Dissolved air flotation in drinking water production

T. Schofield
8A Rounds Hill, Kenilworth, Warwickshire, CV8 1DU, UK (E-mail: tom-schofield@email.msn.com)

Abstract Dissolved Air Flotation (DAF) has become increasingly important in the field of potable water treatment, as a preferred option for treating upland and stored lowland waters. This paper outlines the development of dissolved air flotation (DAF) in potable water treatment, the benefits and disadvantages and the recent advances that has taken the process technology from an art to a science.

Keywords Water treatment; dissolved air flotation; flotation; design, operation

Introduction
When the first international conference on DAF was held in Felixstowe, UK in June 1976 (1), the Water Research Centre (WRc) were co-ordinating a series of large-scale pilot studies. Three full-scale DAF plants were being proposed but no works had actually been built in the UK. However, in Scandinavia there were over 16 water treatment plants already in operation, plus several industrial and wastewater applications and these were useful reference sites.

The WRc programme of pilot studies arose from an awareness that whilst DAF had become established in industrial water treatment there had been no applications in potable water treatment except for one in 1965 at Windhoek, Namibia for the flotation of algae laden water (2,3).

Currently, there are over 90 water treatment installations operating in the UK utilising the DAF process and around the world it has been reported that there are in the order of 37 works in Finland, 26 in Australia, 26 in South Africa, 20 in the United States, 15 Sweden, 5 Norway, 3 Canada (and 3 under design), 7 France, 5 The Netherlands, 3 Belgium and 1 in New Zealand (4). Although, these numbers are still extremely small compared with the numerous applications in industrial and wastewater treatment, it clearly reflects the benefits of the DAF treatment process and the established position it now holds in water treatment.

The majority of these plants were built after 1976, so what were the factors that recommended this process as opposed to the vast array of other clarification options such as sedimentation, floc blanket clarifiers, lamella plate, tube sedimentation, adsorption clarifiers, Sirofloc or even ballasted floc clarifiers? Process selection in potable water treatment increasingly requires a range of performance guarantees, covering water quality compliance, flexibility, reliability and not least, cost of ownership. These were all comprehensively demonstrated in practical evaluations (1,5,6,7), which also highlighted the potential technical advantages of DAF, compared with other processes:

- high rate (>10 m/h), small compact plant
- rapid start-up and the ability to withstand periodic stoppages
- high solids capture, particularly of finer solids (80–90%)
- better algae removal (50–80%) at the higher hydraulic loading
- reduced chemical usage and often no polymer assistance required
- clarified water of consistently high chemical and bacteriological quality
- relatively robust to hydraulic and quality variations in raw water
- positive control over separation process.
However, there were also a number of inherent disadvantages:

- complex and mechanically intensive process
- requires electrical power
- higher service costs
- requires a separate flocculator and the DAF cell must be covered
- large number of process control variables.

The latter disadvantages dissuaded many European design engineers in the 1970s and early 1980s from recommending the process and consequently the development and application was rather slow and hesitant. However, the technical advantages of the process in the specific treatment of

- soft, low alkalinity, upland waters
- stored, lowland and eutrophic (algal rich) waters
- waters at low temperatures and low contaminant levels
- supplies requiring large variations in output.

Plus a general five-fold increase in hydraulic loading, clearly demonstrated the economic benefits for treating these types of waters and the process became more widely accepted. Nevertheless, the applications were not supported by a continuing development in the technology and even in the late 1980s there was marked lack of information and design knowledge (8, 9). It also prompted the comment, more in frustration than in anger that the lack of fundamental design criteria in 1991, painted a rather depressing picture of DAF design expertise and whilst DAF had existed as an art form for over 30 years, as a science it was much less developed (10).

The increased interest in the 1990s marked a step change in the research directed towards optimising the design and operational variables and as our knowledge has increased the DAF process has become increasingly more attractive for specific applications. The process has even veered into the treatment of source waters that were previously considered unsuitable, such as surface waters with turbidities greater than 60 NTU.

General developments in the least ten years

Prior to 1990, DAF designs were still generally based on the various approaches of process plant manufacturers and the innovative research and development work done by the UK Water Research Centre (5, 6, 7,11,12).

However, by 1990 individual developments around the world had started to provide a greater understanding of the process and the need to build larger DAF facilities like the 450,000 m³/d Frankley WTW, UK (13,14) raised a number of fundamental questions concerning design criteria and the optimum engineering envelope for DAF units.

In 1993 the Water Research Commission of South Africa produced a comprehensive set of design guidelines for Dissolved Air Flotation based on existing South African practice (15). This excellent document also recorded and analysed the growing wealth of information on DAF technology in the world’s literature. It was therefore the benchmark of South African, as well as international theory and practice, and established one of the first comprehensive publications of design parameters for DAF in water treatment.

Specialised DAF conferences and workshops (16,17,4) have served to expand and promulgate this knowledge and to promote further investigatory activities. The increased activity in research and development together with an increasing amount of pilot and full-scale operational experience has now developed to such an extent that our experience is now effectively and healthily starting to overturn some of the previously held design tenets. This continues to demonstrate the technical and economic attraction of DAF for treatment of upland and stored lowland waters.
Specific developments and optimisation in water treatment

Coagulation

One of the earlier advantages of DAF was the fact that the process required a lower coagulant dose than conventional sedimentation or floc-blanket clarifiers and there was no necessity for polymer addition. However, operational experience showed that under cold water conditions, coagulation with aluminium salts (alum) was increasingly difficult despite the provision of long flocculation times. Therefore, coagulant/flocculant aids were introduced to improve performance (18,23).

Iron coagulants are not as prone to this problem but most plants now use a small dose of a polyelectrolyte (0.03–0.1 mg/l) to provide higher turbidity removal and greater adhesion and stability within the float. The increased adhesion also alleviates some of the problems of scouring, where large floc particles are removed from the base of the float (by the force of the incoming flow) and transported out with the clarified subnatant. The improved availability of the polymerised aluminium and also iron salts has enhanced the speed and efficiency of the coagulation process, making it less sensitive to the need for pH optimisation and temperature factors. Operational experience clearly indicates that the use of these polymerised coagulants, such as polyaluminium chloride (PACl), generally reduces coagulant dose requirements without loss in clarified water quality. The reduced need for coagulant pH correction also provides savings in acid or alkali usage and therefore despite the increased cost of these coagulants overall cost benefits can usually be achieved.

Static mixers have been increasingly used (in addition to weirs, jump weirs and flumes) for effective and rapid dispersion of coagulants, replacing high speed, rotating mixers. The simpler and therefore cheaper high energy, vortex, static mixers are also more widely used as they can now be applied to both open channels as well as in enclosed pipes.

Flocculation

DAF requires a discrete flocculation chamber and this may be directly linked or positioned separately in the general flow configuration. The separate flocculation chamber can serve several DAF cells and therefore is lower in capital costs. However, directly linked units of similar cross section to the DAF cell are now preferred as they can be built on the same base slab, provide better flow distribution into the DAF cell with therefore less potential for floc destruction and also provide the ability to optimise individual streams.

Operation and pilot studies have shown that the optimum flocculation energy requirements have not changed very much from those recommended by the WRc studies in 1975, in that velocity gradients of approximately 70 reciprocal seconds are required for optimum conditions. However, flocculation times have been significantly reduced from 20–30 minutes to 10 minutes or less, as it has been proved that smaller but stronger, spherical, pin point floc of 10–100 µm diameter are more effectively separated by flotation.

In practice flocculation is now normally achieved in one or two baffled cells designed to provide turbulent, plug flow conditions with minimum short-circuiting. Hydraulic flocculation is generally considered to lack the flexibility and control afforded by mechanical flocculation and therefore turbulence is now generally provided by vertical mechanical units The large scale experiments with various horizontal and vertical flocculators at Antwerp in 1990/91 (18) and the previous WRc studies showed that there was no significant differences in performance terms amongst the various configurations and therefore as vertical flocculators are easier to operate and maintain, they have rapidly become the industrial standard. However, technological development has now lead to the gradual replacement of the gate type flocculators by the more energy efficient, propeller or axial flow mixers. Tapered flocculation has always been considered to be detrimental to the process (19) but variable speed flocculators can be advantageous in commissioning and optimising...
performance under variable conditions. However, in practice once set the variable frequency drives are rarely modified and the cost of fitting these units on all flocculators is therefore questionable.

Early work with optical systems, followed by confirmatory CFD analysis has shown that two-stage flocculation alleviates many of the previous short-circuiting problems. The studies also showed that plug flow characteristics can be improved if the flow is arranged to pass across each cell in an upward or downward diagonal direction against the rotation of the flocculator. These provisions inhibit rotational flow within the chambers and prevent differential velocity effects being carried through into the DAF cell.

DAF cell

Significant developments have been made in the design and operation of the DAF cell over the past 10 years. In terms of cell geometry, the square or rectangular cell is almost universally used because of:

- simpler construction
- multiple units are cheaper to construct and occupy a smaller footprint
- inlet hydraulics easier to balance with linked flocculation chamber,

although the circular cell offers certain advantages:

- single units cheaper to construct
- simple scraper mechanism
- decreasing hydraulic velocities towards the outlet
- lower outlet weir loadings.

The size of the DAF cells depends on hydraulic loading and this has seen the most dramatic changes with loadings increasing from 5–10 m$^3$/m$^2$/h in 1990, to proposals for 20–25 m$^3$/m$^2$/h in 1996 (20) and more recently this has been expanded to 40 m$^3$/m$^2$/h. (21,22).

In horizontal or radial flow cells the hydraulic loading was basically dependent on the ability of the rising micro bubbles to buoy the floc particles to the surface and thus separate the solids from the clarified subnatant. The separation process was considered to require laminar flow conditions within the DAF cell and several experiments have been carried out to determine the optimum arrangement for the outlet from the reaction zone, with vertical and sloping baffles. However, investigations quickly determined that one of the major factors in hydraulic control was the way in which the subnatant was drawn from the cell. Therefore, single submerged end-wall outlets (that provided a low resistance and low head loss design) have been successively replaced by higher resistance multi-distributed outlets, perforated pipe laterals, sand in combined DAF/filters and lately by perforated plenum floors. Submerged CCTV, tracer studies and CFD have shown these developments have alleviated many of the problems caused by re-circulating currents and have produced more uniform down-flow conditions in the separation zone.

The proposed increased hydraulic loadings nevertheless highlighted a number of features that had previously been considered to be limiting factors and therefore these had to be accommodated or dismissed. The first of these was that at flows above 10 m$^3$/m$^2$/h there was an increased potential for the saturated clarified water to cause air binding in the subsequent filtration stage, especially in combined flotation/filter units (24,25). Second, raising the flows in excess of 10 m/h also increased the possibility for bubble carry-over and the potential for associated solids loss. This was a particular concern at flows around 13 m/h (depending on the configuration of the cell) when laminar flow conditions within the separation zone started to break down. These factors therefore constituted a greater challenge to the filter stage and a loss of performance.
The carry-over of air to a secondary filtration stage was found to be minimised by passing the DAF clarified water over a free-fall weir or intermediate holding tank and solid carry-over has not been found to be significant, especially where polymerised coagulants or poly-electrolytes are used (20,26). The use of lamella modules has also proved particularly beneficial in
- stabilising the hydraulic effects in the cell, reducing the turbulence and re-circulation patterns that have previously disrupted the float layer
- encouraging the separation of the air/solids phase from the clarified water and causing the excess air to coalesce, form larger bubbles and escape to the surface
- directing the separated flows uniformly to the float layer and to the base of the cell respectively (27, 28).

This therefore enabled designers to increase flow rates significantly above 10 m/h without incurring these problems (27,20). However, in the combined co-current DAF/filter, air binding is known to be a bigger problem and therefore for many years design ratings were fixed around 10m/h, although in certain cases the air bubbles were reported to assist filtration. Entrained air can be partially removed by short operational stops or “burping”, the filter with a short burst from the backwash pumps but the use again of lamellae has basically helped to reduce these inhibiting factors.

The advent of the combined, counter-current DAF/filter (CoCoDAFF) process in 1992–1994 introduced the concept of column flotation and turbulent flow (within the separation zone) to municipal water treatment. The fact that the flocculated water in this system must now pass downwards through a deep and rising cloud of air bubbles increases the potential for bubble particle association and therefore greater removal efficiency. The resulting float is also supported with a greater depth of bubbles (>1.2 m) and therefore does not suffer from eroding currents prevalent in conventional DAF units. The process is consequently more stable and robust to increased flows. The simple downward flow system also allows a filter to be easily incorporated into the structure.

In potable water treatment the increased flow potential has resulted in smaller footprint plants but conversely the proposed maximum size for a single DAF cell of 60 m² in 1980 (providing 750 m³/h) (29) has been progressively expanded to 145 m² in 2000 (producing 2,900 m³/h or even 4,350 m³/h) (20,21,30), producing a basic doubling of the treatment capacity per square metre. The depth of the units has increased from a minimum of 1.5 m to over 5m in some designs and the geometry of the tank surface has moved progressively from long rectangular tanks to a more square arrangement. The outline design concept of length to width ratios of 1:2:1 or 2:1, to achieve good hydraulic conditions in horizontal flow tanks has been basically replaced by better design techniques using CFD modelling where the inlet arrangements from the flocculators via the reaction zone has taken on more importance. Many process contractors still consider DAF cells longer than 10 metres significantly increase the risk of “fall out”, from the float and have no operational benefits. However, the maximum size of the flotation tank is usually determined by hydraulic conditions and the method of sludge removal. There are therefore several tanks operating satisfactorily at over 12 m in length but width has been generally limited to 8.5 m due to the fact that this was the maximum span of most mechanical skimmers. The trend towards hydraulic removal of the float has therefore alleviated this problem and cells are currently being designed with widths approaching 12 m.

The prime factors in the design and operation of float removal systems in DAF have been comprehensively reported in the proceedings of the 1997. International DAF Conference (31) and for the sake of brevity are not detailed here. However, the choice of system has moved more and more over the intervening years from mechanical scrapers to the simpler hydraulic decanting. Unfortunately, this process produces the thinnest sludge
(< 0.5%ds) and the greater loss of water (1.5%) but as most water treatment plants now incorporate the recovery of filter backwash water with sludge thickening the two streams may be brought together with resulting benefits and savings. The benefits to the DAF process of hydraulic desludging are that it is a simpler system to construct and operate, and therefore generates savings in capital and maintenance costs. In addition it has little or no impact on the clarified water quality compared with the odd blips in turbidity that are experienced during float removal by mechanical systems. In combined DAF/filter systems the removal of the float is also usually effectively linked with the backwashing of the filter and this provides further savings in energy, water and manpower.

The position and height of the submerged inlet baffle in most DAF cells has been the subject of continuous design modifications, with variations from a vertical configuration, through various degrees of inclination (up to 30°), contours (chamfers, gull wings) and back again to the vertical. Studies have shown that the vertical baffle generally produces more uniform flows in the contact/reaction zone and the least back mixing (32,33). The studies also indicated that submergence of the baffle is not too critical, providing it does not accelerate the flow into the flotation zone. Re-circulation, variable velocity currents and scouring of the underside of the floating floc blanket are all then related more to tank dimensions and outlet design.

Recycle systems
DAF generally has a lower capital cost than conventional clarifiers but a higher operating cost and over half the operating costs are associated with the generation of the recycle system (34). It is also understood that the amount of air used in full-scale operation is far in excess of that required in theory and therefore notionally there is considerable room for improvements in overall system efficiency.

All studies have shown that packed bed saturators are more efficient than unpacked saturators but in operational circumstances where pressure vessels have to be internally inspected on a frequent basis, it is common practice to select an unpacked system. This diminishes the need to recycle filtered water but it is nevertheless prudent to retain the inline strainers to protect the injection nozzles. Most unpacked saturators are currently equipped with internal or external eductors for dissolving the air into the pressurised water and the air that separates out in the saturator tank is re-circulated via the eductor. The re-circulation improves the efficiency of the unpacked units but it is still considered that they would have to be operated at 100–200 kPa above that required for a packed saturator, to supply similar quantities of air (35). The saturation efficiency of packed saturators by comparison may go as high as 99% of predicted values.

The minimum operational pressure for conventional flotation treatment is in the region of 350 kPa and therefore saturators tend to be operated at between 4–6 bar with hydraulic loadings in region of 50–80 m³/m²/h. The higher the pressure the greater the amount of air dissolved but this must be moderated by cost and delivering the most economic level of air to the injection nozzles. Therefore, the preferred design is to have short delivery pipework with minimum pressure losses to prevent premature release of air. This problem is often alleviated by placing saturators close to the DAF cell.

However, overall efficiency is significantly affected by the ability to effectively precipitate the air once it is in solution and many designs of injection nozzles have been developed that can deliver from about 67% to 94% of the available air (36). The injection nozzles can be divided into two basic classes the fixed orifice e.g., WRc double orifice nozzle and the adjustable orifice, e.g., the needle valve. The fixed orifice is by definition the simpler to use and although it may suffer the risk of fouling the systems are more widely used than the adjustable nozzles. The fixed nozzle limits the range of recycle flows (ca 20%), as it is
restricted to permissible pressure variations but the use of two or three manifolds of nozzles can readily provide automatic stepped control of 3 to 1 or more. However, once commissioning has been completed, it is unlikely there will be a need to fine-tune the recycle beyond these limits and where water treatment plants have a number of DAF cells, it is often easier to start and stop units to optimise conditions than manually adjust hundreds of nozzles. Nevertheless, the variable orifice nozzles do provide this flexibility and power-operated globe valves and pneumatically adjustable nozzles now provide the ability to automate the system and match demands caused by variations in water quality, temperature or flow.

There is a wide range of patented nozzles but all the effective ones incorporate five main features:

- a single instantaneous drop in pressure as close as possible to the point of injection
- a sudden change in direction of the flow (usually through 90°) at the inlet to the orifice
- an orifice of 2.5 mm or less, giving a residence time in the nozzle of less than 1.5 ms
- an impinging surface or shroud set at right angles to the flow on leaving the orifice
- a tapered outlet to reduce exit velocity and encourage bubble diffusion.

Two of the latest developments along these lines have been the T-bar valve developed by the Yorkshire Water Company in the UK and the Pneumatically Adjustable Nozzle produced by the Flemish Water Supply Company in Belgium (37).

A typical globe/needle valve will provide a recycle flow of approximately 0.7 m³/h at 4 bar. By comparison a remodelled nozzle designed to give a radial distributed flow in the CoCoDAFF system is capable of delivering 4–6 m³/h and allowed the process designers to reduce the number of nozzles from approximately 20 per 4 m² to 1 per 4 m². Therefore, there is some scope for increasing the output from fixed orifice nozzles or designing multi-orifice nozzles to effectively reduce the number of injectors in a DAF cell. Process contractors in the UK, often utilise a standard filter nozzle with a drilled metal insert to provide a simple injection nozzle with the appropriate design attributes and diffusion characteristics.

Nevertheless, none of the nozzle systems are capable of producing only micro-bubbles and whilst bubbles in the range of 40–70 µm are preferred, some larger sizes are inevitably produced and this effectively reduces the operational efficiency of the system. However, the designer is required to provide a recycle system that will provide sufficient air under the worse possible conditions i.e., poorest water quality, maximum flow and the maximum range of water temperatures. Therefore, in practical terms the quality of the clarified water is maintained by operating the recycle rate over a range of 6–10%, at pressures between 4 –5 bar, to produce a bubble density that usually equates to an air requirement of 5–8 g/m³ of water at the given temperature. Under normal or average operating conditions the recycle rate and pressure can then be modified to save energy.

Operational performance and water quality

Dissolved Air Flotation offers an excellent, economic and inherently robust method of clarification for most upland and stored lowland waters. Therefore, providing the treatment chemistry is correct, the deficiencies found in some existing plants can be basically attributed to errors in engineering the process. This has left the operator, albeit in a small number of cases, trying to improve performance by modifying the existing systems. The most common faults are a lack of air and removal of the float but hopefully the next generation of plants will encompass all the current experience and provide even more effective and cost efficient units.

In terms of operation the DAF process is in fact generally more robust than conventional clarifiers, in that it will readily withstand stop/start conditions, the ramping of flows and some variations in water quality. It has the added advantage in that it can be started and be
on-line within 30 minutes and can generally tolerate being out of service for several hours without any deterioration in water quality. This is particularly attractive for meeting diurnal supply demands and can often obviate the need for treated water storage.

Energy consumption is inevitably higher than conventional treatment, at around 20 to 40 kWh/ML and due in the main to the production and delivery of the recycle stream (38,39). Maintenance costs are also higher but at 1–2% of installed M&E plant, it is more than acceptable based on the higher hydraulic throughput. The move to hydraulic desludging has reduced the M&E content and therefore apart from pumps and compressors the only other items under routine maintenance are flocculators, instrumentation and possibly nozzles. The use of variable orifice nozzles allows the nozzles to be routinely flushed out whilst in service but the use of in-line strainers effectively reduces this task and therefore cleaning only becomes more frequent when the DAF plant is regularly taken out of service and floc is allowed to settle on the recycle nozzles.

The introduction of the combined DAF/filter process in the late 1960s was welcomed because the process offered significant capital and operational savings by combining the two processes. The sand filter also effectively corrected and masked a few operational problems in the DAF section. The only disadvantages were (a) a failure on one unit meant losing both a clarifier and a filter and this was considered to be a risk to supply if the site had less than four units and (b) the combined unit prevents the operator from modifying the chemistry between the two stages, e.g., to make the conditions suitable for catalytic removal of manganese on the filter.

Further enhancements, such as the application of ozone to the recycle have been developed in the ozoflot and flottazone processes. This technology has operational advantages in that in suitable applications the oxidation afforded by the ozone can be of particular benefit in removing higher percentages of algae and their metabolic (taste and odour) products. Under normal conditions DAF will remove more than 80% of the algal cells depending on the size, specific gravity and motility of the specie. The added benefit of pre-treatment is that in certain circumstances ozone or chlorine may help to immobilise the motile algae species and also dissociate the large and heavier colony’s, making it easier to remove these more difficult species by flotation (40).

Preoxidation with ozone or chlorine can also assist in the removal of particulate matter by altering the surface characteristics of the solids and enhancing bubble attachment. However, DAF is particularly good in capturing solids (80–90%), especially the finer solids. Although, it has been reported that floc particles less than 20 µm will not adhere to bubbles and removal is very poor as the particulate size approaches 1 µm. It is therefore essential that the chemistry, the coagulation and flocculation are effective in converting colloidal (and dissolved) solids into the correct size range.

The effectiveness of the solids capture is particularly reflected in terms of physical and bacteriological quality of the DAF clarified water. An efficient and well operated clarifier will generally achieve a clarified water quality of 1 NTU. Most DAF clarifiers readily attain this value with some exceptional examples averaging 0.5 NTU. The operation of mechanical surface skimmers or the start-up of a plant may cause short-term perturbations up to 2.5 NTU but this is usually short lived and the plant will quickly return to good quality conditions. The high solids capture in a DAF and filter stream can also be shown to be effective in reducing bacteriological counts and in one pilot trial that was devoid of disinfection Coliforms were shown to be absent in 87% of the samples (13) fed with source water containing counts of Coliforms and E coli, in the hundreds/ml range. The US Federal Surface Water Treatment Rule allows a cumulative credit of 2.5 log (99.7%) for removal of Cryptosporidium oocysts by DAF and filtration. This is similar to that received by conventional clarification and filtration, although experimental studies have shown that DAF
alone is capable of achieving up to 2.5 log removal of oocysts and with filtration consistently achieves 5 log removal. The concern over recycling Cryptosporidium oocysts with the filter backwash liquors has also lead to attention being paid to the specific treatment of these liquors. One clarification processes strongly recommended for the treatment stream is DAF as the Cryptosporidia are concentrated in the floated sludge and therefore can be removed in the sludge treatment stream.

The quality of DAF clarified water also provides economic benefits to rapid gravity filtration in that it permits greater throughputs and extended filter runs. It has therefore become economical to construct DAF treatment prior to filters in many plants that were previously planned to be solely direct filtration facilities.

However, solids and turbidity removal does vary with temperature and at low temperatures (<8ºC) the density of the water increases and separation efficiency may decline to a limited degree. The effectiveness of coagulation (based on residual coagulant), may also deteriorate due to a shift in the optimum pH conditions and a decline in the reactivity of certain metal coagulants. In these circumstances minor pH corrections can be beneficial in regaining optimum conditions and the addition of flocculant aids (polyelectrolytes) will help to maintain water quality and throughput.

Generally TOC and colour removal is superior at the lower coagulation pH values (<6.0). Therefore, ferric salts tend to be superior for removal of dissolved and colloidal organic matter in weakly buffered, upland waters but not nutrient rich lowland waters. The aeration afforded by DAF can also assist in removing certain volatile organics and producing an improved taste in the treated water.

Conclusions
DAF meets a range of high performance criteria better than most other clarifiers for upland and stored lowland waters. It is a high rate clarifier, which despite it’s relatively high mechanical and operational complexity, is a reliable, robust and economical attractive water treatment process. The ease at which the process may be started and the ability to vary flows in a short period makes DAF very attractive for meeting changing diurnal or seasonal supply demands.

The relatively higher operational and maintenance costs are effectively recovered by the significant higher hydraulic loadings that can now be achieved in these plants and the previous cost penalty of having to cover the DAF cell has also been gradually diminished by the move to cover all potable water treatment facilities to protect the integrity of the supply.

DAF has therefore achieved an extensive record of success in water treatment and although it may be considered a mature technology, there is still considerable scope for research and development to make the process even more efficient.

References
_AQUA FENNICA_, 18(2), 113–123.


