

THE ROLE OF CHEMICALS IN THIS THIRSTY PLANET

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Abstract

As all the chemical elements and most of their attributable compounds are known there is little scope for further discovery in the science of ‘inorganic’ chemistry. ‘Organic’ chemistry is much more exiting as it is based on carbon which can polymerise into a multitude of different compounds and different shapes. Because the number of carbon-based molecules is huge and increasing at the rate of 30,000/year, the discovery and development of new carbon compounds is inevitable, and some of these will be useful to the expansion of desalting technology.

The single greatest advance in ‘water technology’ has been the addition of chlorine to drinking water; a breakthrough ranked as one of the greatest scientific achievements of all time. Modern membrane technology is newer than chlorination and although ‘Osmosis’ was recorded by Frenchman Jean Nollet in 1748, it was more than 200 years before ‘Reverse Osmosis’ became practical following pioneering work by Sidney Loeb and Srinivasa Sourirajan. The development of the desalting membrane was a true scientific blend of physics and chemistry.

The cost of desalted water has fallen steadily as desalting technologies became more efficient. This paper reviews what major improvements are due to chemicals and asks the question ‘how much further can we go’? The author feels that the ‘great’ chemical discoveries are in the past and this thirsty planet will need to look elsewhere to sustain our insatiable demand for fresh water as chemicals alone are unlikely to result in a quantum improvement in desalting technology. Although technical knowledge doubles with each generation it is a brave man who will dare to predict what the IDA conference will be discussing just 25 years from now, never mind in 2111?

The paper suggests that the biggest scope for ‘chemical’ improvement in membrane operation is with better cleaning formulations and application procedures. Jointly these will reduce system outage, increase water production and extend membrane life, and above all reduce operating costs. Ideas on improved membrane cleaning are dealt with in some detail assuming that every membrane starts fouling the instant water passes through it. It is not easy to quantify the benefits in changing cleaning procedures from today’s well-entrenched methods. Other chemical aspects of membrane technology are likely to be close to maturity apart from better pre-treatment design and operation and improvements in materials science.



1 THE DISCOVERY OF THE CHEMICAL ELEMENTS

Plato was the first person to use the word '*element*' and in Greek mythology the elements were known as earth, fire, water, wind, or ether. The discovery of the elements and understanding their properties in many ways mirrors the development of mankind. Carbon is the first element to be known, dating from when man first used fire. Copper was known to the Chaldeans in Iraq more than 12,000 years ago, and together with tin (identified by the Egyptians) formed the basis of the Bronze Age. Iron, used during the Iron Age, was first purified by the Hittites in Turkey and the Egyptians some 4,500 years ago. By the time of Christ eleven elements were known, including the precious metals gold and silver. There followed a long period of inactivity, with arsenic, bismuth, phosphorus and platinum being identified in the next 1700 years. Figure 1 show the time-line for element discovery and identification.

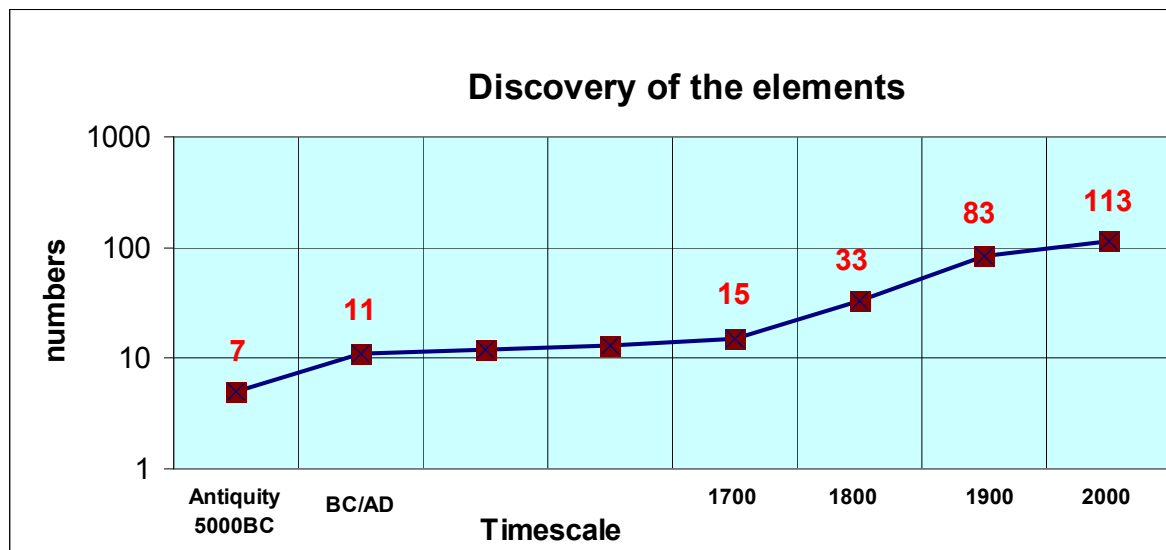


Fig 1: time scale (log) of element discovery

The seventeenth and eighteenth centuries were the age of scientific discovery, with a surge in knowledge driven by the scientists of the day such as von Weisbach, Ramsay, Travers, Currie, von Humboldt, Cavendish, Priestley and others. One of them was Mandelejev who produced the 'Periodic Table of Elements' (see figure 2). In 1871 Mandelejev predicted the existence of Gallium, Scandium, Germanium and Protactinium, four elements later discovered by other researchers. Mandelejev was honoured when element atomic number 101 was named after him. By 1900 most of the elements had been identified.

It may be assumed that no further elements of relevance to us will be found. If we ignore the radioactive elements and the noble gases there are eighty elements that can be reacted together to form compounds. Although this number is limited it can still produce a dazzling array of combinations. A quick look through Wikipedia or any good search engine will show how much technology exists about many of these little known of elements.

1.1 Organic Chemistry

Carbon is the 15th most abundant element on earth and the 4th most common in the Universe. Carbon forms as the three allotropes of graphite, diamond and amorphous carbon; there are more than 3 million carbon based compounds known, and new organic substances are identified at an enormous rate. The

name ‘organic’ originated because our forefathers thought carbon could only be obtained from matter that had lived. It was later discovered that this was not true.

1 H 1.0079																	18 He 4.0026
3 Li 6.941	4 Be 9.0122											13 B 10.811	14 C 12.011	15 N 14.007	16 O 15.999	17 F 18.998	10 Ne 20.180
11 Na 22.990	12 Mg 24.305	3	4	5	6	7	8	9	10	11	12	13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.065	17 Cl 35.453	18 Ar 39.948
19 K 39.098	20 Ca 40.078	21 Sc 44.956	22 Ti 47.867	23 V 50.942	24 Cr 51.996	25 Mn 54.938	26 Fe 55.845	27 Co 58.933	28 Ni 58.693	29 Cu 63.546	30 Zn 65.38	31 Ga 69.723	32 Ge 72.64	33 As 74.922	34 Se 78.96	35 Br 79.904	36 Kr 83.798
37 Rb 85.468	38 Sr 87.62	39 Y 88.906	40 Zr 91.224	41 Nb 92.906	42 Mo 95.96	43 Tc -	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
55 Cs 132.91	56 Ba 137.33	57-71	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po -	85 At -	86 Rn -
87 Fr -	88 Ra -	89-103	104 Rf -	105 Db -	106 Sg -	107 Bh -	108 Hs -	109 Mt -	110 Ds -	111 Rg -							
57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm -	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.05	71 Lu 174.97			
89 Ac -	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np -	94 Pu -	95 Am -	96 Cm -	97 Bk -	98 Cf -	99 Es -	100 Fm -	101 Md -	102 No -	103 Lr -			

Fig 2: The periodic table, after Mendeleev

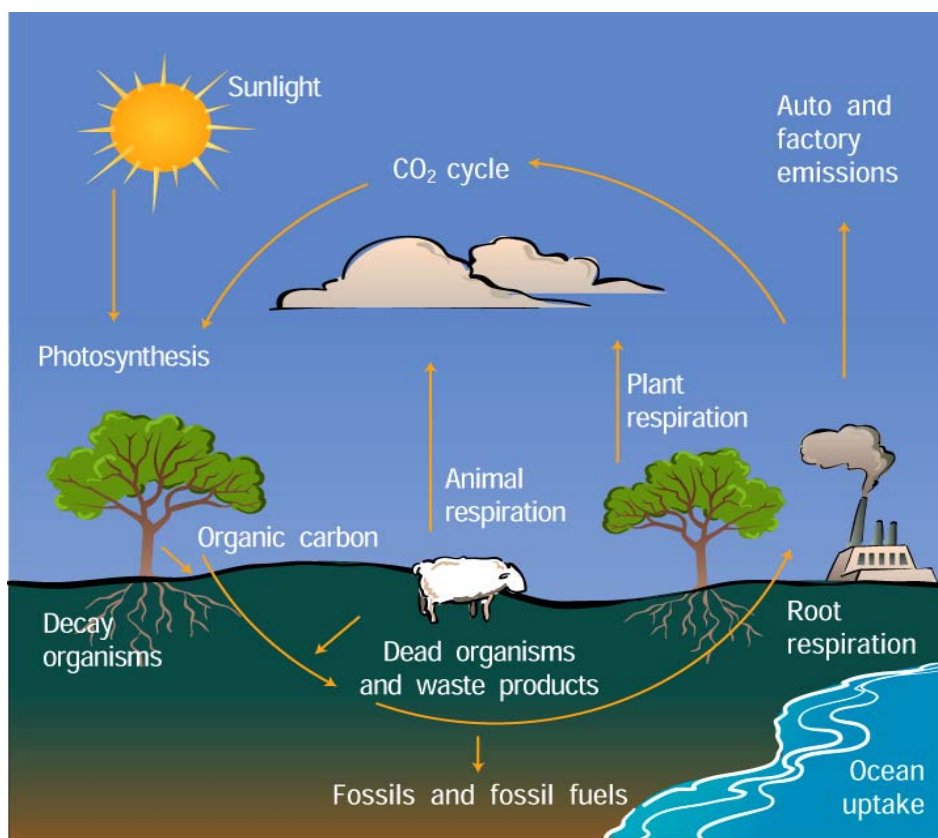


Fig 3: the carbon cycle

Carbon based molecules form the basis of most of what is important today, foodstuffs, medicines, fuels, animal and plant life and humans themselves. We should all be aware of the carbon cycle (see fig 3) as it clearly shows how carbon is recycled within our planet and as such is the cause for global warming as ever increasing amounts of carbon dioxide are released into the atmosphere. In many ways the carbon cycle can be compared with the water cycle; just as there is only a fixed amount of water on Earth so there is only a fixed amount of carbon our planet.

The reason for so many carbon containing chemicals is the number of carbon based structures that can exist. Figure 4 shows an example based on butane, with the simplest being a straight chains *n*-butane although branched chains such as iso-butane. Carbon also forms as rings, the most common of these being benzene:

Common name	normal butane unbranched butane <i>n</i>-butane	<u>isobutane</u> <i>i</i>-butane
IUPAC name	butane	methylpropane

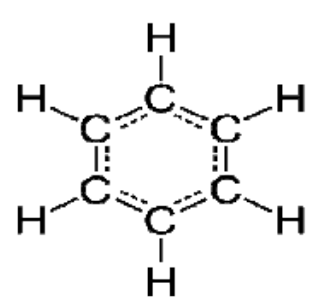
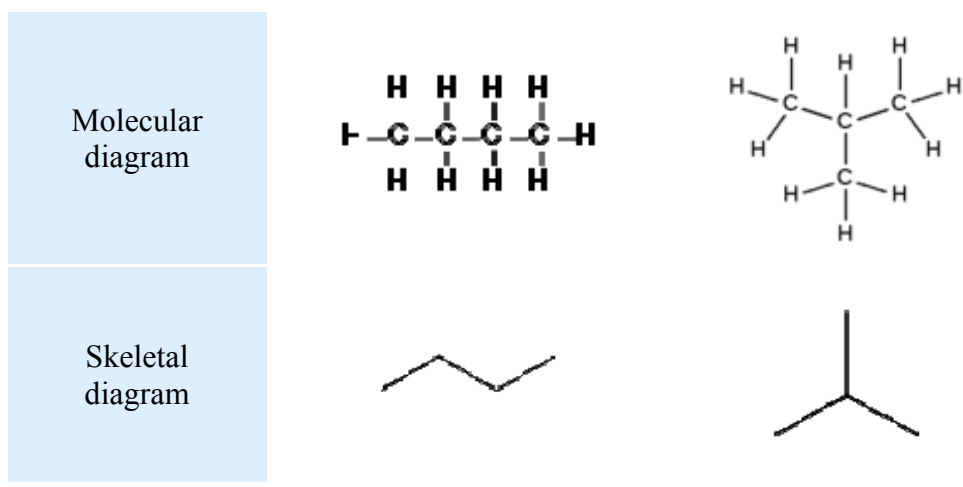


Fig 4: carbon structures, linear, branched and ring.

Carbon also forms as fullerenes, which are structures made entirely from carbon in the form of hollow sphere (figure 5A), ellipsoid, or tube (figure 5B). These fullerenes have amazing properties and are already considered the wonder products of the future.

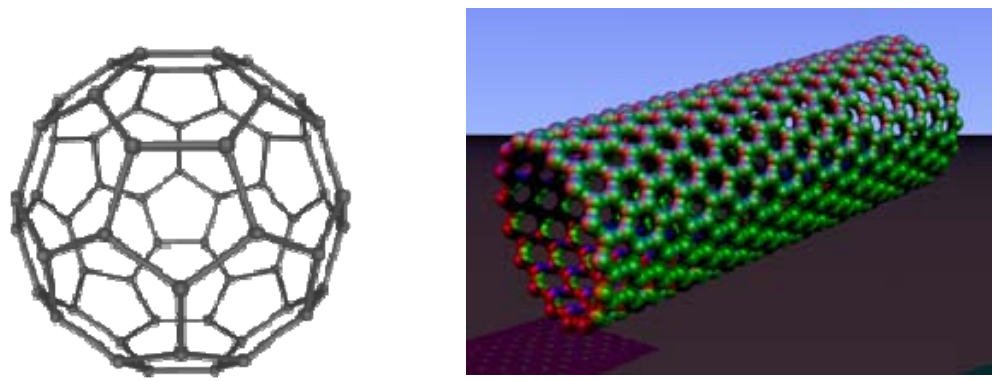


Fig 5A and 5B: spherical and tubular fullerenes

Carbon reacts with many other elements as shown in figure 6 below.

The author feels that future improvements due to chemicals in the desalting industry will come from carbon based molecules and not inorganic compounds, because organic chemistry has a greater capacity

It was left to Harm and Rümpler, two German scientists to prepare the first inorganic ion exchanger in 1903.

In the last 50 years the world's population has doubled but water consumption has quadrupled. There are acute water shortages today, but as Moses knew full well.....nothing changes very much!

Forty years ago, when membrane technology was in its infancy, Dr O.J.Vetter [ref.1] wrote "Scale Inhibition is still closer to being an art than a science". The science of scaling and inhibitory processes has advanced, but water is such a unique solvent there is still enough of the 'art' remaining to make it a fascinating subject.

Modern desalination had its origins in the industrial era that led to the age of steam. In the nineteenth and early twentieth century the 'superpowers' were engaged in a huge warship building programme. For 150-years the world's navies were powered by coal fired steam boilers. To provide boiler feed water when away from port led to the development of the submerged tube evaporator. Seawater was boiled and evaporated using boiler waste heat; the steam from the flashing brine was condensed as pure water for boiler feed and potable water. The system was inefficient and the evaporators suffered massive scale build up problems. The first patent for reducing 'incrustation' in steam boilers was taken out in 1846 [ref. 2] and in 1939 Hatch & Rice [ref.3] recorded the threshold properties of polyphosphate. This latter development was highly significant as in many ways it forms the basis of today's scale inhibition programmes used in all forms of water treatment.

In the 1950's and 1960's Professor Bob Silver and other engineers developed the concept of flashing chambers, each flashing distillate at a lower pressure than its predecessor. The seawater was heated in a heat exchanger within the flashing stage, thus ensuring an efficient heat exchange system. By 1970-1975 the first large 1mgd units were being installed in Kuwait, Abu Dhabi and Saudi Arabia. They worked well and although other thermal processes were used (vapour compression, falling film evaporators, rising film multi-effect etc.) the Multi-Stage Flash evaporator became the workhorse of the Middle East sea water desalting market for the next 25 years.

Early Multi Stage Flash (MSF) evaporators like those at, Jeddah, Al Khobar and Abu Dhabi, operated with a top brine temperature of 121°C using sulphuric acid treatment (pH control) to prevent calcium carbonate and magnesium hydroxide scale formation. At this temperature the use of sulphuric acid invariably led to calcium sulphate scaling in brine heaters and severe corrosion in the flashing brine stages, which even copper, cupro-nickel and stainless steel, had difficulty in eliminating. Consequently top brine temperatures were reduced to ~112-115°C and within 5 -10 years pH control was replaced by polyphosphate or advanced polymer antiscalants.

The Reverse Osmosis industry came of age at around the same time as the MSF industry. Whereas MSF was used exclusively for seawater desalting, early RO plants were used exclusively with brackish water. Seawater RO has only truly come of age in the past 15-20 years due to improvements in membrane salt rejection, the advent of energy recovery devices and improved pre-treatment systems. The first commercial membranes were made of cellulose acetate requiring a low pH feed water to maintain membrane integrity; low pH operation prevented calcium carbonate scaling so early scale treatments consisted of acid addition sometimes supported by sodium hexametaphosphate (SHMP) addition. The advent of the polyamide membrane operating at neutral pH values and higher rates of recovery needed more effective antiscalants.

By the end of the 21st century both acid and SHMP treatments had been mainly replaced by [ref. 4] phosphonic and polymeric based scale inhibitors (see figure 7) in a membrane antiscalant market, valued at \$250 million and growing at ~10% per annum. [ref. 5]. Although the market share of acid and SHMP has declined sharply in the last thirty years there will always be a need for acid in pH sensitive membranes, whilst sodium hexametaphosphate is a cheap antiscalant for ‘easy to treat’ waters.

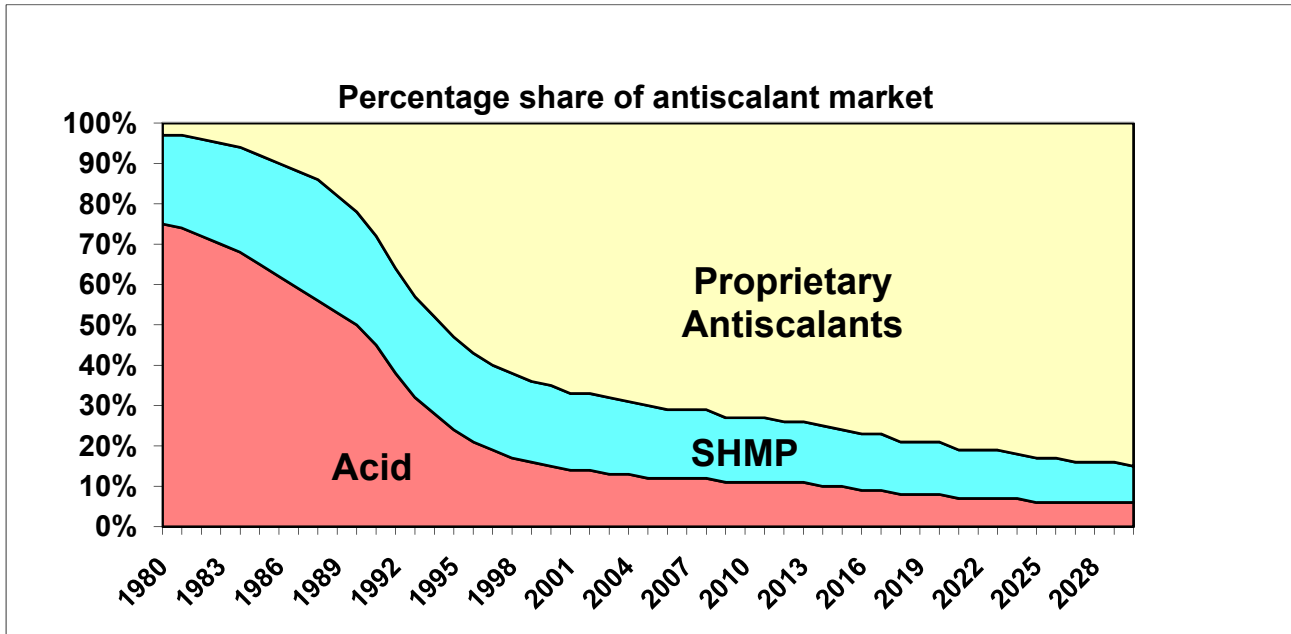


Fig 7: Market share of antiscalant chemicals between 1980 - 2030

2.1 The Development of Antiscalants: a Historical Review

The desire for lower water production costs is the main driving force in the development of chemicals used by the membrane industry today. Technical improvement and regional legislation are also important driving ‘forces’ but are not mutually compatible with the primary requirement of reduced water costs. The continual demand for improved membrane efficiency and ever-lower operating costs require an improvement in the performance of commercial antiscalants so the service companies are changing the way formulations are developed and sold. Of the chemical groups shown in fig 7, advances in antiscalant chemistry has had the greatest impact on ‘cost reduction’ by allowing systems to operate with ever deteriorating water quality at ever-higher recovery rates.

The water treatment and detergent industry are huge users of scale inhibitors. In the water treatment industry antiscalants are required for, boiler water, cooling water, enhanced oil recovery, thermal desalination and membrane processes. Although there are numerous antiscalants in use today, the market is dominated by a few specialised service companies whose products are marketed and sold internationally.

In the 1930's Langelier, working for the AWWA, defined calcium carbonate solubility in an equation called the Langelier Saturation Index (LSI) (Ref. 6). Although Ryznar, Puckorius and others made later modifications to the LSI calculation, the original LSI equation remains the basis of predicting calcium carbonate scaling potential.

Antiscalant technology used in the early days of membrane operation was borrowed from the boiler-water and cooling-water industries. Although most antiscalant formulations used today are based on either phosphonate or polymer chemistry; compounds have also been synthesised combining the features of both these chemical groups. Since polymers and phosphonates were first manufactured there has been a significant improvement in their performance. Not only are the manufacturers producing purer and more active products, but the service companies are more adept at making synergistic formulations of two or more of these raw materials. Despite these improvements there has not been a major chemical innovation in the water treatment industry for almost fifty years.

Chemical producers tend to restrict chemical research into their own field of expertise. This tends to limit the discovery of new molecules as the raw material manufacturers become more and more specialised. Service companies like Genesys International Ltd take raw materials from many manufacturers, and develop synergistic blends for specific applications.

The cost of *new* product development is increasing sharply and fewer and fewer service companies are doing basic chemical research or even making detailed application studies. Consequently, innovation is lacking in the market-place with many companies merely copying the work of the market leaders, which is relatively easy to do nowadays as health and safety requirements frequently require the complete disclosure of formulation data. Patents are seldom an option for the Service Company and although Trademark registration gives some protection, the sale of low-price copycat products is widespread.

The membrane market is changing in character with the use of membrane bio-reactors and the increasing use of micro-filtration and ultra-filtration membrane technologies. Water production costs are falling due to energy-efficient membranes, high flux membranes with improved salt rejection, and high-pressure seawater membranes. The quality of water at source is deteriorating due to global industrialisation and the contamination of ground waters.... and the demand for desalinated water continues to grow at around 10% a year. Water remains essential to mankind's wellbeing despite today's global recession.

Potable water applications demand the highest standards of health and safety whilst chemical handling, storage, transport, product labelling, discharge restrictions, toxicological and environmental impact are important issues in the 21st century. Chemicals that can meet the needs of enhanced membrane performance have fallen foul of restrictions and a host of approvals, endorsements and registrations.

3. HOW CAN CHEMICALS IMPROVE MEMBRANE EFFICIENCY?

There are five categories of chemicals used in any membrane system. A summary of these together with technical know-how and customer support are show below.

3.1 Coagulants and flocculants

These are used to improve system pre-treatment, ensuring the feed water has a silt density index (SDI) suitable to meet the criteria given by the membrane manufacturers.

Many large membrane systems have complex pre-treatment systems. The author feels that many of these systems operate less efficiently than intended, or as designed, and optimising their performance is frequently a major challenge. There are hundreds (even thousands) of flocculants available for use in aqueous and non-water related technologies. Many of these could have excellent application within the desalting industry but the difficulty of evaluating flocculent performance has excluded them. In recent times the use of Particle Counters mean that much of the ‘field’ work that had to be carried out on site can now be done more accurately within the confines of the laboratory. Although the days of doing on-site jar tests are behind us, we still need the technician to do the tests and interpret the results. Work with the Particle Counter when combined with simple membrane autopsy has confirmed that certain cationic flocculent structures can be safely used without irreparable membrane damage [Ref. 7].

There remains plenty of scope for improving the pre-treatment of most systems as very few are working anywhere near their optimum efficiency. Chemicals may well play their part: a recent paper by a team from Rice University, USA, and Monash University, Australia report that a nanomaterial graphite oxide improves sand filtration fivefold [Ref 8.].

3.2 Membrane Antiscalants

Antiscalant additives are used in the membranes themselves, inhibiting all the common scaling species.

Antiscalants have probably been improved as far as far as possible and additives are available for all the common scaling species. This does not mean that membranes will be scale-free for evermore; many systems use incorrect or poor products or the correct product is poorly applied. The drive to reduce operating costs has led to many poorly-operated systems using inferior antiscalants, where the operator feels this is normal or the best that can be achieved.

3.3 Membrane Cleaners

There is plenty of room for improvement in membrane cleaning and the following membrane parameters should be considered:

- More effective cleaners. Although some work has been started on the rate of membrane re-fouling following cleaning, much remains to be done. There are great benefits in extending the time between cleaning cycles. There may be financial savings in cleaning more frequently; operating with a ‘cleaner’ membrane gives a reduction in pumping costs, and a foulant that is far easier to clean – see later. It is probable that electrical costs will become more important as energy prices increase.
- Multipurpose formulations. At present, alkaline, acidic and biological control cleaning programmes are carried out separately. Imagine the benefit of a single clean that will remove all foulants; the saving in plant outage and chemical usage would be considerable.

- Shorter cleaning times. With large systems there are significant advantages in reducing the cleaning time. Many of the alkaline cleaning formulations in use require long contact times (4 – 10 hours) to be effective, which when combined with heating system requirements and extensive flushing programmes can lead to outages of up to 24-hours or more, with the associated loss of production. There is considerable scope for shortening cleaning times.
- “Greener” products. Most of the cleaning formulations are discharged to waste. As these are predominantly based on alkalis or acids or oxidizing and chelating agents there is scope to make more environmentally friendly products.
- Products less reliant on temperature and pH changes. Most cleaning chemicals are more effective at extremes of temperature and pH. Cleaning programmes running at more neutral pH values and ambient temperatures usually need longer contact times. However cleaning chemicals that are effective at more pH neutral value would be environmentally more acceptable and would please the membrane manufacturers.
- Cheaper membrane cleaning programmes. There is much to consider here, and the developments listed above are unlikely to result in cheaper cleaning programmes. There has to be a balance between the needs and actual cleaning costs. The true cost of chemicals is known; what is not clearly understood is how much energy (if any) is saved by cleaning more frequently, or the savings in membranes themselves, or savings in chemicals. Shorter cleaning times reduce plant outage and increase operation time, a saving that should be balanced against more or less chemical usage.

The following section of the paper looks at one way the author believes significant cost savings can be made with membrane cleaning, at the same time satisfying some of the environmental and safety issues that exist. It is also known that more stringent rules concerning the handling and use of chemicals are anticipated.

Consider figure 8, which measures fouling with time. The perception line indicates the border at which the operator ‘perceives’ a change to system operation, whether this be a change in flux, pressure, or salt passage. In fact as soon as water passes along the membrane (initial time = T_0), the membrane starts fouling. It is important to appreciate this fact; the membrane is fouling from system start up, but nothing is observed until the fouling line crosses the perception line, at which point the observer can see there is some change in the operation. The membrane is like a huge sponge with myriad active surfaces, so a significant amount of surface fouling can take place before any operational change is observed. It is recommended that the operator starts cleaning when one or more of the main observation parameters have changed by 10-15%, although most operators delay the start of cleaning.

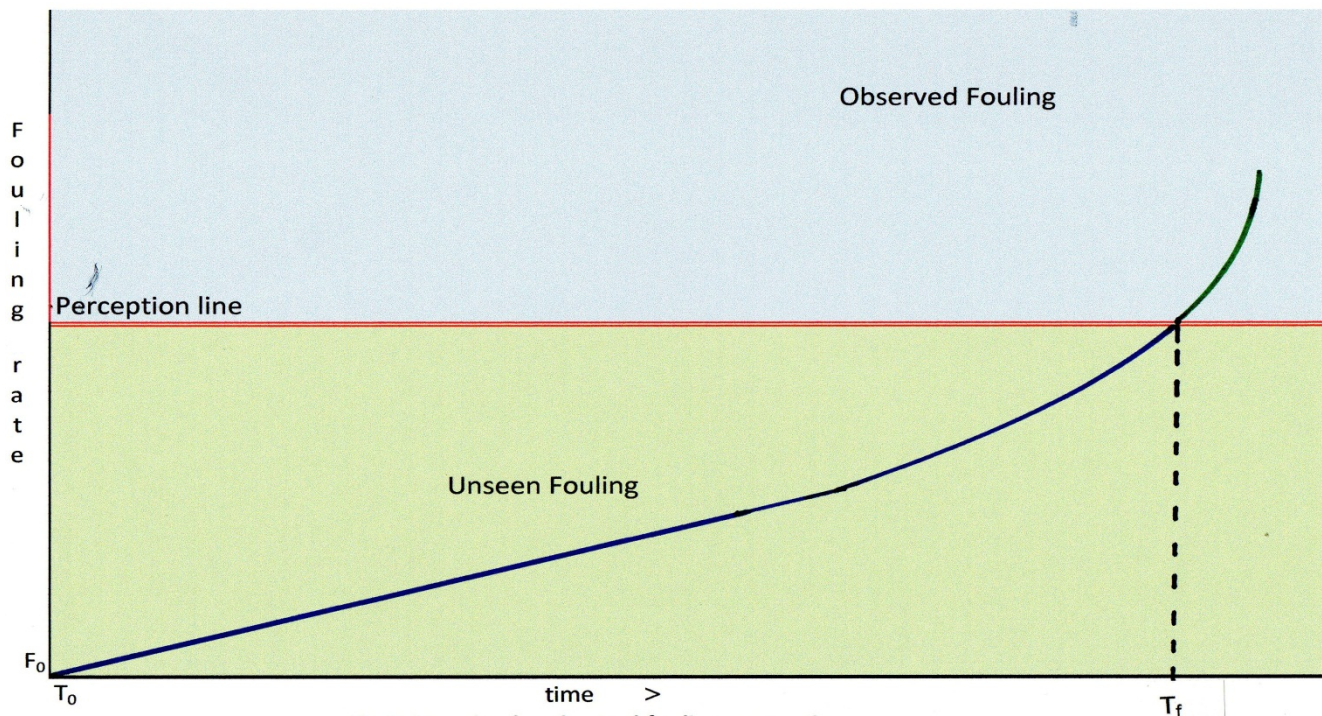


Fig 8. Perceived and actual fouling rate v. time

Laboratory studies from numerous autopsies have confirmed that the sooner the membrane is cleaned after time T_f the easier it is to clean. If the foulant is not cleaned it becomes more difficult to shift, until finally the membrane cannot be cleaned at all.

Figure 9 below shows a typical cleaning schedule for a fouled membrane system. Assuming cleaning takes place when the observer notices change at the 'perception line' the membrane is rarely cleaned to its original cleanliness. After Clean 1 the membrane starts fouling again but this is not observed until the fouling appears above the Perception Line again; some while later Clean 2 takes place and the procedure is continually repeated.

The weakness of the typical cleaning procedure is that all cleaning takes place at or around the Perception Line. It would be far preferable to clean much sooner as indicated in figure 10 below.

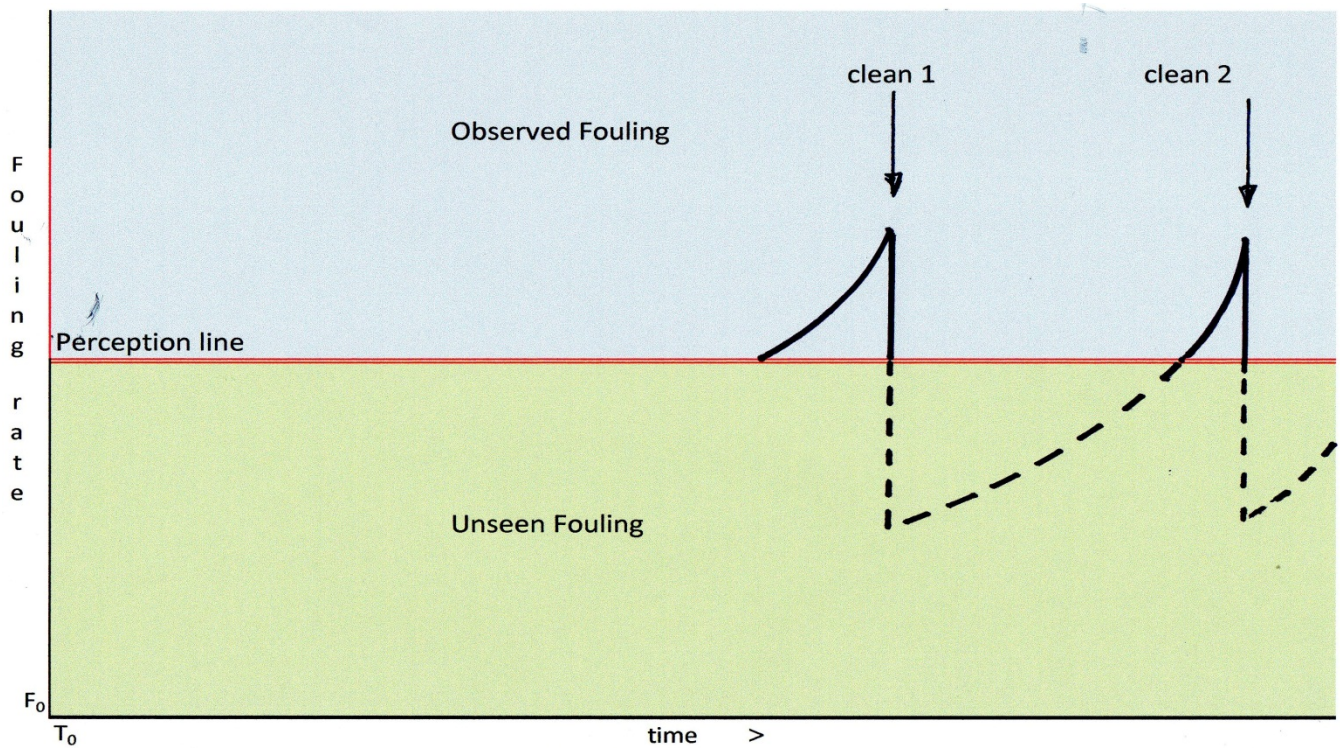


Fig 9. Typical cleaning schedule

The main advantages of cleaning before the system appears to need it is that the foulant is easier to remove and ‘softer’ cleaning solutions can be used thereby avoiding extremes of pH and temperature and reducing plant down time with a consequential saving in energy and water produced, not to mention extending membrane life. Work is progressing well to develop new membrane cleaners that can be used in protocols as indicated in figure 10.

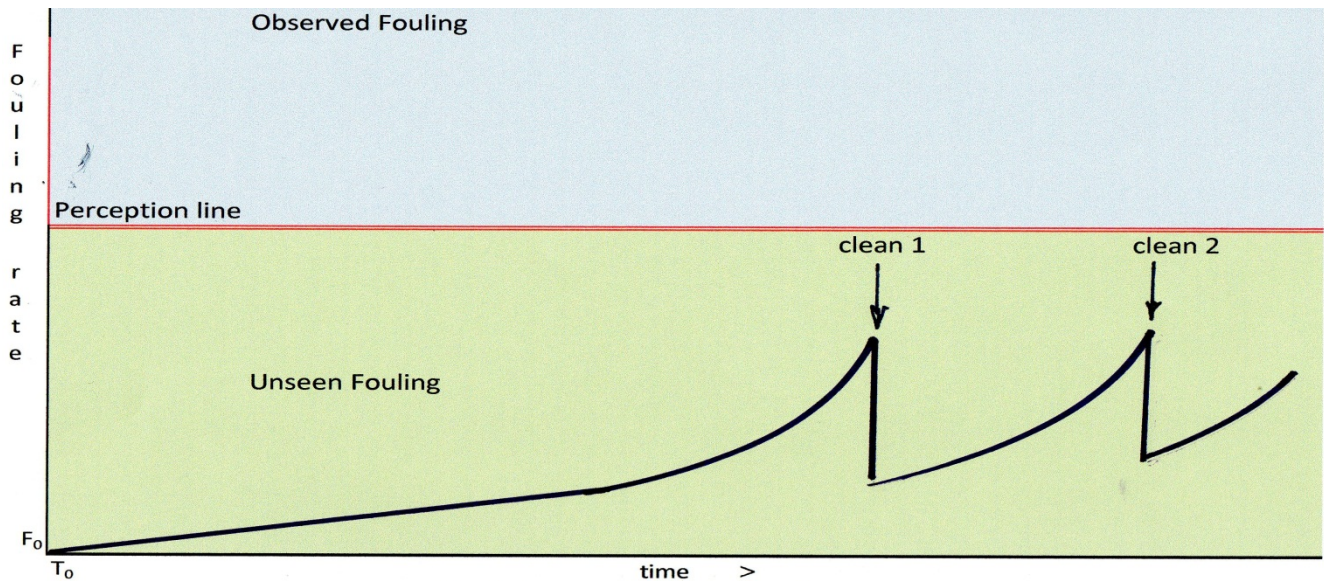


Fig 10. Proposed cleaning schedule

It may seem counterintuitive to clean a membrane before standard limits are reached in terms of flux, pressure etc. but it is thought that over the lifetime of a membrane element, cleaning frequency could actually be reduced. The one missing piece of data from the puzzle is the ability to calculate the actual fouling rate of the membrane in its semi-clean or indeed semi-fouled state.

3.4 Product water treatments

Although the requirement for chemical treatment of permeate water depends on water usage, it includes chlorination, hardness addition (in the case of potable water) and possible corrosion inhibition. It is unlikely (never say never!) that there is much in the way of improvements to be made to product water additives. In the case of potable water the World Health Organisation (WHO) recommends what mankind should or shouldn't drink with respect to the minerals present. At present potable water needs some calcium, bicarbonate, a pH limit and some small chlorine residual for sanitisation.

3.5 Biocides

Biocides are used within the pre-treatment system and sometimes within the membranes themselves. There is a huge potential for membrane compatible biocides, as bacterial fouling of membrane surfaces is an on-going and pervasive problem.

The benefit of replacing chlorine with a non-oxidizing biocide in a polyamide system is enormous as it would permit some level of sterilisation on the membrane itself. Even if membranes were bacteria-free, this would not guarantee a clean surface. Although chlorine is a highly effective biocide, readily available and cheap to use, as an oxidant it is damaging to the membrane. All biocides being biocidal need to meet the European Biocide Regulation (ref 7) and the new REACH legislation (ref 9).

In the USA and many other markets formulation details have to be declared on the chemical container so there is little encouragement for new product development. Whenever new legislation is enacted biocides are the first group of chemicals to be affected and although there are already some membrane compatible non-oxidizing micro biocides available it is difficult to see how they could gain widespread acceptance in the market place.

3.6 Know-how and technical support

Many different engineering disciplines are involved in all RO systems include plant designer, membrane supplier, chemical supplier and of course the operator. Which of these has the best overall knowledge and know-how of the operating system?

User help and support exists in all shapes and forms. The author considers that support services are essential. In a global industry where it is always possible to 'buy it cheaper' the concept of top-quality back-up support will set one service company apart from another.

4 THE FUTURE OF OUR INDUSTRY

Life Magazine cited the filtration of drinking water and the use of chlorine disinfection as 'probably the most significant public health advance of the millennium', coming 46th in a list of 100 greatest historical events, ahead of DNA, X-ray, anaesthetics, and food storage. Whilst there is no doubt that chlorination

has saved millions of lives, it does not enjoy the fame and favour it once did, and questions are being asked about its reactivity with trace organic chemicals and the formation of halogenated by-products, their role as carcinogenic precursors and their impact on health. We must remember that what was once considered the best and latest technology in the earlier centuries is being shunned today, for example, asbestos, formaldehyde, mercury, tobacco, radio waves etc.

It is said technical knowledge doubles every ten years. Jonathan Huebner a physicist working at the Pentagon's Naval Air Warfare Centre in China Lake, California studied the number of scientific and technological advances made since the Reformation in proportion to global population. His prognosis, (ref. 10) indicated that the rate of innovation peaked in 1873 and has been in decline ever since. The rate of innovation/head of population in 2005 is similar to the rate of innovation in 1600. The graph below shows 'significant innovation' per head of population based on data available in a standard work entitled "The History of Science and Technology".

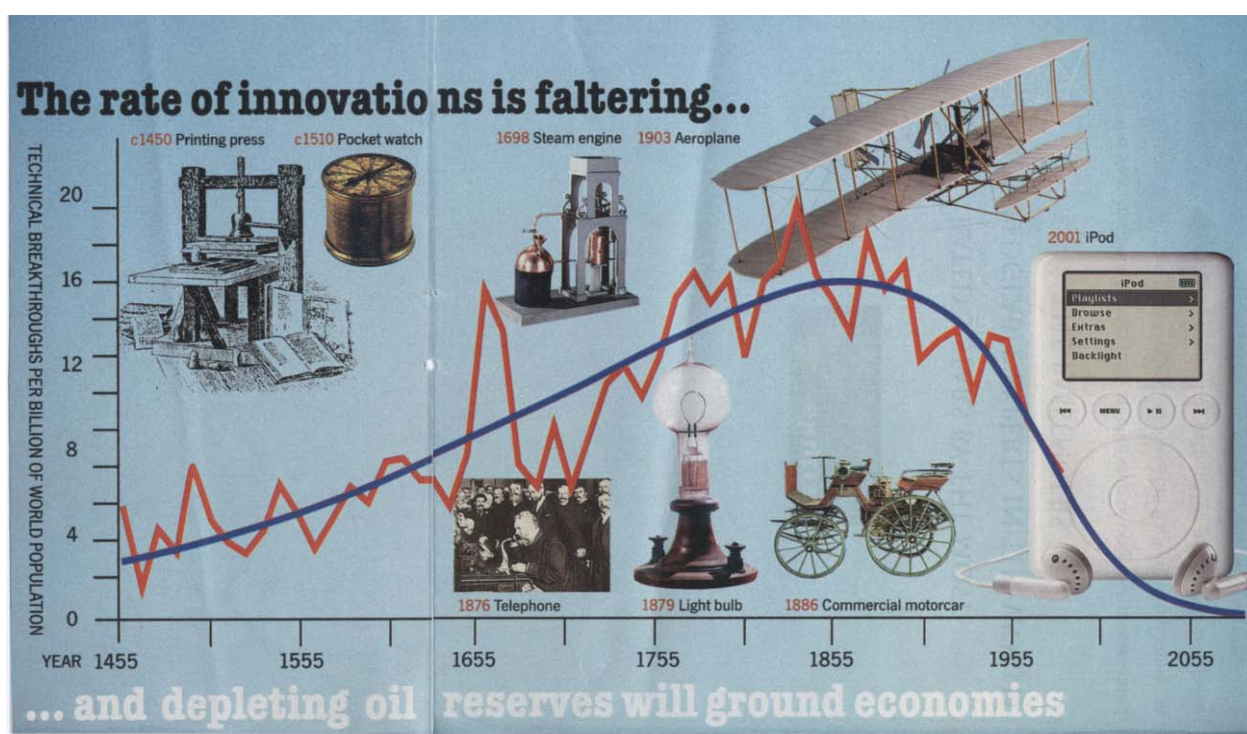


Fig 11: Rate of significant innovation/capita since the reformation

When we study innovation in the water treatment industry, chemistry or engineering, one finds a decline similar to that observed by Huebner. The two innovative water purification processes of the last century were thermal evaporators designed and developed by Professor Silver and others some 50 years ago and the development of the Loeb-Souririjan membrane around the same time. It can be argued that the MSF evaporator is merely an improvement of the submerged tube evaporator. Although advances have been made in construction materials and system design but there has not been any new seminal innovation in desalination in half a century, has there?

4.1 Legislation

4.1.1 The Chemical Industry of the future.

During the next thirty years many changes to the membrane and chemicals market are expected. These fall into two types, those based on improved technologies and those imposed by national or international legislation

The use of chemicals is an inherent part of the desalting process. Although desalting is a blessing to mankind, chemicals do not always enjoy a good press. Recent legislation concerning the use and discharge of chemicals, and biocides in particular, will surely delay new product development.

4.1.2 The European Union Biocides Regulation

The Regulation came into force in 2000 and is an example of imposed International Legislation whose impact could have been dramatic. The Directive will lead to the elimination of ‘eco-unfriendly biocide actives’, a move that is surely beneficial to the environment. Consequently fewer multi-functional blends are now available, even if these are based on acceptable raw materials. Furthermore, the Raw Material manufacturers consider products sold in small volumes to be uneconomical to support, and some of these have disappeared from everyday use. The future development of new and improved biocides is unclear. A completely new biocide costs between \$5-\$10 million to bring to the market, and it then takes five years or more to obtain the appropriate registrations. Thus there is no solution in sight for the problems of membrane biofouling other than better design and improved operation.

4.1.3 New European Law

At the end of 2005 the European Parliament approved a law that will force companies to test thousands of chemicals – many used in common household products like paint, cleaners, toys and furniture – for their effects on human health and the environment. The law has been described by the European Union industry commissioner as “possibly the most controversial and complex piece of legislation in European history”.

Known as REACH, or the Registration, Evaluation and Authorisation of Chemicals system, the law moves the burden of proving that chemicals are safe on to industry. At present, the burden of proof lies on national and European regulators, who are obliged to demonstrate that suspect chemicals are unsafe. This law affects about 90% of chemicals in everyday use, including most of the Genesys product range. It is estimated that some 30,000 chemicals will need to be registered with the new European Chemicals Agency. The law came into force in 2007, after which manufacturers will have between seven and eleven years for product testing. The European Commission has estimated that the total cost of REACH will be between \$2.5 billion and £5 billion. Who will pay for it? We all will!

We can envisage a market, thirty years hence, where the end-user will not handle any of the chemicals they use. Everything will be outsourced with the supplier bringing chemicals to site, using automatic handling equipment and then removing chemical waste and empty chemical containers. The supplier will probably require a license to be involved in the supply, handling and removal of chemical wastes and although it will become a safer world for all, but at a significantly higher cost to the system operator.

CONCLUSIONS

Good quality water is becoming an ever-scarcer material. To meet short-term global demand for good quality water at lower costs there must be continued growth in all forms of desalination. As the quality of water supplies deteriorates there is a greater need for more recycle and effluent treatment, which in turn demands more effective chemical treatments. Although legislation tends to slow-down pure chemical research and development, advances in technology will keep pace with market demand in the short term. This is particularly true of the membrane chemicals market over the next 20-30 years.

Figure 12 below shows the writers view on how the state of the RO industry may be judged in 50-years' time when considering chemical adjuncts. Some sectors such as potable water treatments and antiscalants are reaching maturity, whilst others, cleaners in particular, offer scope for great improvement.

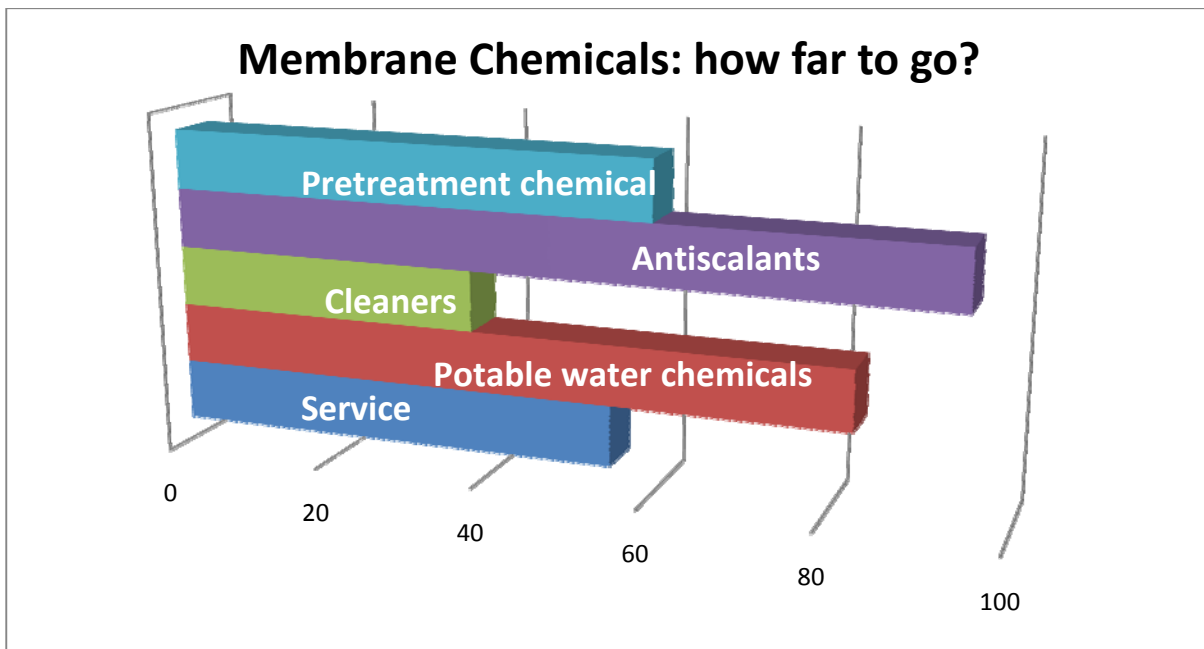


Fig 12: Chemical progress in the next 50 years

Chemicals do not enjoy a good press, yet we cannot survive without them. Although issues of 'climate change' and the acidification of the world's oceans will impact on mankind one day, global legislation is being enacted now which will change the way we live and work and will have a massive impact on the use and discharge of chemicals, which will certainly push up the cost of desalted water.

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