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# Koi pond filtration basics

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## Product Positioning

This document delves into the basics of Koi keeping and positions the products that HappyKoi.co.za sells.

It is intended to outline why the products offered by HappyKoi.co.za do what they do and why their performance is superior. It should become clear that over the lifespan of a pond, these products will save considerable money, time and require a lot less effort whilst delivering Koi keepers a consistently high standard of water quality.

There is an excellent resource on the Internet called [www.fishdoc.co.uk](http://www.fishdoc.co.uk) that outlines in some detail the mechanics of Koi keeping. I have referred to it and summarised some of the more salient points here, particularly on the theoretical side. I have tried to match the theory with the practicality and the benefits of the products that we sell.

Whilst this should be basic stuff for most of you I hope that you'll find a few nuggets of useful information contained here. If you have any questions please do not hesitate to contact either myself, William on 082 886 7114 or Mark on 082 806 or contact either of us on our e-mail addresses ([william@happykoi.co.za](mailto:william@happykoi.co.za) / [mark@happykoi.co.za](mailto:mark@happykoi.co.za)). We'd be only too pleased to help.



## Water Quality

Successful Koi keeping revolves around maintaining an artificial environment that simulates as closely as possible the natural environment in which Koi are to be found.

This is no different from traditional tropical fish keeping with which many aspirant Koi keepers may be familiar already.

Koi keeping is an expression of successful fish husbandry. Why is this so?

Koi have the potential to grow substantially larger than any other popularly kept fish species. They can attain an overall length of over one metre and weigh as much as 12 - 15kg. With a life span of approximately 30 years, an investment in Koi keeping can be considerable both in terms of financial commitment as well as in maintenance work required from the Koi keeper.

Typically Koi are kept in large outdoor ponds, the larger the better for reasons that we will see further on. The challenge lies in keeping a balance maintained in the pond that is conducive to Koi health.

Koi are voracious eaters. Their nickname is "pig fish" because they literally will consume almost anything and will do so in much higher quantities than other fish. They can consume 1% of their body weight daily and can increase this figure to 2% and beyond.

Water quality is intricately and intimately linked to the health and the well being of Koi. In a natural pond, the constraints that face Koi keepers are nowhere to be seen. Koi have literally millions of litres of water that surround them, and they simply cannot produce enough waste material to in any way significantly affect the vastness of the lake or dam in which they reside.

A Koi pond by comparison has a much, much higher fish stocking density. The wastes that Koi produce become extremely significant since they are not diluted by nearly the same volume of water as in a natural environment.

Good water quality does NOT mean water clarity (think about any dam or lake). However, it is possible to have good water quality AND good water clarity.

The relationship between Koi and their watery home is critical. Koi are 90% water themselves (whereas you and I are only 65%) and they cannot isolate



themselves from their environment. Vital substances that sustain life are continuously exchanged between the Koi and the water – oxygen, wastes, carbon dioxide, salts and minerals etc.

This life long exchange of various substances between the Koi and its habitat takes place through a thin semi permeable membrane. Semi permeable means that some substances can only pass one way through the membrane.

Koi can not selectively choose which substances it will allow to pass through the membrane, much though that would be to its advantage. The semi permeable membrane has been developed over millennia of evolution, evolution that has taken place in natural lakes and rivers, not in Koi ponds! This means that the process has assumed that conditions in lakes and rivers will be the ones that Koi are reasonably going to be expected to have to deal with.

Conditions in lakes and rivers are stable eco systems because of their size. Large fluctuations in concentrations do not occur, and if they do it is a very gradual process over decades that allow the Koi to adapt or die. In a pond however, conditions can fluctuate wildly in the space of a day, leading to death and destruction.

Fluids that are in close contact with each other tend to mix. The fact that there is a membrane separating the Koi from it's watery environment is not sufficient to prevent a case of "what's in the water is also in the Koi"! Diffusion is the process that allows the Koi's internal fluids to be highly influenced by those external to the Koi.

Therefore:

1. If you change the environment, you change the Koi.
2. The bigger the pond, the more stable it is likely to be (the more capacity it has to absorb changes)
3. Fish can only adjust to changes in their environment in a restricted fashion and over a small tolerance or range

This then is the challenge of Koi keeping. The maintenance of water quality that is consistent, stable and predictable.

The products that HappyKoi.co.za distribute will help Koi keepers achieve exactly that. They perform better and deliver a better water quality that is more stable and more predictable. They offer significantly less maintenance from the Koi keeper and they will afford him the opportunity to keep Happy Koi for many years to come better than any other product can.



They also offer you the opportunity to grow the hobby with more contented Koi keepers and fewer filled in abandoned Koi projects which loses everyone in the industry money.

## **Differences between life on land and life in water**

[www.fishdoc.co.uk](http://www.fishdoc.co.uk) is an excellent resource in which the concept of treating Koi as open systems is introduced.

In summary the website outlines that fish (Koi) are remarkably well adapted creatures. They maintain no body temperature because unlike land living creatures, fish are remarkably energy efficient.

Oxygen that is available in water to fish can only be accessed once it is dissolved in the water in which the fish live. Whilst water is a remarkable solvent, being able to dissolve almost anything, water can only contain about 9% dissolved oxygen. Compare this to the air that we breathe which comprises our external environment and in which the oxygen content is 21%.

Add this to the fact that water is 800 times denser than air and that oxygen dissolves into it very slowly and you can appreciate the efforts that fish have to go to in order to just get a decent breath! In the same way that we do, fish produce carbon dioxide as the by product of the respiration/metabolic processes. Koi are no different to any other fish. Their food needs are similar to other animals in that they require fats, proteins, carbohydrates, minerals, vitamins etc. They have limited access to oxygen which means that they must use it as efficiently as possible.

Because they are in constant contact with water they also need to deal with the constant diffusion and osmotic processes that take place. Osmosis, the movement of water from a location of higher concentration to lower, requires energy. Energy requires oxygen. Imagine a fish had to not only control this process, but also generate its own body heat. It simply could not get enough oxygen from its watery environment to make this feasible.

Water fortunately has a high resistance to temperature changes. It takes a lot of energy to heat water and relatively speaking water can hold its temperature in colder conditions for a lot longer than other substances of similar chemical composition.



What does happen as water temperature drops is that the metabolic processes in our Koi slow down. Conversely as the temperature rises, the metabolic processes speed up and in the case of Koi, feeding rates can get to impressive levels.

The gills of a fish are highly efficient oxygen extractors and the membrane separating the water from the blood supply is often only one cell thick. This is tiny and represents precious little protection for the fish in the event that things in the pond water turn nasty. In turn, anything that affects the gills of a fish can have devastating consequences.

The rule of diffusion is a critical one to understand properly when it comes to understanding the processes that happen in a Koi pond.

Simply put

Substances will diffuse from one area of greater concentration to an area of lesser concentration in an ongoing process until equilibrium is reached.

This may sound like a mouthful but consider a cup of hot coffee with a spoonful of sugar at the bottom of the cup.

As the sugar dissolves into the coffee it is at its highest concentration closest to the solid sugar pile. This is perfectly logical.

This concentrated sugar then diffuses into the coffee and over time eventually once all the sugar has dissolved the sugar concentration in all parts of the coffee mug will be equal. This is known as equilibrium.

It is important to understand that at all times, all substances and properties (such as temperature and pH) in a Koi ponds seek to be at equilibrium. – i.e. at equal concentration. It is the ideal natural state and there is a constant push and pull in order to get there. The fact that equilibrium very rarely happens is not important. What is important is that things try very hard to get there.

Osmosis is exactly the same process as diffusion. It is a term that refers specifically to water diffusion which is why it has a special name. Water will diffuse from areas of high concentration (i.e. pure water) to areas of low concentration (water with a lot of dissolved substances in it), in exactly the same way that the sugar dissolves into your coffee.



This means that even if the sugar decided to ignore physics for a while and not diffuse by itself, the water in the coffee would do the job for it and eventually the sugar concentration would be the same in all parts of the coffee due to the water diffusion process, which we call osmosis.

Now this is fine and well if you're a cup of coffee. Imagine now that you're a Koi. Your salty blood that is separated from the pond water by a membrane one cell thick is going to have a lot of water zipping across that membrane due to osmosis. Your blood is salty, the water is not, hence the natural osmotic process takes place.

If the Koi did not get rid of all this extra water through constant urination it would explode.

So this means that the water in the pond is being constantly circulated through the Koi.

Can you see how important water quality is to successful Koi keeping?

## **Maintaining a balance**

Fortunately for Koi and all other fish, Nature has thoughtfully provided mechanisms to deal with the realities of life under water. One of these is the ability of the Koi to constantly excrete water it doesn't want or need inside it. It tries to keep as many of the useful salts and minerals it needs and extracts these. This requires energy and once again, anything that affects this ability of the fish is likely to result in a dead fish pretty quickly.

Balancing low oxygen availability with a constant osmotic pressure on it's internal fluids and still maintain an active lifestyle and then still look gorgeous seems like a tall order. Yet Koi manage it.

Water quality is the key.

## **How do we define water quality?**

This is of course the million dollar question. In a natural lake there would be literally thousands of parameters that one could measure. Mineral contents, aquatic life forms, dissolved poisons, pathogen counts, mammal life, kg of fish per cubic meter of water – it would be nigh on impossible to measure them all meaningfully.



At this point in time as Koi keepers we can only focus on what we know we need to control to maintain what we think is a high water quality. We know what we need to be able to achieve to keep our Koi alive and to allow them to prosper. We know enough about water quality to virtually guarantee any Koi the opportunity of reaching old age (30 years for a Koi).

So what is all this then that we need to know?

The nitrogen cycle is something that every Koi keeper must be intimately familiar with. Understanding what happens in this process is vital to successful Koi keeping. It is the very basic building block of Koi keeping and it is the one that so often causes countless Koi deaths and abject misery amongst Koi keepers worldwide, because its importance is often overlooked, or the complexity of the cycle is underestimated.

The nitrogen cycle is a natural process that occurs in lakes, rivers and other natural habitats of Koi. It happens continuously and it is dynamic. It is an aquatic process and it too is a function of water quality. Bad water quality can lead to a poor conclusion of the nitrogen cycle and dead Koi the net result.

The cycle is simple enough to understand. Nature decided to evolve Koi with the ability to excrete their waste material directly into their habitat. Makes good sense really.

Land living animals with an abundance of oxygen and energy almost all convert their wastes which are similar in composition, from highly poisonous ammonia into urea.

Koi aren't so lucky. Their wastes are excreted directly as ammonia (to save precious energy which would otherwise have to be used to create urea). This would not normally present a problem in a big lake, where there is lots of water into which the ammonia would be dissolved to negligible concentrations. In a Koi pond with limited water availability however, if the ammonia is not removed, Koi, which can now be viewed as little swimming ammonia factories, can poison the water to lethal levels in short order.

This is not helped by the fact that they're the 'water pigs' of Nature eating everything that gets in their path, which only adds to the volumes of waste produced.



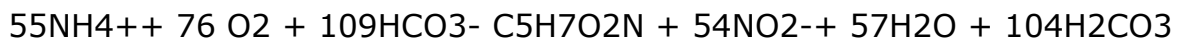


So we have waste production in the form of ammonia taking place. In the nitrogen cycle, bacteria called Nitrosomonas are used to break down the ammonia. This process results in the production of nitrite which although not as bad as ammonia, is still dangerous even in low concentrations.

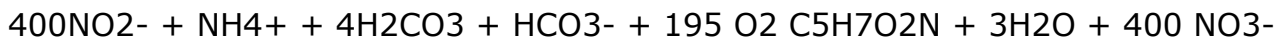
Once more bacteria are called in to help. This time Nitrobacter break down the nitrite into nitrate and this is relatively harmless below about 100 mg/l, and ideally below 50 mg/l for Koi.

These are the equations that of the reactions that the bacteria enable.

For Nitrosomonas:



For Nitrobacter:



What is important from these reactions is to note how much oxygen is used.

Remember that dissolved oxygen is in limited supply in water and the warmer the water, especially in temperate climates like South Africa, the less oxygen dissolves into water. 4.3 mg of oxygen is consumed by the bacteria when converting 1 mg of ammonia into nitrates.

Warmer water means more Koi metabolism, more food, more waste, less dissolved oxygen in the warmer water - greater filter load - the picture can quickly get horribly out of shape.

Also of importance is the effect on alkalinity. Gradually, pH will decrease as the pond becomes more acidic due to the production of nitric acid. This has implications for the water hardness and the pH stability over time. Koi ponds thus to regularly monitor water hardness and pH buffering capability.

## **Dissolved waste vs solid waste disposal**

When the water is warm, Koi can excrete between 50 and 100 mg of ammonia per kg of Koi bodyweight daily. This starts to give us an indication of the size biofilter we need - or more accurately - the performance that is required by the



bio filter. Sizing of bio filters is covered by one of my articles at [www.happykoi.co.za](http://www.happykoi.co.za) – just click the articles link.

This is all well and good as far as the dissolved wastes produced by Koi are concerned. Of equal importance however are the solid wastes that comprise mainly of proteins and there is a great deal of solid waste that is produced when Koi are large and feeding as Koi do.

These solids if allowed to decompose also contribute to the ammonia load in the pond. Dead algae and other organic matter contribute to the ammonia generation process.

Solids removal in a Koi pond is NOT as simple as straining of the material. It is here that we first assess the viability of sand filters in a Koi pond.

A sand filter traps solid material very efficiently. The solid wastes that are trapped are almost immediately set upon by bacteria that break down these proteins into, you guessed it, ammonia! But the general idea is to get rid of ammonia isn't it?

It is true that some nitrification might take place within the sand filter. Note I said "some" since in any location where there is oxygen, water and ammonia you are likely to develop a few beneficial bacteria.

However, as we already know, the nitrogen cycle uses 4.3 mg of oxygen per mg of ammonia produced. If protein decomposition is taking place in the sand filter by bacteriological processes (other than the nitrification bacteria – there are many, many different types of bacteria in a Koi pond, not all of them good) then a good portion of the oxygen present in the water is going to be used right then and there in the sand filter by the nitrification bacteria (that do happen to be present) and the countless fast growing heterotrophic bacteria that are breaking down the solid organics.

This means less oxygen is left over for the bio filters that come directly after the sand filter.

Even then, can you see the big problem with black box bio filters? The only oxygen present to enable the reaction to take place is that is dissolved in the feed water that enters the filter at the start. Once this oxygen is used up, the rest of the bio filter has to make do without oxygen. These type of conditions are called anaerobic – "no oxygen" and in these conditions there are a number of unwanted consequences that can arise.



Anaerobic conditions quickly become pathogen breeding grounds. Toxins from anaerobic breakdown of organic material can quickly accumulate, paralysing or adversely affecting other beneficial bacterial processes. Conditions for disease ripen and Koi immune systems are placed under considerable duress.

There are few conditions in any Koi pond where anaerobic conditions can contribute anything positive to water quality and hence Koi health. Sand filters in a Koi pond are a slow but sure death sentence. It may take a few years, but eventually Koi will pay a terrible price.

Solid wastes are bad news. Trapped solid wastes in the path of your filter cycle are even worse.

## **Look after your beneficial bacteria**

It should be clear that as much as you look after Koi, you need to take care of the beneficial bacteria that contribute to keeping your Koi alive. You should minimise the potential for growing unhealthy or unwanted bacteria in your pond by staying away from anaerobic conditions as far as possible.

There are a few drawbacks to our beneficial nitrifying bacteria though. Unlike some nasty bacteria that can double in numbers every hour (think about the sand filter), these good bacteria grow very slowly. They are easily influenced by poor water quality (aside from high ammonia levels that is) and without oxygen will die off completely within 8 hours. It can take several months to re-colonise some bio filters with these bacteria.

Their required pH range is quite specific and is between 7.5 and 8.6 – remember the acidifying effect of the nitrification process?

As with most living organisms their growth rates are affected by temperature and chemicals added to a Koi pond are likely to affect them adversely. Antibiotics will have predictable results!

It's a common mistake that filters need to be dirty in order to encourage the growth of bacteria. Whilst it is true that bacteria thrive under mucky conditions, it's the wrong bacteria that grow. Fast growing heterotrophic bacteria end up competing with the slower growing nitrification bacteria for precious oxygen.



It is perfectly logical – nitrification bacteria feed off dissolved wastes. Wastes that are visible to the eye are therefore not desirable food for nitrifying bacteria. Dirty filters are a haven for potential disaster since the heterotrophic bacteria that grow in them can and do easily produce by products from the breakdown of rotting organic material that inhibits the nitrification process either by direct toxicity or by creating a hostile microenvironment.

Dirty sludge filled filters are a no go in Koi ponds. If it smells bad, it is bad. In an ideal Koi pond there are no bad smells. Let your nose be a warning beacon of serious trouble!

The implication here is that filters need to be regularly cleaned and if they are constantly becoming clogged with solid gunge then this is true. They do have to be cleaned and this is indeed an unpleasant side to the hobby and represents a considerable maintenance workload for the Koi keeper.

The problem with cleaning the filter system is that some, if not all of the beneficial bacterial colonisation is destroyed, depending what stage of the filter system becomes dirty (the bio filter stage ought to never be dirty).

This maintenance can thus reduce filter efficiency until the colonies can re-establish themselves and this in turn places an ammonia load above normal levels in the Koi pond. Reduced feeding is one easy way to balance out the effects of filter cleaning but try tell a large hungry Koi that this is actually in its own best interests! It might also take weeks for the bacterial colony to fully re-establish and in a pond with a filter system that is only just coping with a full load, the possibility for disaster grows ever larger and more ominous.

Note that trouble can take years to manifest itself. As Koi grow larger, and the numbers of Koi in the pond remain the same, the load on the filtration system increases exponentially. A 60cm Koi places 8 times as much load on the filter system as a 30cm Koi does because it weighs 8 times as much!

## **Nitrates**

Quite often, nitrates are overlooked completely. Once the nitrification process is taken care of by our friendly somewhat temperamental bacteria, the end result is no ammonia, no nitrites and a whole bunch of nitrates instead. Whilst nitrates are largely harmless new thinking leads to the belief that in excess quantities they can be linked to a number of fish diseases.



Typically nitrates are used by plants as food. Algae is a plant and hence excess algae growth in a pond can, but not necessarily, be linked to a high nitrate concentration.

Good algae growth, the short manageable stuff that grows on the sides of the pond walls is in fact to be encouraged. It gives the Koi something to browse on, it removes some of the nitrates in the pond and it contributes to the stability of water quality in the pond. Too much algae on the other hand is a problem and the dreaded blanket weed can make pond maintenance a royal pain and quickly rob the Koi keeper of much pleasure.

Nitrates can also be broken down by bacteria into nitrogen gas. This is a little more easily said than done however. This is called the denitrification process. The key to this process is that it takes place under anaerobic conditions, something which I've stressed is not something that we want in our Koi ponds or in our filter systems.

The process is once again a two step affair. The first step involves undoing all the hard work of the Nitrobacter by converting nitrate back into nitrite. The second step involves converting the nitrite into 3 different gases namely nitric oxide, nitrous oxide and nitrogen gas.

The problem with dealing with nitrates in Koi pond is that it simply isn't practical to build a denitrifying filter large enough to do the job as is done in aquariums. You also need a constant organic carbon source, which would mean keeping some of the solid sludge material in the filter. It is difficult in the extreme to keep control over.

Nitrate build up in a pond is thus most commonly handled by water changes, and the build up of beneficial algae, or by using Kaldnes bio media. A popular trend is to make use of a so called vegetable filter which is a natural way of using up nitrates by making use of plants for which nitrates are an ideal food source.

You have to take some care with vegetable filters. Koi, remember will eat just about anything and a tasty plant (to a Koi ALL plants are tasty!) will go down very well thank you. Ideally you want a plant that can make do with as little soil as possible – you don't want soil getting into your pond and placing unnecessary load on your mechanical filtration. You also don't want a large anaerobic volume which is what a big bed of plants and soil will become. Soil can also become a breeding ground for all sorts of parasites and you certainly don't want this in your pond.



But as with all things in Koi keeping there is a balance. If you design your pond correctly a number of planting options can become available all of which are imminently suitable for Koi keeping without the risks. Existing ponds are also not beyond help.

## **The danger of nitrates – beware!**

If your pond suffers from low oxygen levels, the denitrification process can take place quite naturally, especially in a gunge filled filter with the result that nitrite is fed straight back into the Koi pond. This is most common when conditions are warm (remember that warm water dissolves less oxygen) and at night when algae take up oxygen instead of releasing it.

Heterotrophic bacteria accumulating with any rotting solid organic materials will switch to nitrate reduction overnight, releasing all these poisonous nitrites into the pond – only to reverse the process once more when oxygen levels return to higher levels with the onset of photosynthesis – i.e. daylight.

The message is clear: Be rid of solid wastes to be rid of any potential problems. Also, oxygen levels are once more demonstrated as being of critical importance in a Koi pond, and especially so when it's warm.

## **The products – finally!**

The products that HappyKoi.co.za sells and distributes have been designed and engineered to effectively deal with Koi pond systems and their filtration requirements.

These are products that have been designed from the very outset to focus on one thing and one thing only: Water quality for Koi!

They are not modifications of existing technology that is used elsewhere for different applications – the sand filter being one obvious example.

They are more expensive but they represent exceptional value for money over years, not months.

They are very low maintenance and hassle free. Access to the systems is very easy.



They are durable and will last a lifetime if looked after correctly.

They are the best performing filtration systems for Koi keeping.

## **Active Bed Bio Media**

So called as this is exactly what it is. "Active" as in it moves around in an agitated state (we use air bubbles to perform the agitation), "Bed" because it comprises of thousands and thousands of small plastic tubes that float and "Bio Media" because it is designed to grow bio film – the active site and location of the beneficial bacteria we seek to cultivate in our filter systems.

### **Benefits**

The bio media and hence the nitrification process is run under oxygen saturation conditions. This ensures that the nitrogen cycle is seen to completion (i.e. the whole of the bio filter is used – there are no dead spots or any areas where anaerobic conditions can be found).

Active bed bio media is slightly positively buoyant which means that the air injected into the chamber housing it is more than sufficient to vigorously and turbulently mix the media in a chaotic 'moving bed' process.

This moving bed combines the efficient bio media with oxygen, water, nutrients (ammonia waste produced by the Koi) and beneficial bacteria in a continuous process.

The saturation of the water in the filter means that return water to the pond is still saturated with dissolved oxygen and does not place any additional strain on the dissolved oxygen levels of the pond.

An Active Bed bio media chamber is easily up to 1 000% more efficient at removing dissolved wastes than any other static media.

The Active bed chambers or vessels have a relatively small footprint due to this phenomenal performance.

The speed of waste removal is beneficial to Koi in that ammonia concentrations are far more rapidly reduced to zero levels than with any other bio filter of equivalent size.



The bio media, due to it's chaotic movement is self cleaning with dirt particles and other solid material being knocked off.

The self cleaning nature of the media means that very little maintenance has to take place, with little or no effect on the bacteria colonies. In worst case (total disaster) scenarios, half the media can be cleaned and the other half cleaned a few weeks later. This means a more consistent biological performance over many years, with the associated benefits for the Koi.

The continuous rubbing of the Active Bed bio media against each other also removes old dead and dying bacteria from the bio film, encouraging the growth of new, young and hungry bacteria.

Inside the 'tube' of the bio media, the bacteria colony is relatively protected and can conclude a natural life span of growing and maturing biofilm.

The bio filters can be upgraded as easily as adding another bag of bio media to the filter. It can grow with an increasing load placed on it by Koi that grow or by additional Koi being added to the pond.

Active bed bio media – each 50l can process approximately 250g of high grade Koi food per day, rapidly.

## **Air Pumps**

Happy Koi also supplies air pumps that are powerful, quiet and reliable.

### Benefits

Long life operation means fewer hiccups. No / insufficient air being injected into the bio filters loaded with active bed media affect performance of the filter.

Pumping rates are rated at 2m below surface level. Will measurably deliver superior performance.

Minimal maintenance means fewer headaches in the Koi keeping experience.

Can be used for big aquaria purposes too!  
ENDS.

