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Treating Water Contamination using Ultraviolet Radiation to Control Cryptosporidium and E.Coli

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TREATING WATER CONTAMINATION - USING ULTRAVIOLET RADIATION TO CONTROL *CRYPTOSPORIDIUM* AND *E.COLI*

Concerns about the quality of drinking water in Ireland have come into sharp focus with the recent Cryptosporidium outbreak in Galway City. In this article Michael O'Hehir, David Kennedy Chartered Engineer and Tom Dunphy Chartered Engineer of the Faculty of Engineering DIT Bolton Street look at how ultraviolet radiation can offer a potential solution in the control of Cryptosporidium contamination.

The quality of drinking water in Ireland is currently under threat from a number of sources including pollution, effluent, farm waste, practices in agriculture and outdated/undersized water treatment plants. Nationally, this is a serious issue, effecting the health and welfare of adults and children and damaging the tourism industry. The frequency of these water related problems in Ireland are increasing and the intervals between outbreaks are decreasing. Until recently, the major bacterial problem associated with drinking was contamination with *E.coli*. This is a water-borne organism originating from human and animal waste. This pathogen can cause serious illness and sometimes can prove fatal. This contamination can readily be treated initially by boiling the water. A more long-term treatment is chlorination. However, the ultimate solution would be to protect the water supply. The most recent outbreak of pathogenic contamination in Ireland is cryptosporidium. To date the outbreak of this in Galway is the largest Irish contamination of public water supplies by the *Cryptosporidium* parasite in the history of the State [1].

This parasite causes the same problems as *E.coli* but is more difficult to treat. This paper outlines one possible solution whereby water may be treated for *E.coli* and *Cryptosporidium* by using ultraviolet radiation. Figures 1 - 2 show samples of these contaminants.

An Immunofluorescence image of *Cryptosporidium* parvum oocysts is shown in Figure 1 after it was purified from murine fecal material. The oocysts were stained with commercially available immunofluorescent antibodies. Oocysts have an intense apple green fluorescence on the periphery of their oocyst wall and measure 4 to 6 microns in diameter. The scale bar shown is 10 microns.

Figure 2 shows a fluorescence image of *Cryptosporidium* parvum oocysts, purified from murine fecal material. The oocysts were stained with 4-6-diamidino 2-phenyl-indole dihydrochloride (DAPI). DAPI interacts with nucleic acids and stains the nucleus of each sporozoite within the oocyst. There are normally four sporozoites each with one nucleus, or four stained nuclei in each oocyst. Oocysts that appear to have fewer than four stained nuclei, may have four nuclei with the others not visible in this plane of focus. Oocysts with no nuclei visible may be dead, be resistant to DAPI staining or may be organisms other than *Cryptosporidium* parvum.

In the recent water problems in Galway city for instance, the *Cryptosporidium* parasite has been detected at levels above that acceptable by the EPA recommendations, resulting in the purchase by consumers, householders, hoteliers and businesses of bottled water from outside the region.

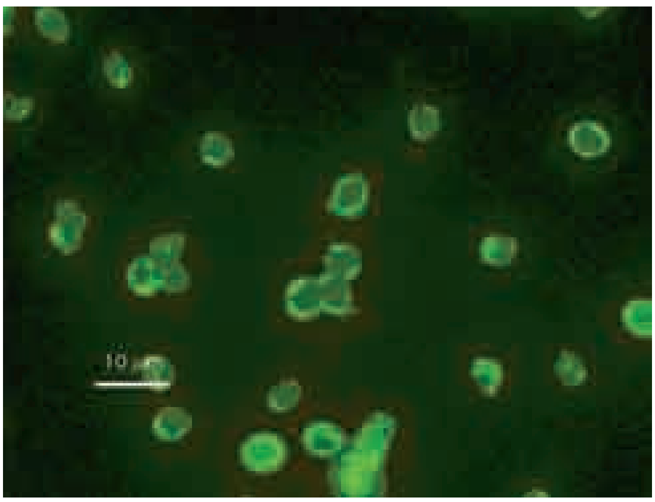


Figure 1: Immunofluorescence [2].

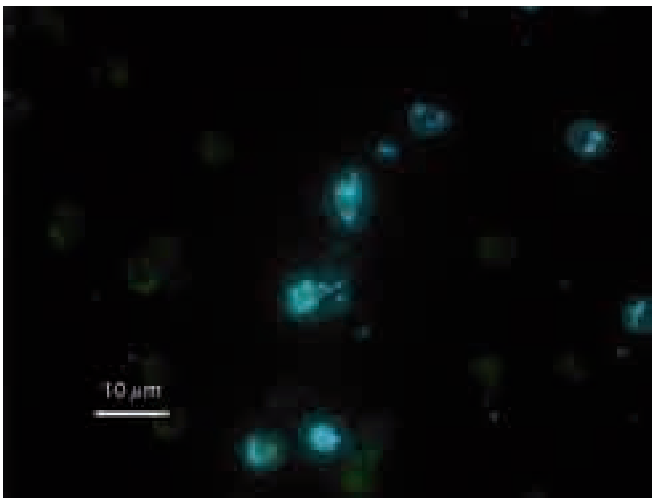


Figure 2: *Cryptosporidium* [2].

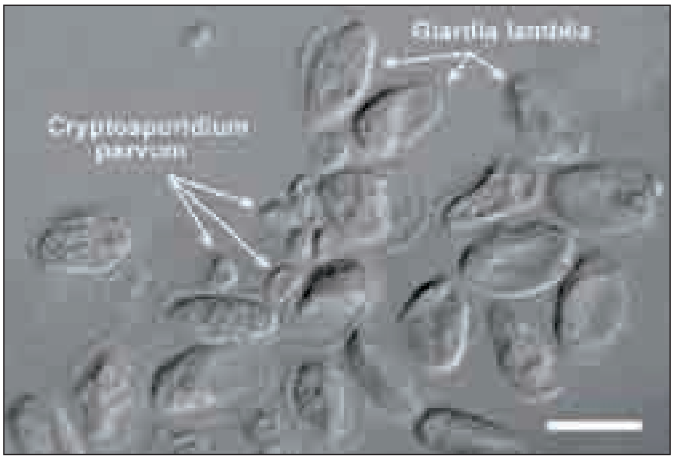


Figure 3: Cryptosporidium and Giardia cysts.

Figure 4. E coli cluster

Microorganisms and UV light treatment

Microorganisms encompass a wide variety of unique structures and can be classified into five basic groups, including:

(i) Bacteria
(ii) Virus
(iii) Fungi
(iv) Protozoa
(v) Algae.

Some of these microorganisms are shown in Figures 3 and 4.
A microorganism is made up of a cell wall, cytoplasmic membrane and the cell's genetic material, nucleic acid. It is this genetic material or DNA (deoxyribonucleic acid) that is the target for the UV light.
As UV penetrates through the cell wall and cytoplasmic membrane, it causes a molecular rearrangement of the microorganism's DNA which thus prevents it from reproducing. If a cell cannot reproduce, it is considered dead [3]. The structure of a typical microorganism is shown in Figure 5.

What is *Cryptosporidium*?

This is a microscopic parasite classified as protozoa, which is present in almost all surface waters. When ingested through drinking water, it can cause *Cryptosporidiosis*, an illness characterised by severe abdominal cramps and diarrhoea, which can be fatal to individuals with suppressed immune systems and children. *Cryptosporidium* is resistant to chlorination because it is an "ocyst" i.e. the parasite is encased in a shell, which protects it from chlorine. In the Milwaukee *Cryptosporidium* outbreak of 1993 for instance, despite testing the chlorinated water, no coliforms were detected even though high levels of *Cryptosporidium* were present[4]. It was estimated that 403,000 humans were effected with watery diarrhoea and over 100 deaths were attributed to this outbreak, mostly among the elderly and immunocompromised.
The reasons for such an outbreak was attributed to poor filtration systems, poor water quality standards and inadequate testing of patients [5].

Chlorination.

Chlorination is the commonest form of disinfection for water treatment since chlorine is cheap and relatively safe and easy to use. When in concentrated form, chlorine is very toxic [6], but is considered relatively harmless to humans when mixed correctly with water [7].

Final Disinfection.

On leaving a treatment plant, water is delivered to the consumer through the distribution network where it should contain a residual chlorine concentration in the order of 1.0 - 1.2mg/l. The level of concentration depends on the length of the pipeline to the first consumer, who must not receive more than 0.5mg/l. The last consumer should receive not less than 0.20mg/l at periods of maximum consumption [8].
One of the major drawbacks of chlorination is the formation of by-products and reactions which take place within the water. One such problem was discovered with the development of gas chromatography and mass spectrometry. This technology can "expose" natural and man-made organic compounds with concentrations of less than 1µg/l, which were otherwise undetectable.
Some of these compounds can react with chlorine to form complex and occasionally-dangerous chemicals known as Trihalomethanes (THMs). These are all considered to be carcinogenic.

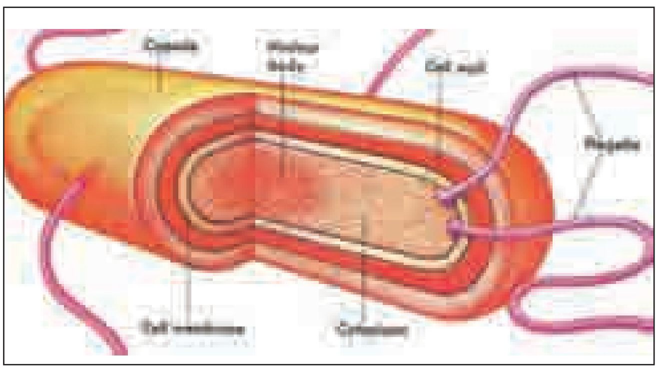


Figure 5. Structure of a microorganism *Cryptosporidium.*

Figure 6: Ultra violet bulb in quartz glass sleeve.

Figure 7: Filter and ultraviolet unit.

Ultraviolet (UV) Radiation

Ultraviolet radiation is normally classified as either “UV A”, “UV B” or “UV C”.

UV A is naturally occurring in sunlight and has a wavelength of 325 – 390 µm. It has little germicidal effects.

UV B has a mid-range wavelength of 295-325 µm. It is best known for use in sun tanning lamps and is also found in sunlight. It can provide some germicidal effect if exposure is sufficient.

UV C is the short wavelength class with a wavelength of 200-295 µm. It has the most optimum germicidal action. This UV is generated artificially, typically in a low-pressure mercury vapour lamp [3,9].

UV is a proven technology for the inactivation of *Cryptosporidium*. LeChevallier and Au [10] confirmed this in a report issued on behalf of the World Health Organisation 2004, in which they showed that ultraviolet light inactivates microorganisms through reactions with microbial nucleic acids and is particularly effective for the control of *Cryptosporidium*. In the United States, the US EPA has implemented a groundwater rule, requiring any site with a *Cryptosporidium* risk to put in place relevant technology to eliminate that risk. It has referred to UV as an acceptable treatment option for this problem.

Factors affecting UV

The effectiveness of a UV system in eliminating microbiological contamination is directly dependent on the physical qualities of the influent water supply.

It is vitally important that suspended solids or particulate matter are totally eliminated as these can cause a shielding problem in which a microbe may pass through the steriliser without being actually exposed to direct UV penetration. This shielding effect can be reduced by the correct mechanical filtration of at least five microns in size [9]. However, the importance of the shielding effect appears to be nullified by tests carried out by Linden and Darby 1998,

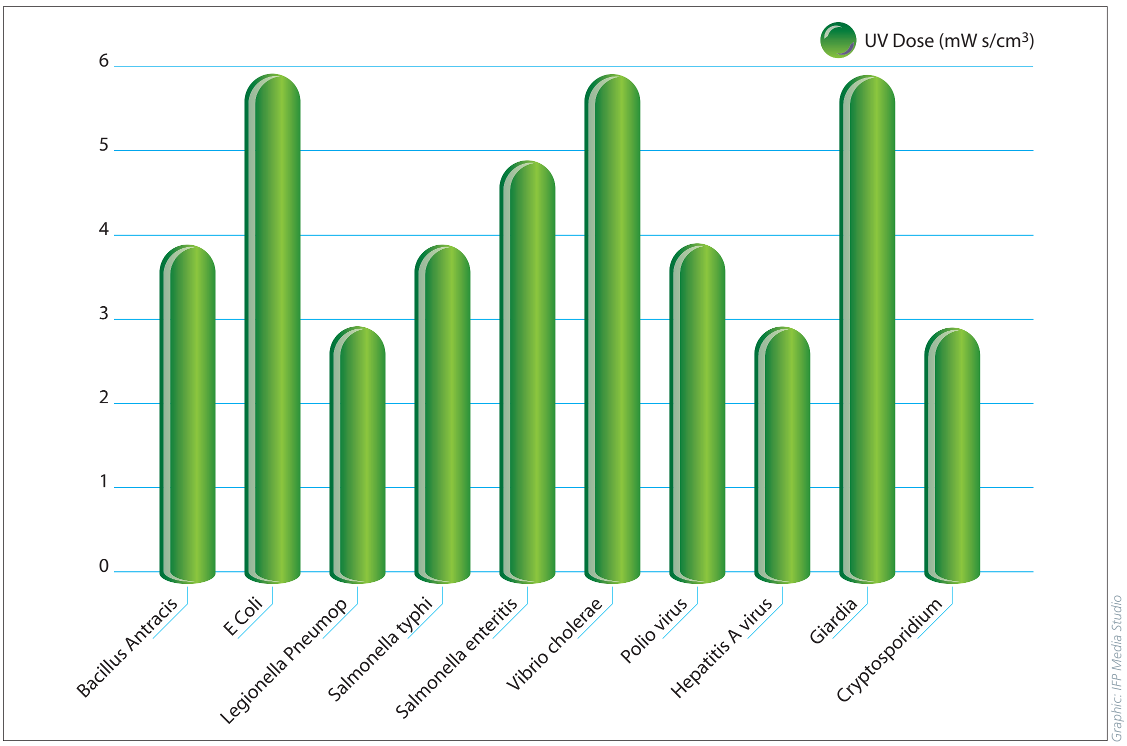
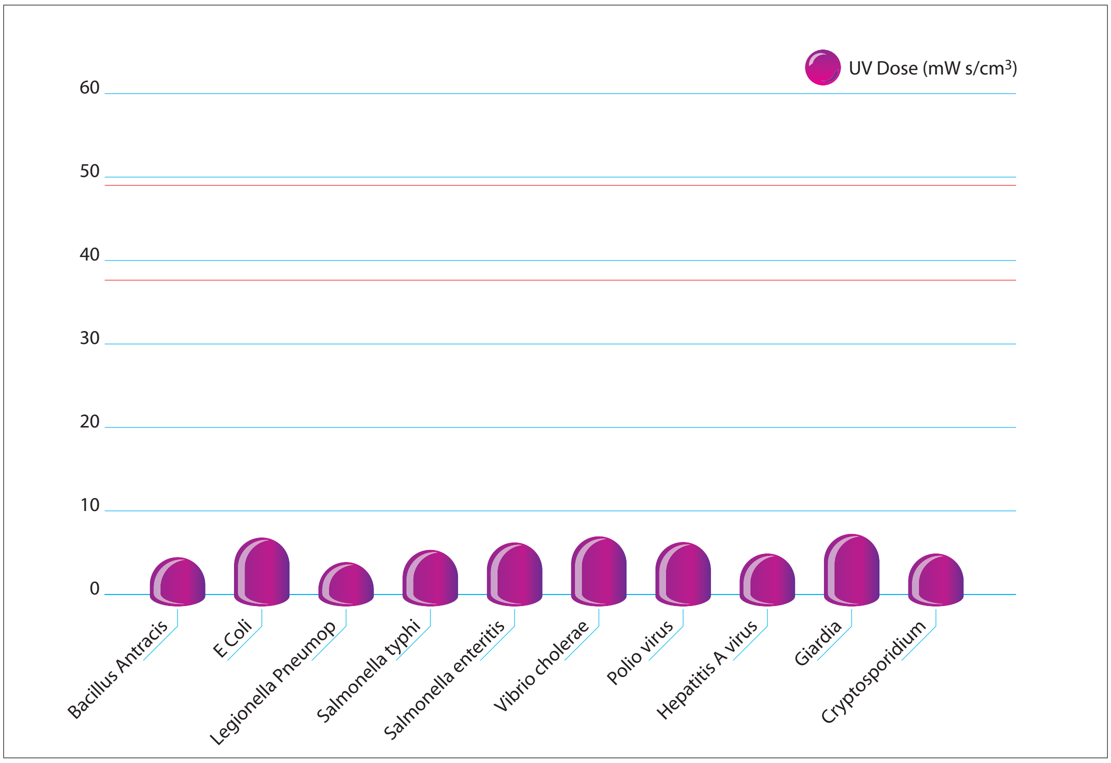


Table 1: Inactivation levels and doses.



Graphic: IFP Media Studio

Table 2. Inactivation levels of microorganisms compared to set levels.

Emerick, Loge 1999, and according to work done on UV by Alicia Cohn 2002 [10]. These authors reported that turbidity is not the limiting factor in treating water with UV. If the dirt particles or solids in water are not UV absorbers, then these particles can be a problem if the organisms are embedded within them. These cannot be destroyed by the UV radiation in this case and the parasites can survive the treatment process to the detriment of the consumer.

In effect, cloudy or turbid water may not be treatable by UV and this quality issue can be reduced or eliminated by using a relevant filtration system.

In order to ensure compliance with the terms of usage supplied by the manufacturers of the UV units and to ensure total clarity of the water, the use of a fine pore filter is recommended. Individual reactor tube manufacturers would recommend the rating of such a filter.

Inactivation of pathogens and dose required.

The dose applied to the pathogen is a product of the length of time of exposure and proximity to the low-pressure mercury bulb that emits the ultraviolet radiation. This bulb is protected in a hard quartz glass sleeve as shown in Figure 6 (page 348).

The exposure time of the water to the light and the flow characteristics is crucial to the success of the system. The units of dosage are milliW-sec/cm^2. The US EPA accepts 50milliW-sec/cm^2 as the minimum dose for UV water treatment while 38milliW-sec/cm^2 is the standard set by the National Sanitation Foundation. Table 1 shows the dose required for inactivation of various organisms [10].

Table 2 shows the inactivation levels of various microorganisms compared with standards set by the US EPA (upper boundary line). And the standards set by the National Sanitation Foundation (lower boundary line).

Advantages and Disadvantages of UV Light

The main advantages of UV light[11] are as follows:

(i) Provided people take basic precautions, they are environmentally friendly in that they produce no residues. There are no dangerous chemicals to handle or store and there are no problems of overdosing.

(ii) The initial capital cost of applying UV is low. Furthermore, operating expenses are reduced when compared with similar technologies such as ozone, chlorine, etc.

(iii) It is an immediate treatment process. Therefore, there is no need for holding tanks, or long retention times.

(iv) It is an extremely economical process. It is capable of treating thousands of litres, at a very low operating cost.

(v) Since there are no chemicals used in the process or added to the water supply, there are no by products produced such as with chlorine.

(vi) There are no changes in taste, odour, pH, conductivity or the general chemistry of the water.

(vii) The process of applying UV is automatic. There is no need for special attention or measurements and it is operator friendly.

(viii) It is simple to maintain; the only maintenance required is periodic cleaning and annual lamp replacement. There are no moving parts to wear out.

Disadvantages of UV Light

The main disadvantage of UV disinfection is the lack of residual disinfection. Residual disinfection applies to chlorination, where the disinfectant is in the water right up to the point of use, thus disinfecting the water long after being chlorinated. UV disinfection takes place only at the point of treatment. However, in a domestic situation if the unit is placed as close as possible to the point of use this is not a concern. Figure 7 shows a typical domestic installation whereby the water being treated is ground water and being used as drinking water and water intended for ablutions. One main disadvantage however is the cost. A typical installation is in the order of €800.There is no installation costs associated with chlorine, but when chlorine is unsuccessful and multiple purchases of bottled water is the only alternative, not to mention the cost and inconvenience of boiling water, UV treatment may not be that expensive. Φ

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