of the farm.

Any calculated feeding ratio does not remain static but is dynamic and according to the rate at which the fish grows. The quantity of feed to be given to a pond depends on the number and weight of the fish and the quantity to be given should be based on the biomass present (total weight of the fish).

Sometimes you may read a manufacturer's instruction like 'feed 5% of biomass per day' for a dry feed, this may appear vague but since you do not have only one single fish the total weight of all the fishes in the pond (biomass) should be calculated. Note that a single ratio calculated should not be applied throughout the growing cycle as it will certainly result in gross overfeeding for young fishes in the early stages near starvation for adult fishes. Feeding rate should not stay steady throughout the whole of the growing cycle to market size, they must be modified according to the size and age of the fish. Water quality should also be monitored on routine bases

Applying a feeing rate accurately depends on an accurate estimate of average animal weight and of the numbers of surviving animals in the production unit (pond, cage etc.) Average weight can be obtained directly from weighing samples or by measuring the length if the animals, where an accurate length/weight relationship has been established.

To obtain the weight of stocked fish, Take a random sample from the total stock, weigh it and divide the total weight by the number sampled to get average weight

For example; out of 500 fish stocked in a pond,
30 were weighed and total weight = 20kg
convert to grams by multiplying by 1000 and divide by 30 fish
to obtain their average wt. i.e. 20kg= $\frac{20{,}000\text{gm}}{30}$ = 666.67gm
Each fish is 666.67gm 666.67x500 = 333335gm biomass = 333.335kg
Feeding at 3% body weight is 0.03x 333.34 = 10.00kg
The pond will need 10kg of feed daily

For example if a pond contains 5000 fish weighing 20gm average weight,
and the recommended feeding rate will be of 5% of their body weight
Then the daily feeding rate will be
$\frac{5000 \times 20 \times 5}{100}$ = 5000gm /day, so convert to kg $\frac{5000}{1000\text{gm}}$ = 5kg per day.

Another pond may contain 10,000 fish with average wt of 10gm, the quantity of feed to be given each day should normally ne based on a percentage of the biomass present like 7% a day, the amount of feed to be given every day is:

$\frac{10{,}000 \times 10 \times 7}{100}$ = 7000 g (7 kg per a day)

If the farmer now chooses to feed the fish twice a day he will then divide 5kg into two portions. Preferably at an interval of 12 hours but for adult fish if the ration is given once daily, the fish will still grow normally.

In practice feeding rate should be adjusted weekly or twice monthly based on estimate of biomass together with knowledge of environmental conditions mainly temperature and pH.

Feeding frequency and other factors

The most effective method of feeding with respect to location, time of day and frequency varies from species to species. Its cost effectiveness depends also on other factors such as the availability of feeding labor or automatic feeders, size of pond or cost labor and the personal preference of the farm manager, based on observations and results.