Advantages And Disadvantages Of Re-cycling Water To Help Maintain Australia Water Supply

Introduction:

Water is one of the fundamental necessities that all living organisms require in order to survive. It is one of the essential foundations that can potentially determine a population's quality of life, economic growth and surrounding natural environment. The quality and supply this water holds is significant to all who use it; from humans and animals to even plants. As Australia is a country that experiences a variety of weather conditions which have previously affected the nation's water reserves on several differing occasions; including but not limited to, the 2011 floods, recent droughts and minor dust storms in rural areas. The need to maintain and preserve (if not increase) the amount of potable water available to the general population is at an always increasing high. Currently, all throughout Australia it has been recorded that droughts, floods, and fires have been endured for millennia. (Patrick baker, 2019). From having been labelled as the driest continent on earth(Gagovau, 2019), there is no doubt that change needs to occur in the near future. As shown in the diagram below, the substantial land mass of Australia is currently suffering from severe and/or serious deficiencies on natural rainfall as recorded for over a period of 4 months. Having known this information, a plethora of waste-water is still continually disposed from households, industries and businesses daily. This waste-water excreted, is then treated to be returned to public waterways rather than being used in a more efficient manner.

Figure 1: Rainfall Deficiencies – 4 months (Bomgovau, 2019)

It has only been recently that the government's strict guidelines of water usage have been halted.After being implemented since the early 2000's, these restrictions are still in place in certain areas of the continent where the driest weather conditions apply. Researchers and environmentalists do not wish to have these guidelines re-enacted and have proposed that the re-cycling of wastewater be considered along with several other solutions. However the solutions that have been suggested are as varied and controversial as the general public's views and beliefs on it. This is mainly due to the lack of knowledge on the matter of water recycling and the current water guidelines already enacted. The highly inaccurate assumptions the general population have acquired over time are false and far from true. After appropriate treatment, waste-water can easily become potable for human consumption if a suitable method is applied. (Recycledwatercomau, 2019) Enabling this method of water preservations, would be able to ensure that Australia's water reservations are reliable and have the ability to become a future 'investment' of sorts. In this report, the process of recycling waste water and the methods involved in hygienically and safely cleansing it will be discussed in detail. Proving as to whether or not recycled water has the ability to be a viable option for the future.

Treatment Processes:

To effectively and hygienically cleanse waste-water to a standard for human consumption, multiple treatment barriers must be passed in order to achieve drinking quality standards.

(Queensland Water Commission, NA). These 6 barriers are divided into three sections depending on the specific process occurring. These 3 processes can be labelled as; Primary (solely physical extraction of solids from water), secondary (both physical and chemical changes used to extract soluble substances) and tertiary processes (solely chemical changes used for cleansing). These follow as Source Control, Screening Processes/Filtration which occur during the primary treatment. Microfiltration, Reverse Osmosis and Advanced Oxidation are then apart of the secondary treatment, and lastly chlorination is used in the tertiary treatment process stage. (Choicecomau, 2019).

Barrier 1 – Source Control

The first barrier taken into effect of the treatment of wastewater is source control. These are the restrictions put in place to control and limit the amount of harmful chemicals being discharged into wastewater. (Mvsdorg, 2019). Generally these restrictions only occur in businesses and industries such as hospitals. This is mainly completed by prohibiting the release of specific waste into the water systems; such as sinks and drains. Once this barrier has been enacted, water-waste is then carried out through to a waste water treatment plant.

Barrier 2 – Screening Processes/Filtration

It is during this stage that several large physical changes occur as a treatment plant carries out screening processes. This ensures that most solids, large particles and organic matter are able to be removed effectively. Two methods are most commonly used during this process which are: large mesh screens that act as a form of barricade for soluble substances and/or sand filtration. (Epagov, 2019). This certifies that physical objects are ultimately removed from the water as it flows through.

Barrier 3 – Microfiltration

The water is then dispensed into a pipe containing semi-permeable materials, more commonly known as polymeric membranes. These are similar to thin layers of plastic that can have thousands of minute cylindrical holes in them that are not easily visible from the naked eye. These membranes are used for solute separation and the extraction of micro-organisms, bacteria, hormones, nutrients and some viruses within the water by having transmembrane pressure applied throughout it.(Synderfiltration, N/A) Microfiltration is essentially a pressure-driven separation process that employs a membrane for both mechanical and chemical sieving of particles and macromolecules (Babu, 2016). Membrane filtration involves the use of membrane technology for the separation of biomolecules and particles for the concentration of process fluids. During separation, a semi-permeable membrane acts as a selective barrier retaining the molecules/particles bigger than the pore size, while allowing the smaller molecules to permeate through the pores (Fig. 2). Membrane filtration processes can be distinguished based on the type of force driving the transport through the membrane, and are named by the size of the pores in the filter. (Sciencedirectcom, 2019)This use of micro-filtration is most commonly used for bottled water, soft drinks and sterilised medicine however can be enacted for recycling water. As shown in the figure below, microfiltration allows most substances through that are able to be safely consumed for humans.

Figure 2: Particle Size in differing filtrations (Sciencedirectcom, 2019)

Figure 2: Microfiltration (Synderfiltration, N/A)

Barrier 4 – Reverse Osmosis

Reverse Osmosis is then able to be used to extract any waste left within the water. This is completed by forcing the water through several non-porous membranes from the application of excess osmotic pressure. This means that in order to separate any solvents still freely moving in the water, pressure is needed to be applied to separate them. This pressure enables water to pass through the membranes while having the remaining solvents (mostly waste) abandoned. As these membranes are significantly smaller in comparison to micro-filtration, a higher amount of excessive pressure is required for it to work. This technique is commonly used within many home filtration systems and can remove most substances excluding the substance sodium.(Purewatersystemscomau, 2018) The distinction of Reverse Osmosis from other filtration processes is able to cause a sense of confusion in regards to microfiltration, ultrafiltration, and reverse osmosis. In order to clearly distinguish these separation processes, Porter (5) presented a useful method which will be adopted here, based on the smallest particles which can be restrained by the various membranes. According to this approach, reverse osmosis has a separation range from 0.0001 to 0.001 ?m, or 1 to 10 Å. (Demeuse, 2009). The osmotic pressure ? of the solution can be calculated by van't Hoff's equation. The van't Hoff theory describes that substances in dilute solution obey the ideal gas laws, resulting to the osmotic pressure formula ? = (n/V)RT = [Ci]RT where R is the gas constant, T the absolute temperature, and [Ci] the molar concentration of solute i in dilute solution (I). (Arxivorg, 2019)

Reverse osmosiss is the complement of forward osmosis, which is synonym for osmosis.4 The driving force of reverse osmosis is the difference between the outer or back pressure pb and the osmotic pressure difference ?. The mass transfer can be described according to eqn [28]:

[28]JS=nS/t=PApb?fR?

JS, P and A are the mass flux of the solvent through the separation membrane, the water permeability of the membrane and the membrane area, respectively. The mass flux is influenced by the reflection factor fR, which is a measure of the interaction of solvent and solute in the membrane. fR is correlated with the rejection of the solute.5

The osmotic pressure difference increases continuously during the enrichment of the solutes in the donor solution up to pb = fR?. The rejection ratio R is defined by eqn [29]:

[29]R=1?ci,Aci,D,o

with ci,A as the solute concentration in the filtrate, and ci,D,o as the initial concentration in the donor solution. The rejected solutes accumulates on the membrane surface (Figure 4). This phenomen is called concentration polarization. Achieving the saturation level the solute will start to precipitate forming a secondary layer on the membrane, which drastically reduce the mass flux through it. The analytical and technical usefulness of the reverse osmosis is based on the high enrichment factor E, which is calculated according to eqn [30]:

https://www.sciencedirect.com/topics/chemistry/reverse-osmosis

Barrier 5 – Advanced Oxidation

After having all solids separated from the water advanced oxidation is then able to occur. Oxidation is defined as the transfer of one or more electrons from an electron donor (reductant) to an electron acceptor (oxidant) which has a higher affinity for electrons. (Wioaorgau, 2019) This procedure is recommended to be completed due to being an additional form of protection against any pathogens, micro-organisms or organics as it will ultimately have them destroyed.(Parsons.S, 2004) Advanced oxidation occurs most commonly from the method of ozonation. This is completed by having the unstable gas, Ozone (O3) absorbed into the filtrated water. As can be seen in the equation below (Oxidationtechcom, 2019):

H2O2 + O3 —- > O2 + 2OH–

Due to it being known that the substance of Ozone is easily degraded to form Oxygen (O2) while leaving an Oxygen atom spare and highly active and extremely effective oxidising agent, this is used to the advantage of cleansing the water (Suezwatertechnologiescom, 2019). This therefore means that the atom will have the ability to attract and take electrons away from other substances and disrupt the structure of the molecules. Any bacteria and/or viruses still contaminating the water die off and therefore still have a spare oxygen still remaining. This displays the full potential of ozone in regards to its effectiveness in disinfecting due its ability to breakdown into oxygen and a free oxygen atom with ease. Therefore causing the oxidation of bacteria to be a simpler process.

The first reaction that takes place is accelerated ozone decomposition by a type of initiator. This can be an OH-molecule, see reaction 1:

1: O3 + OH- -> O2• - + HO2•

This radical has an acid/ base equilibrium of pKa = 4,8. Above this value, this radical no longer splits, because it forms a superoxide radical, see reaction 2:

2: HO2• -> O2•- + H+ (pKa = 4,8)

Radical chain-reaction

Now, a radical chain-reaction takes place, during which OH-radicals are formed. The reaction mechanism is as follows:

3: O3 + O2•- -> O3•- + O2

4: O3•- + H+ -> HO3• (PH

The OH-radicals that have formed react with ozone according to the following reaction mechanism:

5: OH• + O3 -> HO4•

6: HO4• -> O2 + HO2•

During the last reaction, HO2• radicals are formed, which can start the reaction all over again (see -reaction 2). As a result, a chain-reaction develops, which is maintained by so-called promotors.

https://www.lenntech.com/library/ozone/reaction/ozone-reaction-mechanisms.htm

Barrier 6 – Chlorination/De-chlorination

From being the final treatment barrier required to achieve drinking quality standards, Chlorination is the process of combining chlorine and water to produce the products of hypochlorus and hydrochloric acid. (Hydroinstrumentscom, 2019) This can be visibly seen form the equation below:

$Cl_2 + H_2O \rightarrow HOCl + HCl$

Chlorine + Water –> Hypochlorus acid + Hydrochloric acid

In the equation displayed above, the hydrochloric acid is separated into its two individual ions which are H^+ and Cl^-. After this chemical reaction has occurred, two different scenarios are likely to occur which are based on the pH of the water.(Sciencedirectcom, 2019)

When the pH level of water has the value of 6 or below, the hypochlorus acid produced is separated to form hypochlorite ions (OCl^-) as can be seen from the equation below:

$HOCl + H_2O \rightarrow H_3O^+ + OCl^-$

This then causes the hypochlorite ions to separate into their individual ions as shown:

$OCl^- \rightarrow Cl^- + O$

From this separation, it can be seen that a free oxygen atom is then able to oxidise and destroy bacteria and/or viruses by destroying the chemical bonds found within the water. This is also similar with the free chlorine atom as it can also, to some effect, disrupt and change the shape and function of bacteria which can cause it to die. As shown in the figure below, the distribution of hypochlorus and hydrochloric acid is clearly indicated.

Figure 3: The Distribution of HOCl and OCl^- in Water (Commonwealth of Pennsylvania, 2016)

If the pH level of water has the value of 4 or above, this will cause hypochlorus acid to not separate into its individual ions as the value is too high (Bowman, 2007). This means that the acid will then have the ability to destroy any pathogens found throughout the water. Although this method is generally efficient t in terms of disinfection, the average pH levels of recycled water is roughly 7.5, which in this this case would equate to a ratio of half of the hypochlorus ions remaining the same while the other half separate into their individual ions.

Due to chlorine being a highly re-active element, it is believed that will easily react with other substances within water and possibly transform them into a less harmful solution that is suitable for human consumption.

However, once the process of chlorination has been completed, the recycled water is then to undergo de-chlorination. This process is to essentially remove the chlorine and/or by-products (of hypochlorus and hydrochloric) ions still remaining from the previous disinfection. If this process is not completed, the recycled water could have the potential to be severely dangerous for consumption. This process is generally completed by having specific chemicals added to the water to reduce the amount of chlorine concentration in the water for an acceptable level for human consumption. The most known method of de-chlorination is the use of Sodium Metabisulphite. (Epagov, 2019) This substance is first used to react with water in order to produce Sodium Bisulphite as can be seen by the equation displayed below:

$Na_2S_2O_5 + H_2O \rightarrow 2NAHSO_3$

The product is then reacted with the chlorine located in the water as shown from the equation below:

$2NAHSO_3 + 2HOCl \rightarrow H_2SO_4 + 2\ HCl + Na_2SO_4$

All by-products that are then still left over from this reaction are safe for human consumption as no free chlorine atoms are then available. This therefore makes the water safe for consumption and proves that chlorine is an acceptable disinfectant when it is extremely dilute and in minor form. When this treatment barrier has been finished, the recycled water is now able to have the ability to be placed into reservoirs, dams and other water reserves or be transported directly to the general population for home, business or industrial use again.

Quality of Recycled Water and Associated Concerns:

Throughout the general population of Australia, the judgment for the quality of the re-cycled water has been determined to be the main concern for the reason of it not being as widely used. This is due to the belief that not all waste products are effectively removed from the water and can affect the hygienic standards of drinking it. Along with the lack of knowledge surrounding this process of recycling and the general connotations it is attached too, such as home commodities (human faeces), this leads to a rather overwhelming negative response. As shown in the figure below, the general response and attitudes of an urban Australian population and the believed risks to be associated with recycled water:

Figure 4: Perception of risk related to recycled water use (Hurliman, 2008)

Several variables are taken into account when determining the quality of water and whether it is safe for consumption. The aesthetic appeal of water is what is believed to have the most effect on the general population as to whether it determines cleanliness. These judgments as based mostly on the turbidity and discolouration of re-cycled water. Turbidity is essentially the measurement of how opaque the water is. It is generally associated in most societies, that the clearer a water source is, the cleaner and more likely safer to drink from. Similarly, the discolouration of water effects the aesthetic appeal of drinkability as it is believed that the clearer water is, the safer it is to drink as there will be less likely to have toxins or impurities in it. Both of these details are taken into account for making recycled water more aesthetically pleasing.

Clear Water – Guidelines

As it is believed by general populations, clear water primarily indicates safe drinkable water. The Australian Drinking Water Guidelines (ADWG) (2004) provides an aesthetic guideline value for true colour to not exceed 15 Hazen Units (HU) but also advises that up to 25 HU may be acceptable if the turbidity is low.. (Wioaorgau, 2019) If water is above this value, then it is restricted from being consumed by the general public as it does not meet to safety standards. Recycled water generally is recorded an average water colour of 5.4 HU (Hunter water corporation, 2016) when in comparison to tap water is extremely similar in values. This therefore proves that recycled water definitely clears the water discoloration guidelines.

Water Opacity – Restrictions

Cloudier water is inferred by most of the general public as a suggested sign of unsafe and undrinkable water as it presents the possibility that substances and bacteria are still active and alive. (Kahetsu, 2015) Recycled water has an average turbidity of around 0.4 Nephelometric Turbidity Units (NTU) which is significantly under the minimum requirements of 5NTU. Although this still successfully fulfils requirements for safe drinkable water, tap water has been recorded to have a turbidity of near 0.1 NTU. (Usgsgov, 2019) However, this is only slightly different in comparison and when both Opacity and colouration of recycled water are observed, they are well under the required specifications and completely safe for consumption where it would be relatively difficult to compare differences at eye level. Therefore proving that the quality of re-cycled water is up to satisfactory standards.

Cyanide, Trace Metals and Faecal Coliforms – The Potential for Poisoning

Furthermore, extending from the cloudiness, another major concern that has been highlighted is the substances such as cyanide, faecal coliforms, trace metals and nutrients that are still able to be significantly harmful if consumed in high amounts. Cyanide is a chemical compound consisting of nitrogen and carbon that has a severely dangerous and fatal effect if consumed in large doses. (Cdcgov, 2019) A human is able to handle small doses of Cyanide which can be similarly found in all water, whether it has been recycled or not. All water has been estimated to contain up to 0.2 parts per million Cyanide and it is believed that all re-cycled water indefinitely contains this.(Nswgovau, 2019) With the most efficient process for removing cyanide being reverse osmosis and chlorination, that generally occurs during the recycling process, it can therefore conclude that the levels of cyanide in water is generally lower than the required restrictions implemented and therefore suitable for consumption.

To provide another measure of safety and maintain a recycled water plant that has suitable levels of cyanide remaining low, regular and mandatory tests are able to be performed. This will ensure that water is up to human consumption standards before being filtered to the general public. Another concern highlighted is the substance of faecal coliforms with the drinkability of water. Faeces contain various types of bacteria, viruses and infections, including but not limited to E. coli which has the ability to be severely dangerous when consumed. However, this possibility of occurrence is highly unlikely from consuming reclaimed water. To ensure this, routinely tests are taken of all water and of these, a minimum of 98% of results have no detection of faecal coliforms. When in regards to normal tap water, generally no traces of faecal coliforms are able to be found as it has not been passed through any living organisms. As can

be seen in the figure below, chlorine has on E.Coli is highly effective.

Figure 5: The Effect of Cl2 on E.Coli (Commonwealth of Pennsylvania, 2016)

However, these significantly small and minute traces (specifically regarding trace metals) may prove to be beneficial to the human immune system as a study conducted throughout several recycled water treatment plants in Florida discovered to have varying low amounts found in the water. Data collected from several treatment plants, it was recorded that there was between 0.125 to 0.367 mg/L of Iron, 0.126 to 0.169 mg/l of Aluminium, 0.104 to 0.153 mg/L of Boron and 0.123 to 0.211mg/L of Zinc to have been still in the water. The guidelines for the amount of trace metals permitted in drinkable water is dependent on the metal. For Iron, it required to be below 0.3 mg/L, Aluminium is below 0.2 mg/L, Boron is below 0.3 mg/L and Zinc is below 3mg/L. In comparison to tap water, recycled water is only a slightly higher concentration and therefore can be shown that on average, the amount of trace metals found within recycled water is perfectly suitable for consumption. Therefore it is clear and justified to see that substances found in recycled water passes guidelines that have been put into place during most occasions and if there has been a breach in conduct, there are several ways in diluting it for human consumption. Showing that there is no need to be cautious are what substances are in recycled water .

Advantages:

Ever since the notion of re-cycling water to help maintain Australia water supplies had been proposed as a viable option, it has had varied opinions on whether it has the ability to truly be beneficial. There have been several countries throughout the world that have transitioned to adopting recycled water into their general populations. Such as, areas in America, Namibia, Belgium, Singapore and the UK. (Cho, 2011) Although this has proven to be effective in other regions, it does not necessarily prove that it should be recommended for Australia. However, several areas in New South Wales, Western Australia and Queensland have already enacted recycled water schemes that are currently in effect from the government. Even though there is still concern over the investments being made.

Numerous advantages have been highlighted in regards to recycled water. One of the major benefits is the supposed drought proof water supply Australia will be able to maintain. Due to this continent having to experience droughts, it’s a common occurrence for water supplies to become a precious and limited resource. Recycling water however will enable both rural and urban communities to have enough of a supply of water to manage comfortably.

Another advantage that has been highlighted which will prove that Recycling is beneficial to a population is the ever increasing demand for water. While the Australian population is gradually increasing, the natural water levels are not and soon will not be able to substantiate for the growth. Therefore, as the population continues its growth, alternative methods for the conservation of water are going to be required. Recycled water is definitely one of the most effective and efficient methods that will assist the population throughout the country as it grows. There will come a time when Australia will not have the ability to supply enough water to the population and methods like recycling water will become increasingly popular where even people who currently disagree with these methods will have a change of view at how beneficial they really are.

Even though there has been several studies conducted in regards to the safety and drinkability of recycled water, there are still many who disagree with its use for public consumption. People who have attained little knowledge of the process to ensure the drinkability of recycled water is the main cause. If more information was given to the general public about the processes, the views and opinions may be considerably changed and have less bias against drinking this water.

Disadvantages:

From having all the benefits noted in regards to recycling water, there is also a few disadvantages that are needed to be aware of as well. This includes the cost it would need to construct, maintain and run large scaled recycled water plants for large populations as a substantial amount of money is needed to be provided and invested into the treatment plants. The process of converting to drinkable water is undeniably costly, and to produce the highest quality, a significantly higher amount of money is spent. This aspect can cause uproar within the populations allocated with the treatment plants as it could affect the price of taxes issues by the government to maintain a healthy environment.

Another issue that needs to be noted is the amount of time planning and the manual labour required to set up a treatment plant. However, if a drought is most likely to occur soon, it would be time worth spent as a drought protection scheme for many rural communities.

One of the last disadvantages that concerns the use of recycled water is the greenhouse gas emissions that occur in the process of cleansing the water. Before chlorination can occur in the process, certain bacteria’s thrive to the specific environment. Specifically during ozonation, these bacteria can have the ability to convert the substance nitrogen into nitrous oxide. As Nitrous Oxide is one of the most prominent gases that is currently severely effecting the environment can rise into the atmosphere. Recycling water is one of the mains reasons an increase in levels of this gas which can cause powerful hallucinations, a euphoric and relaxed feeling and in extreme cases, death. Therefore, it can be easily assumed that if recycled water is to be used in higher amounts, then the levels of nitrous oxide and other similarly harmful greenhouse gases emitted will increase as well.

Recommendations:

Overall, the benefits and disadvantages that have been noted in regards to recycled water and the opinions of the general public have all been taken into account. It is an undeniable fact that Australia is currently experiencing and will again at some point, experience another drought in the near future. Meaning the population will therefore need a clean, reliable and accessible source of water that will be able to assist, if not maintain, the general populations during this time. Recycled water is the most consistent method in regards to this process and although backlash from the public may occur due to cost and faecal connotations, it is still believed to be the most justified option. Being is in their best interest for future prosperity of the country, in this case the positive aspects most definitely outweigh the negatives. However, recycled water would not necessarily be needed for human consumption if instead a guideline was put in place to assure that only business and industrial practises have to be used for recycled water only. The majority of water used in a community is normally found in such areas as industry and agriculture anyway. As these areas do not require the high quality standard of cleaning water for

households and personal consumption, this means that the cost of production may most likely be significantly cheaper. Meaning some of the several steps in recycling water are able to be removed. Although backlash would still be prominent for having recycled water in agriculture, it would be as less severe as having the general public.