AFM water treatment for biodiversity, a solution to Global Warming ??

A water filtration project for Life & the Environment. Support by the European Commission LIFE 02 ENV/UK/000146 AFM

Dr.Howard T Dryden

Dryden Aqua Ltd

AFM:

Sustainable Water treatment to protect Biodiversity

Dr.John Hargreaves CEO Scottish Water, & Mr Ross Finnie, Minister for the Environment visit an AFM site in Scottish Water (2003)

Dryden Aqua are Marine Biologists specialising in the environment and water quality control. Most environmental water treatment systems have been developed by engineers and as such the biological component has been ignored or not fully understood. At Dryden Aqua, we have focused on the practical biology of the processes and their implications to the design of water treatment systems taking biology into account. This approach has led to a dramatic improvement in system performance and the potential to make a profound impact on public health, biodiversity and our environment. This is a rather bold and sweeping statement, however it is based on three years of intensive research and development funded by WRAP and the European Commission under the Life Environment initiative and the main technical points can be substantiated.

One of the water treatment systems re-designed by Dryden Aqua, is the simple sand filter. Sand filters treat most of our drinking water supplies, and they are the most common filtration technology used for waste water, sewage effluent, grey water recycling and water treatment in general. In every sand filter, each grain of sand will be coated by bacteria, the bacteria excrete and alginate glue that they use to stick themselves on to the sand. After a period of a few weeks or months, the alginate glue starts to stick the sand grains together which eventually leads to coagulation of the filter bed or channelling of water directly through the filters. The rate at which channelling and coagulation occurs ranges from a few days to several months depending on the water temperature, chemistry and nutrient load.

Sand filtration suffer serious coagulation problems in nutrient rich water such as sewage effluent and industrial waste water which makes the process difficult to manage. In drinking water systems channelling of water through the filter allows bacteria, parasites and chemicals to enter our water supplies. From WHO, 6% of all human disease in Europe is related to our drinking water supplies. In chlorinated systems such as swimming pools the channelling through the filters results in a 10 fold increase in chlorine consumption and the production of chlorine reaction products that are carcinogenic or cause respiratory disease and asthma in children.

We have therefore identified some fundamental problems with the existing technology, the following section explain how they can be resolved.

Sand filtration

Good quality equipment must always be used such as pressure filters designed and manufactured to German DIN standard specification, and filters should be operated at appropriate water flowrates for the application. However irrespective or the quality of the equipment and management of the system, sand will always become fouled by bacteria and the performance of the system will be compromised.

At Dryden Aqua, extensive R&D on the chemical and biological inter-reactions of a type of sand called zeolite was investigated. The sand in question is an alumino-silicate zeolite called clinoptilolite which has molecular sieve ion exchange properties. It was discovered that the surface chemistry and the nature of the sand substrate had profound implications on the bacterial species diversity and the rate of biofouling experienced by the filter media. A second R&D program was therefore initiated to develop a sand substitute that would make it difficult for bacteria to become established. Zeolites loaded with catalysts proved to be successful, but the performance could not be maintained without regeneration cycles which made the process impractical.

Zeolites can also be manufactured that have some very useful properties, one of the raw materials used in their manufacture is glass which is, itself an alumino-silcate. However as opposed to manufacturing a completely synthetic product, we were able to re-process waste glass and just alter the surface shape of the glass at a molecular level. The net result is a product called AFM (Active Filter Media) which acts like a mechanical filtration media, just like sand, but it also carries a high surface negative zeta potential and catalytic properties.

The high negative Zeta potential reacts synergistically to remove sub micron solids and dissolved organics that have been coagulated and flocculated by PAC or polyelectrolytes. The negative potential coupled with catalytic properties also makes it very difficult for bacteria to become established.

The implications are that simple sand filtration technology can now be used with AFM filter media to eliminated chlorine reactions products in applications such as the swimming pool industry. Filtration performance is increased by 30% to 80% in municipal drinking water filters which potentially eliminates up to 6% of all disease and cancers in Europe. For the first time we have a simple means of treating sewage effluent to a very high standard, thereby eliminating eutrophication and list 1 chemical contamination of the marine environment.

Swimming pools

In swimming pools the principal chemical that you smell when you enter a pool is not chlorine, but a chlorine reaction product called trichloramine (nitrogen tri-chloride). The same chemical is responsible for causing eye irritation, and if your eyes sting then the gas will also be damaging your lungs, you just can't feel the damage being inflicted to your lungs. There have been many reports published by the European Respiratory Society and Research supported by the European Commission around Europe which have made a connection between swimming pools, trichloramines level and childhood asthma. Asthma levels in children have increased from around 5% in the early 1970`s to a figure in excess of 25% of the population to-day. It is unlikely that swimming pools are responsible for all the cases, but there is a strong connection. As biologists working in the aquaculture industry, if you identify a serious problem for aquatic animals, you eliminate the cause however you must first understand the mechanism of production. Dryden Aqua were the first biologists to thoroughly investigate the biological inter-reactions in chlorinated systems and the publish the mechanism of trichloramine production.

Chlorine is an oxidising agent which will kill most bacteria within 30 seconds, but only if the bacteria are free in the water. Most bacteria will be glued onto a surface, and the alginate glue provides the bacteria protection from the chlorine. Indeed chlorine actually promotes bacteria such as *Pseudomonas spp,* that can produce copious quantities of alginates. By far the largest surface area in contact with the water is the sand in the sand filters. A typical 25m pool will have around 15 tonnes of sand, and each tonne of sand has 3000 square meter of surface area. The bacteria will actually fully colonise new sand coating every surface in contact with the water l in a matter of a few days.

The bacterial layer on the surface of sand creates an acidic micro-environment which is required for the production of trichloramine. Since AFM does not support bacterial growth, this means there is no acid layer which means that trichloramine production is dramatically reduced or eliminated. There are now many swimming pools operating in Scotland with AFM which have greatly reduced levels of trichloramines and up to 100 times lower concentrations of chlorine reaction products. By way of example, it is now the policy of Edinburgh Leisure to only use AFM in all their public swimming pools for the City of Edinburgh.

Simply by replacing the sand with AFM eliminates the production of trichloramines and reduces chlorine consumption by up to 90%. Because less chlorine is used the concentration of chlorine reaction products such as THM's is also reduced. THM's such as chloroform are highly carcinogenic, and exposing children to carcinogenic chemicals must be avoided. The application of UVc (Ultra Violet) and ozone in swimming pools actually increases chlorine consumption and may be responsible for up a 5 fold increase in THM levels. The use of UVc and ozone technology should be avoided until we have absolute verification that it is not harmful.

Aquatic animals such as dolphins, whales, seals and penguins all require water as good if not better than swimming pools. Aquatic mammals and birds often suffer from lung damage in chlorinated systems, the most common cause of mortality is pneumonia. The condition is linked to the air quality just above the surface of the water. The same situation exists in swimming pools, it does not matter if the pool is out-side, if the water has a high trichloramine and THM concentration, the air layer just above the surface of the water will also have a high concentration, and this is the air that you are breath when swimming.

Swimming is an extremely good form of exercise and should be encouraged. The equipment installed must be to a high quality, and the staff must be trained to a high standard. The sad fact is that in many pools and health clubs you would probably be better off standing out side the pool chain smoking cigarettes as opposed to entering the building. A report published by Dryden Aqua is available from www.AFM.eu explains what needs to be accomplished in the swimming pool industry to solve the problems. The solution is not difficult, indeed it will result in pools which are easier to manage, they will have a lower carbon foot print and the return in extra capital expenditure will be recovered in less than 18 months.

Drinking treatment

Sand filters used for treating drinking water will always suffer from worm hole channelling and instability after back-washing to some degree, this can not be avoided.

Viri, bacteria and parasites such as cryptosporidium and giardia will pass directly through sand filters suffering from channelling. PAC (poly aluminium chloride) is used as a coagulant and flocculent prior to most sand filters. If the filters are channelling then aluminium will enter the water supplies. Considering that aluminium may be linked to brain disorders and that all aluminium cooking pots were actually banned in the 70`s, it is worrying that filters with worm hole channelling are allowing aluminium to enter our drinking water.

If a filter is experiencing channelling then it also means that organic matter will be passing into our supplies. Chlorine is added to the water, the chlorine reacts with organic matter to form carcinogenic THM's. In an effort to try and reduce the THM level it is estimated that at least 25% of the water companies in the UK add ammonium to the water. The ammonium reacts with chlorine to form mono-chloramine, di-chloramine and tri-chloramine. These are the same chemicals that are formed in a swimming pool. However it is safer to drink water containing chloramines rather than it is to breathe them in via you lungs. The chloramines still have a disinfection capacity, albeit reduced somewhat, but the advantage is that it prevents the chlorine forming reacting with organic mater to form more carcinogenic THM's.

The above problems can all be solved by the elimination of biofouling and channelling of water through the filter bed. Simply by replacing the sand in sand filters with AFM will eliminate

biofouling and channelling of water through the bed. Trials conducted by Suffolk & Essex confirm a 30% improvement in filter bed performance over the first 10 weeks, by changing from sand to AFM In filters which have run for up to 12 months, AFM will be remove up to 80% more solids (measured by turbidity) than is possible for a high quality filter sand. These results translate into huge chemical and energy saving. The public health implications can not be quantified because they are almost too great to be taken seriously.

Sewage effluent treatment

Most of our aquatic pollution arises from sewage effluent discharge to rivers and the sea. Sewage effluent is a complex mixture of bacteria, chemicals and nutrients. The most dangerous of the chemicals are those that are persistent bio-accumulated substances such as mercury, TBT and PCB's. There are many of these substances which are collectively known as *List 1* chemicals, technically they are discharged below detection level. The chemicals are dangerous because they are not broken down by effluent treatment system or by the aquatic environment and as such they are considered to be one of the most serious threats known to the aquatic environment and public health.

Bacteria in effluent treatment systems tend to concentrate *List 1* chemicals. Protozoa in rivers and the sea then ingest the bacteria discharged from the sewage works and concentrate the chemicals. The chemicals continue to pass up the food chain, from protozoa, through organisms such as nematodes and zooplankton and eventually to shellfish and fish. Through each stage the concentration of *List 1* chemicals increases exponentially. It is now a UK Government recommendation that you do not eat more than two oily fish per week from the North Sea due to *List 1* toxic chemical contamination. The chemicals eventually end up back in the human food chain either by eating fish directly or indirectly from farm animals given fish meal as an animal feed.

The *List 1* chemicals may be discharged from sewage works below detection level, however through the process of food chain amplification the concentrations increase exponentially. One of the most extreme examples occurred in Minamata in Japan which resulted in almost 2000 deaths and 10,000 cases of mercury poisoning. We are also seeing high levels of mercury building up in the Mediterranean and even the Pacific Ocean.

With regards to low level *List 1* discharges from sewage works, the effects of public health are more insidious and long term leading to such conditions as an increase in cancers and sub-

lethal chronic health issues. While the treatment for cancer has greatly improved in recent years, we are now seeing a massive increase in the number of cancers because we are exposed to many more carcinogenic chemicals in our environment, food and water that we consume.

List 1 chemicals are dangerous because of their persistence in the ecosystem, however the chain can be broken if bacteria are removed from sewage effluent discharge. In order to achieve this task you need a very efficient means of filtration. Sand filters are used for the tertiary treatment of sewage and the system can work well. However due to rapid bacterial fouling of the sand, the filter beds tend to coagulate rapidly making it difficult to maintain the performance of the filters. By changing the sand to AFM, biofouling is eliminated thereby solving the filter problem.

AFM provides a simple technique which allows sand filters to treat sewage effluent to a very high standard. The system can cope with solid loads up to 150 mg/l and remove in excess of 90% of the bacterial cell biomass, solids and *List 1* chemicals. AFM therefore has the potential to offer a low cost solution using existing sand filter technology to essentially eliminate aquatic environmental pollution.

Biodiversity, Carbon Dioxide & Greenhouse gases

We are all very concerned about the increase in carbon dioxide levels and green house gases, but few appreciate that the sea is the main carbon dioxide buffer and its role in locking out carbon dioxide has dropped by up to 50% over the last two decades in many locations. The pH of seawater has also dropped by around 0.05pH units which represents a huge change in the carbon dioxide / carbonate balance. The questions should now be raised "what has happened" and can it be reversed. The sea and biodiversity of marine life in the sea, perhaps holds the key to climatic change and the stability of our environment. We know that bio-accumulated list 1 toxins affect the growth of algae, and since algae are responsible for 90% of our oxygen and elimination of carbon dioxide we have to insure that we do not destroy or upset this ecosystem. For the first time simple sand filtration systems using AFM media provides a low cost approach to the tertiary treatment of sewage effluent and reduction in list 1 chemical discharge to the environment.

The marine environment should recover, but only if we stop discharging list 1 chemicals. Control over the marine environment holds the key the atmospheric control, we really can not hope to have any impact on global warming and green houses gases unless we protect the marine environment. AFM filtration may provide the means and offers a partial solution.

Biofuel

The sea and controlled mid oceanic eutrophication, could provide a mechanism for eliminating carbon dioxide and nitrogenous waste and increase aquatic productivity at the same time. There may even be the possibility of creating a new ecosystem with a productive fishery. The cultivation of phytoplankton using waste nitrogen, phosphate and carbon dioxide could also be used for the production of biofuels. This is now a practical proposition which is many times more efficient than growing corn or cane as a bio fuel.

Algae bioreactors are at least 100 times more productive than a corn field, the powdered algae can be used directly as source of energy or the oil extracted and used as diesel. The first

diesel engine was actually powered by coal dust, and with minor modification the engines will work on dry algae powder. Algae can also be made to produce hydrogen as opposed to oxygen, so this may offer an interesting alternative. Land produced biofuel will at best only provide about 10% of our requirement. Given the much higher productivity of algae, algal production systems could meet all of our energy demands. Cultivation could even be carried out in the sea thereby saving land for the production of food crops.

The way forward

Good water quality is essential for public health and well being. The elimination or reduction of aquatic environmental pollution and the maintenance of biodiversity is absolutely essential for our survival. Dryden Aqua are marine biologists specialising in water quality and water treatment, and in this context we see the adoption of AFM technology as one of the most significant developments in water treatment technology in recent years. The process has the added benefits; in as much that it is simple, low cost and uses existing sand filtration systems that can be easily retrofitted.

AFM is a 100% sustainable product which replaces sand mined from the land or dredged from the sea bed. Good quality filter sand is a finite resource that is no longer available in some countries. AFM therefore provides a solution to the problem and provides us with a way forward to protect our environment and public health.

Dryden Aqua Ltd
Butlerfield
Bonnyrigg
Edinburgh EH19 3JQ
Scotland

Website: http://www.AFM.eu
Contact: Howard Dryden
Email: aqua@drydenaqua.com