ANH CONSULTANCY LTD

INTERIM REPORT
AQUA-NU / PURITYCAP™ FILTRATION TESTS

March 2009

This report has been prepared by Robert Verkerk BSc(Hons) MSc DIC PhD, at the request of Aqua-Nu Filtration Systems Ltd, Brid a Crinn, Dundalk, County Louth, Ireland.

A short biography of the report's author appears below:

Dr Robert Verkerk is an internationally acclaimed expert in agricultural, environmental and health sustainability, environmental toxicology, nutritional science and risk assessment. During the course of his work over the last 24 years, he has focused on a diverse array of issues ranging from environmental protection, to reducing pesticide and synthetic chemical inputs in homes and in agriculture, to the development of novel nutritional and sustainable approaches to healthcare.

Following his first degree in ecology, he spent some 10 years in the private sector in Australia working in the field of sustainable environmental management. He returned to the UK in 1990 and completed a Masters Degree at Imperial College London (with Distinction) and continued his studies, being awarded a Doctorate in 1995. Dr Verkerk remained at Imperial College for a further 7 years as a postdoctoral Research Fellow and still maintains research links with the College today, through Imperial College Consultants Ltd. He has worked extensively in Australia, Africa, Central and South East Asia, and has regularly acted as an advisor to governments and development agencies. In 2002, he founded the Alliance for Natural Health (ANH) (www.anhcampaign.org), a pan-European and international, non-governmental organisation dedicated to positively shaping the scientific and regulatory environment required to facilitate the future development of natural and sustainable healthcare. Through Dr Verkerk's leadership, as ANH's Executive & Scientific Director, the ANH has become one of the most prominent forces working to protect natural healthcare worldwide through its implementation of a diverse range of strategies based around the application of 'good science' and 'good law'. The ANH collaborates closely with some of the leading experts in the field of medicine, science and law worldwide to effect its objectives. Dr Verkerk also acts as a consultant on a wide range of issues relating to both health and agriculture, through the ANH's consultancy arm, ANH Consultancy Ltd.

Dr Verkerk has authored over 60 original articles in peer-reviewed journals, scientific symposia and special interest magazines, as well as several books. He is a regional fellow of the Royal Society of Medicine (London).

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In general terms, the analyses cover three main areas:

Inorganic elements: Many elements may be found in drinking water, the most common usually being calcium and magnesium, which are more properly regarded as nutrients, rather than contaminants. Iron is also found in many drinking waters, and again, its presence may be beneficial. Some waters may also contain lead, aluminium and other elements (e.g. cadmium, barium, arsenic, lithium, rubidium) which are generally regarded as contaminants, although scientific research is increasingly demonstrating biological functions for these elements at very low dosages.

Organic compounds: These include a very wide range of compounds that, by definition, include carbon in their structure. Of the contaminants present in many drinking waters, they include disinfection by-products, pesticides, petrochemicals and solvents. Increasing amounts of scientific research is demonstrating that long-term, low dosage exposure to mixtures of these compounds may contribute to significant health risks, including cancer. Some of these compounds are effectively indirect carcinogens, in that they are converted to carcinogens following their reaction with other chemicals (in water, in food, in the body), while others are directly carcinogenic.

Micro-organisms: Diseases caused by waterborne microbes (pathogens) constitute one of the greatest risks relating to consumption of drinking water in many parts of the world. These pathogens are the target of disinfection technologies used in drinking water treatment, such as chlorination and ozonation. Where disinfection levels are inadequate or not present, pathogens pose a serious risk, causing diseases such as gastro-enteritis or dysentery, or even Legionnaire’s disease, cholera or typhoid. Water that has been previously treated with chlorine or chlorine dioxide may readily become contaminated given that the disinfection capacity will be reduced following the volatilisation of the disinfection agents over time (most of the chlorine will volatilise from standing tap water in under 2 hours).

METHODS

Test solutions of the contaminants exceeding the highest levels likely to be found in contaminated drinking water were made up in demineralised water by CAL Ltd (Dun Laoghaire, Co Dublin).

Analysis was conducted of samples prior to filtration, and then following passage of 3, 30 and 100 litres of water through the prototype Aqua-Nu filter cartridges.

Analysis was performed by one of two leading, accredited laboratories in the analytical field, these being Eclipse Scientific Group (ESG) or Severn Trent Laboratories (STL) in the UK.

The filter cartridges are composed of three distinct filtration media: two specific grades of AnalaR grade activated (oxygen-treated) carbon, and a unique ceramic medium (Patent Pending) that is comprised, prior to firing, of diatomaceous earth and a bactericidal agent. The ceramic media are overlaid with nylon mesh when assembled into the cartridge. The ceramic media is the final filtration media through which filtered water passes within the PurityCap™ (which itself includes a one-way valve and which has its inner surface covered by an agent with anti-bacterial properties). The carbon media were separated within the cartridge by nylon mesh or the ceramic media which is in turn overlaid with nylon mesh.

Apart from these key analyses which have been conducted to test the efficacy of the unique PurityCap™ microfilter, some additional tests have been conducted. The results of these tests are given in the Results section of this report following from Table 1.

Additionally a range of pathogen tests have been undertaken using the ceramic, given that this is the key medium for pathogen flltration and in some cases may be appropriate as a stand-alone product. The *Cryptosporidium* and *Giardia* tests to-date have been conducted by challenging each ceramic disc with 11L of distilled water spiked with approximately 200 *Cryptosporidium* oocysts and 200 *Giardia* cysts. The filtrate flow rate ranged from between 150 and 200 mL per minute. The *Legionella* challenge was conducted with 500 mL of filtrate, with an intended concentration of 1,000 cfu/100 mL. The actual precount level differed slightly from this, being 8,100cfu/L. The *E. coli* test involved just 100 mL of filtrate but with a very high loading, approximately 50,000 cfu/100mL.

RESULTS

A table of summary results is given below, which includes the maximum level of filtration for each contaminant (Table 1) as determined before and after passage of filtrate through the Granular Activated Carbon (GAC), as well as for a range of pathogens (Table 2), using only the ceramic, which is the key medium for filtration of pathogens.

Table 1. *Summary analyses for key contaminants (GAC only)*

Category	Contaminant	Pre-filter concentration	Post-filter concentration	% reduction
Inorganic				
- *disinfectants*	Chlorine	0.505 mg/L	0.074 mg/L	85.3%
	Chlorine dioxide	1.36 mg/L	0.11 mg/L	91.9%
- *elements/salts*	Aluminium	1.63 mg/L	1.31 mg/L	19.6%
	Lead	42.5 mcg/L	35.3 mcg/L	16.9%
	Iron	0.322 mg/L	0.13 mg/L	59.6%
	Nitrite	0.93 mg/L	0.68mg/L	26.9%
	Nitrate	To follow	To follow	To follow
	Bromate	11.7 mcg/L	<0.8 mcg/L	>93.2%
Organic				
- *herbicides*	MCPA	0.544 mcg/L	0.085 mcg/L	84.4%
	Mecoprop	0.448 mcg/L	0.090 mcg/L	79.9%
- *solvents*	Isoproturon	0.54 mcg/L	0.13 mcg/L	75.9%
	Benzene	2.02 mcg/L	0.24 mcg/L	88.1%
- *xenooestrogens*	1,2 dichloroethane	14.3 mcg/L	3.65 mcg/L	74.5%
	Trichloroethene	23.0 mcg/L	3.7 mcg/L	83.9%
	Bisphenol-A	40.4 ng/L	21.4 ng/L	47.0%
	Estrone	0.66 ng/L	< 0.05 ng/L*	>92.4%
	Estradiol	0.90 ng/L	<0.1 ng/L*	> 88.9%

* Limit of detection (LOD) of analytical equipment.

Table 2. *Summary analyses for key pathogens (ceramic discs only)*

	Cryptosporidium	200 oocysts/11 L	0	100%
	Giardia lamblia	200 cysts/11L	0	100%
	Legionella pneumophila	4050 cfu/500mL	0	100%
	E. coli	50,000 cfu/100ml	0	100%

Alkalinisation:

Demineralised water of a pH of 4.6 (TDS = 33 ppm) was found to have a pH of 7.2 (TDS = 33 ppm) - 7.8 (TDS = 33 ppm) following passage through the filter.

Stability and anti-bacterial function of the ceramic filter media:

A bactericidal agent was included in the ceramic media (at up to 7.2 g Cu/kg) to facilitate an anti-bacterial action. Tests were conducted to test the stability of the bactericidal agent within the ceramic and following passage of water through the filter, the bactericidal agent could not be determined in excess of the Limit of Detection (0.1 mg / L). The bactericidal agent was thus found to be stable within the ceramic following its firing.

Initial prototypes of the ceramic disc (2 mm thickness), loaded with 7.2 g bactericidal agent/kg, reduced *E. coli* counts by 82.2% compared with the pre-filter concentration, as against 35% for a control disc which was not treated with the bactericidal agent. This resulted in the inclusion of the bactericidal agent in the ceramics used in the final, composite filter including granulated activated carbon (GAC), where the thickness of the disc was 1.8 mm and loading of the bactericidal agent was just 2.5 g/kg. Despite this reduced concentration of the bactericidal agent, complete (100%) elimination of *E. coli* was achieved (as shown in Table 2).

Anti-bacterial action in mouthpiece:

E. coli colonies were exposed to the coated mouthpiece for 20 minutes and before and after exposure colony counts were conducted (see Table 3). The results demonstrated that the bactericidal agent reduced the presence of viable colonies by 97%.

Table 3. *Mouthpiece test*

Starting value	33.2 x 10^6 cfu/100ml (*E.coli*)
Final value	1.04 x 10^6 cfu/100ml (*E.coli*)
% Reduction	96.9% x 10^6 cfu/100ml (*E.coli*)

Pre-treatment of filter with surfactant:

Pre-treatment with 0.01% Tween 20 surfactant (overnight soaking, followed by 3 L wash of distilled water), demonstrated that pre-treatment of the surfactant increased the efficacy of the filter during the early phase of its use (see Table 4).

Table 4. *Tween study with iron, total as Fe. Fortified at 0.4 mg/l (T0 = pre-filtration; T3 = after 3 litres filtration; T30 = after 30 litres filtration ; T100 after 100 litres filtration)*

	Blank Level	T0	T3	T30	T100
No Tween	<0.025 mg/l	0.408 mg/l (100%)	0.340 mg/l (83.3%)	0.146 mg/l (35.8%)	0.212 mg/l (52.0%)
Plus Tween	<0.025 mg/l	0.408 mg/l (100%)	0.232 mg/l (56.9%)	0.172 mg/l (42.2%)	0.254 mg/l (62.3%)

DISCUSSION

The contaminant tests (Table 1) demonstrate powerful filtration capacity of the filter for a wide range of contaminants – exceeding the narrow selectivity that is often seen with conventional activated carbon drinking water filters. This very high level of filtration capacity was evident throughout the filter's 100 litre capacity.

The unique ceramic filter demonstrated 100% removal of two species of bacteria namely *E. coli* and *Legionella pneumophila*, as well as 100% of oocysts and cysts of *Cryptosporidium* and *Giardia* respectively (Table 2).

The overall filtration capacity as found through the various studies at CAL Ltd is related to four distinct mechanisms, all of which may act together synergistically:

- Mechanical (physical) trapping of pathogens within the ceramic media (separate studies at South East Water; Results, Table 2)
- Adsorption of pathogens within the ceramic media and killing of bacteria (see Results: Stability and anti-bacterial function of the ceramic filter media)
- Adsorption on the activated carbon media (separate studies by CAL Ltd, not reported in these Results)
- Bactericidal action within the ceramic media (as above)

Given that pathogen contamination is not only one of the greatest health risks associated with drinking water, especially in developing countries, and that pathogen development within filtration systems has also been shown to be common, the anti-pathogen and filtration capacity of the PurityCap™ filter provides a very important commercial advantage over many other point-of-use filtration devices (e.g. jug filters, under-sink units).

The ability of the micro-cartridge to filter out the two most widely used disinfection products (chlorine and chlorine dioxide) was exemplary given the high rates of their inclusion in these tests, being in the range 85-92%.

Of course, some of the greatest risks associated with long-term exposure to contaminated drinking water are not directly the result of toxicity of the disinfection products themselves, but are linked instead to disinfection by-products. For example, very low rates of bromates in water may combine with chlorine to form carcinogenic bromoform compounds. The filter reduced the concentration of bromates dramatically (>93%, see Table 1), and this in turn will substantially reduce the risk of formation of significant concentrations of bromoforms within the body.

The filter's ability to reduce common elements was variable, allowing a considerable number of common trace and ultra-trace elements to be left within the water. Increasing amounts of research are showing biological functionality with the vast majority of elements even those that are typically thought of as toxins (e.g. arsenic, lithium, germanium, rubidium). The filter typically reduces the level of these elements around 50% and therefore reduces the body's burden, while not depriving consumers of the elements completely, given that very minute quantities may be beneficial (Adriano, DC. *Trace Elements in Terrestrial Environments: Biogeochemistry, Bioavailability, and Risks of Metals*, 2nd Edition. 2001. Springer, Berlin. 867 pp. [ISBN: 978-0-387-98678-4]).

On the other hand, organic (carbon-bound) contaminants, frequently produced as pollutants from industry, cannot be seen to be beneficial at any concentration – and these appear to pose a considerable risk to health (e.g. Leffers H, Næsby M, Vendelbo B, Skakkebæk NE, Jørgensen M. Oestrogenic potencies of Zeranol, oestradiol, diethylstilboestrol, Bisphenol-A and genistein: implications for exposure assessment of potential endocrine disrupters. *Human Reproduction*, 2001; 16 (5): 1037-1045; Aksglaede L, Juul A, Leffers H, Skakkebæk NE, Andersson A-M. The sensitivity of the child to sex steroids: possible impact of exogenous estrogens. *Hum. Reprod. Update*, 2006; 12(4): 341 - 349). They include such chemicals as pesticides, solvents and xenooestrogens. The micro-filter exhibited a remarkable level of filtration of these substances, often within the range more typically associated with much more elaborate filtration devices, such as those based on reverse osmosis.

Given that the PurityCap™ is designed for fitment to plastic/PET bottles with universal screw threads, it is of considerable benefit that the filter will remove xenooestrogens (released from leaching plasticizers and from contraceptive pill/HRT residues) from water (see references above).

The studies showed that the filter had the ability to 'condition' the water's pH, converting acidic demineralised water into a neutral, pH-balanced water.

The inclusion of a mouthpiece, the inner surface of which is coated with a bactericidal agent, as an integral part of the PurityCap™, provides a natural anti-bacterial action on any bacteria left in the mouthpiece following oral contact. The *E. coli* test conducted to assess this anti-bacterial effect demonstrated that with only 20 minutes of exposure, *E. coli* counts declined by 97%. This is another important feature/selling point for this product. A one-way valve is also included so that saliva will not run back into the micro-filter itself. It should be recognised that the PurityCap™ housing is designed to be readily disinfected (by boiling, soaking in bleach or microwaving).

Finally, it was found that pre-treatment of the filter increased the effectiveness of the filter during the first few litres of filtration, probably because it encourages a much higher level of contact between water and contaminants and adsorption sites on the filtration media.

Conclusions

The PurityCap™ device and replaceable micro-filter represents a unique approach to portable water filtration. It has tremendous capacity as a mass consumer product and it allows any user to be able to consume high quality, good tasting water while at work, on the move or on holiday. It also has great potential application in developing countries where water-borne disease organisms present a major threat to health, especially to that of babies and children.

There is increasing recognition that water should be consumed 'little and often' and at least 2 litres should be consumed daily. There is great potential for bottled water, soft drink and other drink manufacturers to embrace the product so that they may advertise their brand, while at the same time promoting healthy lifestyles and consumption of clean, filtered water.

Robert Verkerk PhD
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NOTE: Complete reports of analyses from CAL Ltd and South East Water are available as separate files.