Concept of Ideal Water Purifier System to Produce Potable Water and its Realization Opportunities using Nanotechnology

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ABSTRACT

Identifying the characteristics of an ideal system in nature and comparing it with existing real system in a given area for possible improvement is one of the research methods in research methodology. While comparing the ideal system characteristics with existing/real system characteristics the research gap can be determined and further research can be carried out to improve the real-world system. The four basic problems still existing in the society worldwide are related to nutritious food, drinking water, renewable energy, and comfortable health. In this paper, we have studied the characteristics of the ideal water purifier, a hypothetical system used to convert contaminated water into pure water to solve drinking and irrigation water problems. The characteristics of the ideal water purifier system are classified and discussed under four categories as input characteristics, system requirements, Output characteristics, and environmental characteristics. Further, the possibilities of realizing such a system using nanotechnology are also discussed. Nanotechnology is emerging as a multi-disciplinary new frontier of Science & Technology expected to solve many major problems/needs of the mankind of the society which include supply of abundant potable drinking water, pure water for agriculture and plantations, availability of nutritious food for everybody, uninterrupted green energy for society, and comfortable health for everybody. The paper discusses the possibility of using nanotechnology to realize the ideal water purifier using nanotechnology and also the advantages, benefits, constraints, and disadvantages of such technology to improve such system towards the ideal system.

New Knowledge Created/New Analysis & Interpretation : The paper created new knowledge on the concept and characteristics of ideal water purifier, and analysed and interpreted the possibility of realizing it using nanotechnology.

Keywords: Ideal system, Ideal water purifier, Nanotechnology, Nanotechnology based universal water purifier, Potable water, ABCD analysis.

1. INTRODUCTION :

For more than two million years, human beings are struggling and searching to get Nutritious food, clean drinking water, energy in different form, and comfortable health. In the twentieth century, Abraham Maslow (1943) proposed Hierarchy of Needs Theory [1] based on his assumption of five different needs which are defined as Physiological need, Safety needs, Social needs, Esteem needs, and Self-actualization needs. Out of these five needs, the physiological need is the basic need also called the basic problems of human beings including food, water, energy, and health. Other four needs are together categorized as comfortability of human beings. As the civilization is developed with time, the scientific thinking among the human beings is started and science had helped to solve many of these basic problems to a certain extent. After industrialization, the availability of drinking water in many countries is becoming scared and there is a cry on future challenges in earning potable water for many regions on earth. It is reported that between 1990 and 2015, the world population using an improved potable water source has increased from 76 % to 91 %. It is estimated that more than 40 % of global population is affected by water scarcity and is proposed to increase further. In the global scenario, over 1.7 billion people are presently living in river basins where water use exceeds recharge. Similarly, over 2.4 billion people have no access to basic sanitation facilities. It is reported that each day, nearly 1,000 children die due to preventable water and sanitation-related diarrhoeal diseases. It is a challenge for the society to achieve universal and equitable access to safe and affordable drinking water for all. It is a challenge for decreasing substantially the proportion of untreated wastewater by increasing recycling and safe reuse globally. It is also a challenge to enhance the efficiency of use of water across all sectors by producing pure water at low cost and ensure a sustainable supply of potable water to manage water scarcity and hence to decrease the number of people affected from scarcity of potable water. Table 1 lists the causes of water pollution and its types [2].

Table 1 : Causes of water pollution & Types

S. No.	Type of water pollution	Reason	Solution
1	Undissolved impurities	Mix of various undissolved impurities in both surface and groundwater	Filtering
2	Chemical water pollution or oxygen depletion	Natural organic matter (NOM) found in all surface, ground, and soil waters	Most of the NOM can be removed by coagulation, although, the hydrophobic fraction and high molar mass compounds of NOM are removed more efficiently
3	Infected water with microbial	Bacterial cell components and viruses as microbial pollution	Antimicrobial nanomaterials for water disinfection and microbial control
4	Chemical toxin pollution	Various inorganic and organic chemicals	Use of CNTs as adsorbent media to concentrate and remove pathogens, NOM, and cyanobacterial toxins from water systems.
5	Calcium ions dissolved in water	Dissolved metal ions	Nanophotonics
6	Desalination of seawater	Dissolved NaCl	Nanomembranes
7	Treatment of sewerage Water	Inorganic and organic pollutants	Chlorine Dioxide

One of the research methodology to improve the systems in the nature and society is identifying the characteristics of an existing system where improvements are required in terms of quality, cost, and easiness of using the system, and comparing such real system with an anticipated hypothetical predicted system and its characteristics. Based on such comparison, the possibilities and challenges of improvement of present system can be identified. Many ideal system models are developed and discussed in terms of their characteristics. With the spirit of ideal gas model, ideal engine model, ideal amplifier model, many new ideal systems are modelled like Ideal technology and realizing it using nanotechnology [3], Ideal software and realizing opportunities [4], Ideal education system and its realizing opportunity using online education [5,6], Ideal business system and its realization opportunity using mobile business model [7,8], Ideal banking system and its realization using mobile banking model [9,10,11], Ideal strategy using white ocean strategy [12], Ideal library system using universal online library [13], Ideal energy management system [14], Concept of ideal optical light beam limiter [15], Ideal analysis using six thinking hats [16], Ideal computing system [17], Ideal Mobile Banking System [18], Review on various Ideal System Models [19] etc.

2. THE CONCEPT OF IDEAL WATER PURIFIER SYSTEM :

An ideal water purifying system removes both undissolved and dissolved impurities by removing all contamination of water using a filter which uses a fine physical barrier, a chemical process, optical process, or a biological process. It converts impure water of type and any quantity into 100% pure water. Filters cleanse water to different extents for various purposes and various purity levels which include the applications like supplying drinking water, providing water for agricultural irrigation, food processing, constructions, industrial processes, public and private aquaria, and the safe use of ponds, swimming pools, and other water-based utilities. Ideal Filters may use sieving, adsorption, ion exchanges, and other processes to remove unwanted substances from water. Unlike a sieve or screen, a filter can potentially remove particles much smaller than the holes through which its water passes. Types of water filters include media filters, screen filters, disk filters, slow sand filter beds, rapid sand filters, cloth filters, and biological filters such as algae scrubbers. The schematic diagram of ideal water purifying system along with its internal components to convert any type of impure water to perfectly pure water is shown in figure 1. It takes impure water or sea water as an input, processes water for removing both dissolved and un-dissolved impurities and converts it into 100% pure water. For drinking purpose and agricultural purpose, a pre-determined amount of minerals can be added by using the mineral mixing system.

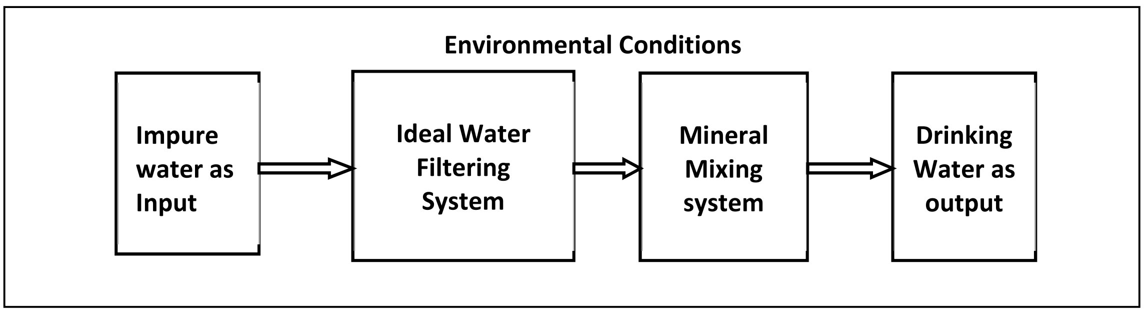


Fig. 1 : Block diagram of Ideal water purifier system

2.1. Characteristics of an Ideal Water Purifier System :

The system model of Ideal water purifier allows us to discuss its characteristics in terms of input conditions, Purifier Requirements, output conditions, and environmental conditions.

Input Conditions :

(1) Ideal water purifier takes any type of impure water for purification.
(2) Ideal water purifier takes any amount of input water at a time for purification.
(3) Scalable system to any level.

Purifier System Requirements :

(4) Ideal water purifier produces 100% pure water for any level for any type of input impurity.
(5) Ideal water purifier system removes both undissolved and dissolved impurities completely.
(6) Ideal water purifier filters water instantly and there is no time lag between input and output.
(7) Ideal water purifier does not consume any external power for filtering process – self reliable system.
(8) Ideal water purifier does not consume any resources for its operation. Hence it has zero operating cost.
(9) Zero investment & zero maintenance cost.
(10) Simple technology & easy to use.
(11) Long life & reliability.
(12) Self-directed & self-controlled & self-regulated system.
(13) Programmability to decide the output quality.

Output Requirements :

(14) Ideal water purifier produces 100% pure water
(15) Ideal water purifier produces zero wastage of water

(16) Separation of by-products for reuse.
(17) Provision to add minerals for specified applications
Environmental Conditions :
(18) No environmental degradation
(19) Safe to use.
(20) Location independency.
(21) Portability.

3. ANALYSIS OF IDEAL WATER PURIFIER CHARACTERISTICS

Ideal water purifier characteristics can be explained based on their effectiveness in improving the quality of water purification. The characteristics mentioned in the ideal water purifier model are depicted in figures 2 - 5 and further discussed below :

3.1 Input Conditions :

(1) Purifying any type of impure water : Ideal water purifier takes any type of impure water for purification. Impure water usually contains either suspended impurities or dissolved impurities or both. Suspended impurities are substances that are not completely soluble in water and are present as particles. These particles usually impart a visible turbidity to the water. Dissolved impurities may contain dissolved minerals like chlorides, sulphates, bicarbonates of sodium, magnesium, calcium, and iron. Wastewater contains both suspended impurities and dissolved impurities including substances such as human waste, food scraps, oils, soaps, and chemicals. Ideal water purifier should have the capability to treat and purify any type of impure water including, salty water, groundwater, wastewater, sewage, river water, etc. for both drinking and agricultural applications. It also allows recycling of water in industrial and household applications.

(2) Purifying any amount of water: Ideal water purifier takes any amount of input water between zero to infinity at a time for purification. This allows purification of water for small-scale (home) to large scale (industrial/agricultural) applications. The ideal water purifier can purify and desalinate sea water in any quantity as well as recycling of used water from any application.

(3) Scalability : Ideal water purifier is a scalable system to any level. It can be used in homes, offices, business units, industries, or irrigations and can take a small amount or a large amount of water at a time at input depending on output requirement.

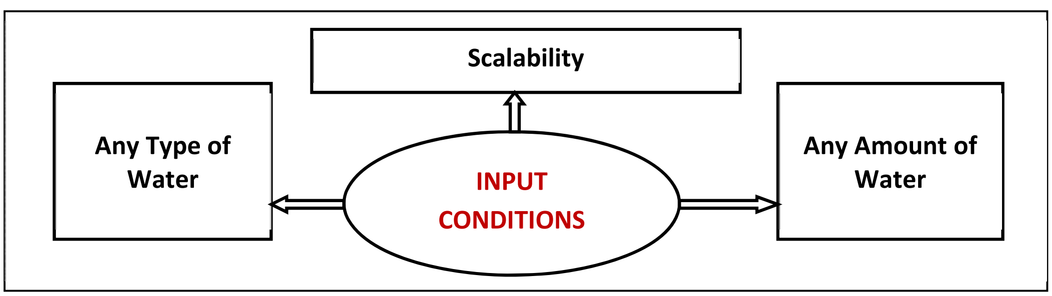


Fig. 2 : Input condition characteristics of Ideal Water Purifier

3.2 Purifier System Requirements :

(4) Production of Pure Water : Ideal water purifier produces 100% pure water for any input level and any type of input impurity. The system removes all undissolved and dissolved impurities including physical, chemical and biological impurities.

(5) Removes all impurities : Ideal water system removes both undissolved and dissolved impurities completely. The undissolved physical impurities like dust, fine sand, clay, rust, etc remain suspended in the water and cause muddy water or cloudiness in water. The amount of chemical impurities dissolved in the water and is usually expressed as 'parts per million' (ppm) or as 'milligrams per liter' (mg/L). The biological impurities like algae, bacteria, protozoa, pathogens, microbes, Viruses, Parasites and their eggs etc. collectively known as microorganisms or germs also contaminates the water and causes various diseases to human beings.

(6) Instantaneous Process : Ideal water purifier converts impure water into pure water instantly and there is no time lag between input and output. This characteristic avoids any processing delay between input and output and hence ensures that all processes used for removal of dissolved and undissolved impurities are ideal processes. This characteristic nullifies the waiting time of the user.
(7) Self-Reliable System : Ideal water purifier does not consume any external power for filtering process. In that sense it is a self-reliable system. Either it produces its power requirement internally or its processes do not need any external power for filtering both tangible and intangible contaminations.
(8) Zero Operating Cost : Ideal water purifier does not consume any resources for its operation. Hence it has zero operating cost.
(9) Zero Investment : By definition, an ideal water purifier system requires zero investment and zero maintenance cost. There is no cost for fabrication of such system. Since it has no operating cost and repairing cost, its maintenance cost is also predicted as zero.
(10) Easy to Operate : Ideal water purifier must be simple for operation and must use simple technology. The simple technology of the system makes easy to operate so that non-technical people should also able to use the system.
(11) Long life & Reliability : Since the ideal water purifier does not need maintenance, it works comfortably for long time without any trouble. Hence such system is reliable and independent on internal failure and environmental catastrophe.
(12) Self-directed, self-controlled & self-regulated System : The ideal water purifier system is a hypothetical system completely independent on external control and external stimulation so that it is a self-regulated and self-directed system. Hence to control the system, human intervention is not required.
(13) Programmable : The ideal water purifier can be programmable to get different water quality at the output for different applications like pure water, drinking water, irrigation water etc. and to get output water for different time intervals.

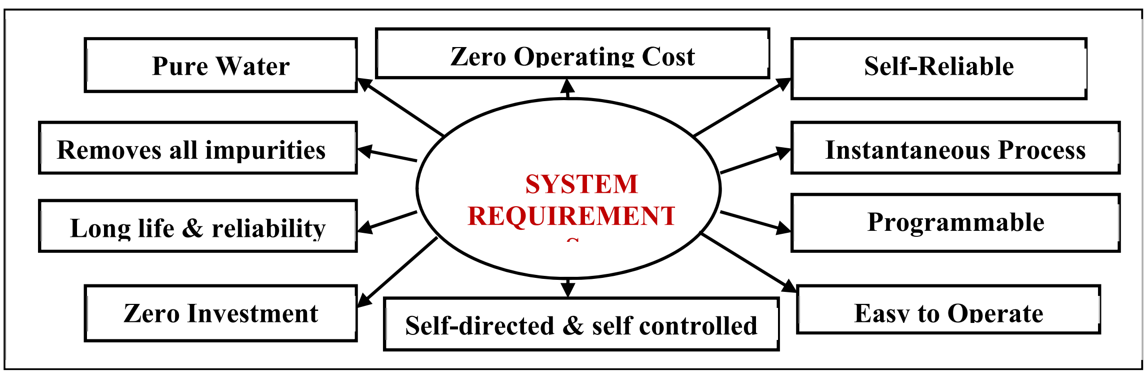


Fig. 3 : System Requirement characteristics of Ideal Water Purifier

3.3 Output Requirement :

(14) Pure water at Output : Ideal water purifier produces 100% pure water at output irrespective of the quality of input water. Such pure water is free from any type of minerals, germs, and any other dissolved & undissolved impurities. For potable purpose, additional minerals in pre-determined amount can be added using a mineral adding subsystem.
(15) Produces Zero Wastage of water : Ideal water purifier will not waste any water during the purifying process. All input water is processed in such a way that the impurities are separated in the form of their actual format and not in liquified format. This avoids wastage of water during impurity separation process.
(16) Separation of by-products for reuse : In ideal water purifier, the dissolved and undissolved impurities get separated in such a way that they can be reused in their original form either as fertilizers or minerals.
(17) Provision to add minerals : For specified applications like producing drinking water/water for irrigation, using additional subsystem, one can add required minerals at the output of ideal water purifier system.

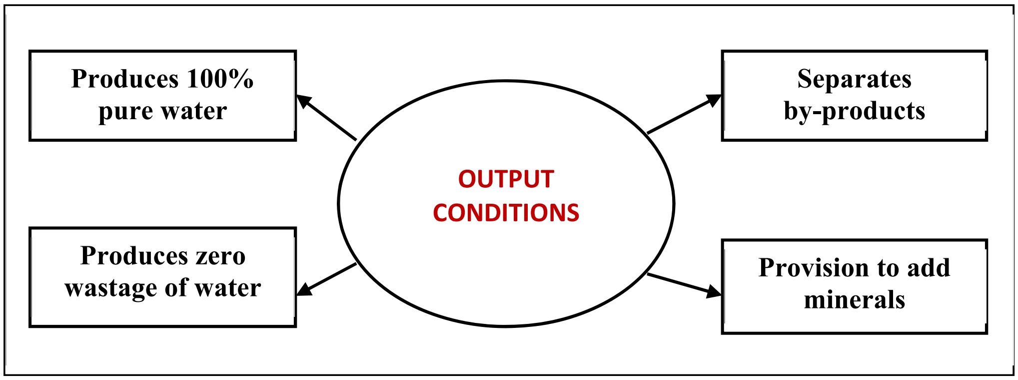


Fig. 4 : Output condition characteristics of Ideal Water Purifier

3.4 Environmental Conditions :

(18) No environmental degradation : In ideal water purifier, the purification process takes place internally without consuming any external resources. As a result, no emission of unwanted green house gases or poisonous by-products to the environment. Hence there is no environmental degradation/pollution occurs.

(19) Safe to use : Since ideal water purifier, is a self-controlled, self-regulated and self-directed system, without consuming any resources externally for its operation, it is safe to use and monitor while producing pure water at output.

(20) Location independency : The performance of ideal water purifier is independent on the geographical region. It should give satisfactory performance at output for any quality of input water at any location in the whole universe.

(21) Portability : An ideal water purifier functions equally in any geographical location and hence portable to any place.

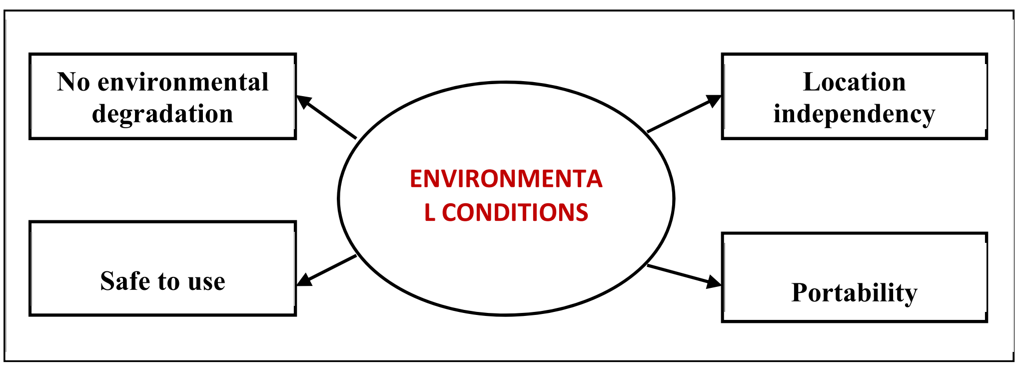


Fig. 5 : Environmental condition characteristics of Ideal Water Purifier

4. CHALLENGES TO ACHIEVE IDEAL WATER PURIFIER :

Conventional water-treatment technologies include filtration, ultraviolet radiation, chemical treatment, and desalination. The general method uses five stages including coagulation, flocculation, sedimentation, filtration, and disinfection. Such conventional water treatment, include a pre-filter for filtrating sediment and removing debris from received water; an ionization and oxidation unit for sanitizing water received from the pre-filter; an ultraviolet (UV) light unit for sanitizing water received from the ionization and oxidation unit with ultraviolet (UV) light; a reverse osmosis (RO) unit including a series of membranes for removing impurities from water received from the ultraviolet (UV) light unit; a remineralization filter for reinfusing water received from the reverse osmosis (RO) unit with trace minerals and salts; and an alkalinization and ionization with integrated (UV) light filtration unit for performing an electrodialysis process on water received from the remineralization filter. But these systems cannot be scalable easily, high cost, and high energy consuming methods needs further

improvement in performing in various stages of the purification process.
Another method frequently used to treat iron manganese, and traces of hydrogen sulphide in utility plants is called Manganese greensand filtration system. It is found that high levels of manganese and iron dissolved in water will damage plumbing fixtures, give water an unpleasant taste and colour and provide nutrients to certain strains of bacteria. The manganese greensand filtration system does not use coagulation and flocculation, but it typically uses aeration and chlorination (or any other type of oxidant addition) followed by pH adjustment of the water.
Most of the seawater desalination systems are energy intensive, which consume a large amount energy like gas, electricity, oil and fossil fuels. These processes lead to carbon footprints, which causes depletion of ozone layer as well as health hazards on mankind. The potential of harnessing solar energy is most efficient and effective for heat to heat conversion. The thermal desalination is a low temperature application processes with one-time investment for life time water production up to 10 to 15 years. There are a variety of solar thermal desalination methods such as direct and indirect methods are being used. The indirect methods are preferable for medium and large-scale desalination systems, whereas the direct methods employing the solar stills are more suitable for small scale systems. The performance of the low cost solar stills can be improved with simple modification by using various locally available materials. These low-cost stills can be easily and economically fabricated for meeting the daily need of the fresh drinking water. These low cost solar stills are sufficient for the small households and communities living in islands, coastal areas. It can also be used for distillation of brackish water for the population residing near river banks. Such a system also suitable for the fluoride affected area to remove fluoride from the water. The low cost solar water purifier is sufficient for the removal of arsenic, mercury, cadmium, coliform, virus, and bacteria [20-21]. Various constraints and disadvantages associated with such system for scalability and to make location independence are discussed [21].
Thus achieving ideal characteristics like : any type of impure water for purification, any amount of input water at a time for purification, scalable system to any level, producing 100% pure water for any level for any type of input impurity, removing both undissolved and dissolved impurities completely, developing purifier which operates instantly with no time lag between input and output, system which does not consume any external power for filtering process – self reliable system, system which does not consume any resources for its operation and hence has zero operating cost, Zero investment & zero maintenance cost, Simple technology & easy to use, Long life & reliability, Self-directed & self-controlled & self-regulated, Programmability to decide the output quality, produces 100% pure water, system which produces zero wastage of water, Separation of by-products for reuse, Provision to add minerals for specified applications, No environmental degradation, Safe to use, Location independence, and Portability etc is difficult using conventional purifier methods and technology. Further, current technologies for purifying contaminated and impure waters are typically expensive and ion specific, and therefore a significant need for new technologies and approaches.

5. POSSIBILITY OF REALIZATION OF IDEAL WATER PURIFIER USING NANOTECHNOLOGY :

Nanotechnology is emerging as multi-disciplinary new frontier of Science & Technology capturing the imagination of scientists and engineers worldwide due to its potential applications in solving many problems/needs/requirements of human beings [22-29]. Nanotechnology has the ability to provide cost effective, efficient, and environmentally sustainable optimum solutions for supplying potable water for drinking and clean water for irrigation and industrial uses. Using nanotechnology innovation, one can develop low cost water purifiers to solve the drinking water problem of the world. Water is one of the Earth's most precious natural resources. Most of the water available on the earth surface is saltwater. Only 3% of the world’s supply is drinking/sweet water and two-thirds of it is frozen in glaciers, ice caps, and icebergs. The remaining 1% is available for human consumption. As per the reports, today 1.1 billion people don’t have access to safe water and 2.4 billion lack sanitation facilities. 80% of developing world diseases are water-borne with an estimate of 3.4 million deaths, mostly children, in 1998 of water-related diseases. Demand for fresh water is increasing. Agriculture currently uses 70% of the world’s water supply. To feed 2 billion more by the year 2030 there will be a 60% increase in demand on the water supply. Considering the current rates of consumption, population, and development, some two-thirds of the world population will be affected by droughts by the year 2050. Nanotechnology will provide a solution for this challenge through inexpensive decentralized water purification, detection on the molecular level of contaminants, and greatly improved filtration systems. This helps the conversion of seawater to drinking water at a very low cost [3]. The use of highly advanced nanotechnology ideas and concepts to traditional process engineering opens new opportunities in technological developments for advanced water and wastewater technology processes. The nano-enabled technologies include a variety of different types of membranes and filters based on carbon nanotubes, nanoporous ceramics, magnetic nanoparticles and other nanomaterials. Ref. [30] contains a comparison between conventional and nano-enabled technologies for water treatment.

Separation membranes with the structure at the nanoscale can also be used in low-cost methods to produce potable water. In a recent study in South Africa, several polymeric nanofiltrations and reverse osmosis membranes were tested for the treatment of brackish groundwater. The tests showed that nanofiltration membranes can produce potable water from the brackish groundwater. As expected, the reverse osmosis membranes removed about 99% of all the solutes, but the concentrations of essential nutrients, such as calcium and magnesium ions, were reduced to levels that were below the specifications of the World Health Organization standard for drinking water. The product water, therefore, had to be spiked with these nutrients to provide drinking water of the required quality.

Nano-enabled technologies for water treatment are already on the market — with nanofiltration currently seeming to be the most mature — and many more are on their way. Although the current generation of nanofilters may be relatively simple, many researchers believe that future generations of water-treatment devices will capitalize on the new properties of nanoscale materials and may prove to be of interest in both developing and developed countries [31 - 43].

A huge amount of research results have been published since 1980 on the idea of the use of various nanomaterials and nanocomposites as water purification filters for both dissolved and nondissolved impurities. Nanomembranes are very useful for treating and purify any type of impure water including, salty water, groundwater, wastewater, sewage, river water, etc. for both drinking and irrigation applications. Table 2 contains some of the published results of use of nanotechnology for different types of water purification processes.

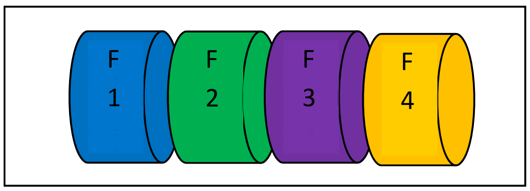
Table 2 : Use of nanotechnology for different types of water purification processes

S.No.	Purification process	Nanomaterial/system used	Reference
1	Water desalination	Carbon nanotube membranes	Das, R., et al [44]
2	Removal of contaminants	Carbon nanotube technology	Upadhyayula, V. K., [45]
3	Removal of arsenic	Nanoparticles of hydrous iron oxide	Sylvester, P. et al [46]
4	Water disinfection and microbial control	Antimicrobial nanomaterials	Li, Q., et al [47]
5	Cleaner water	Bimetallic nanoparticle catalysts	Wong, M. S. et al [48]
6	Water disinfection and microbial control:	Antimicrobial nanomaterials	Mahendra, S. et al [49]
7	Ultrafast permeation of water	Protein-based nanomembranes	Peng, X. et al [50]
8	Heavy metal removal and disinfection control	Smart magnetic graphene	Gollavelli, G. et al [51]
9	Water decontamination	Novel magnetic nanoparticles	Zhang, X. et al [52]
10	Removal of arsenic	Nanocrystalline magnetite	Mayo, J. T. et al [53]
11	Virus inactivation for drinking water treatment	Silver doped titanium dioxide nanoparticles	Liga, M. V. et al [54]
12	Point-of-use drinking water disinfection	Silver nanoparticle-alginate composite beads	Lin, S. et al [55]

13	Nitrate removal from water	Nano-alumina	Bhatnagar, A. et al [56]
14	Complete removal of pathogenic bacteria from drinking water	Nano silver-coated cylindrical polypropylene filters	Heidarpour, F. et al [57]
15	Point-of-use water treatment	Bactericidal paper impregnated with silver nanoparticles	Dankovich, T. A. et al [58]
16	Providing Safe and Clean Water to Each Individual	Magnetic nanoparticles	Roy, E. et al [59]
17	Drinking Water Treatment	Hybrid Nanoadsorbents	Gupta, A. K. [60]
18	Drinking water purification	Nanocomposite filtration membranes	Anadão, P. [61]
19	Elimination of hazardous fluoride from drinking water	Th–Mn nanoadsorbent.	Tomar, V. [62]
20	Rapid water disinfection	Vertically aligned MoS_2 nanofilms and visible light.	Liu, C. [63]
21	Phosphate Removal from Wastewater.	Modification of Titanium Dioxide Nanoparticles	Antwi, D. M. B. [64]
22	Universal water purification	Amyloid–carbon hybrid membranes	Bolisetty, S. [65]
23	General water purification.	Magnetic graphene–carbon nanotube iron nanocomposites as adsorbents and antibacterial agents	Sharma, V. K. [66]
24	High efficiency water purification	$Fe(OH)_3$/g-C_3N_4 composite membrane	Wang, Y. et al [67]
25	Water desalination	Single-layer MoS_2 nanopore	Heiranian, M. et al [68]
26	Water desalination	Graphyne as the membrane	Kou, J. et al [69]
27	Antibacterial behaviour for water purification	Halloysite nanotubes decorated with copper nanoparticles in a novel mixed matrix membrane	Duan, L. et al [70]
28	Adsorption, photodegradation and antibacterial study of for multipurpose water purification application	Graphene–Fe_3O_4 nanocomposite	Santhosh, C. et al [71]
29	Fast water purifier	Cellulose nanofiber intermediary to fabricate highly-permeable ultrathin nanofiltration membranes	Soyekwo, F. et al [72]
30	Water purification for disinfection	Silver–magnetic nanocomposites	Surendhiran, D. et al [73]
31	Effective Water purification	Polymer nanocomposites	Pandey, N. et al [74]
32	Removal of inorganic pollutants, organic pollutants, and biological pollutants.	Inorganic, organic, and inorganic-organic hybrid nanoporous membranes.	Wang, Z. et al [75]
33	General water purification	Gelatin hydrogel nanocomposites	Thakur, S. et al [76]
34	Drinking Water Production	Chitosan-based	Masheane, M. L. et al [77]

		Nanocomposite Beads	
35	Water purification and its applicability to volatile organic compounds	Zinc oxide nano-enabled microfluidic reactor	Azzouz, I. et al [78]
36	Antibacterial water treatment	Nanosized metal oxides (NMOs) and polyoxometalates (POMs)	Carraro, M. et al [79]
37	Removal from Wastewater	Titanium Dioxide Nanoparticles for Phosphate	Antwi, D. M. B. et al [80]

By cascading of different types of nanomembranes in a serial manner for removing all type of impurities leads to the production of pure water in any scale and can be called as universal nanotechnology water purifier as shown in figure 6. This leads to the development of universal water purifier at low cost and low energy consumption which is going to be a step towards achieving ideal water purifier.



Where
F1 = Physical Impurities Filter
F2 = Inorganic Impurities Filter
F3 = Organic Impurities Filter
F4 = Biological Impurities Filter

Fig. 6 : Block diagram of Cascaded universal water purifier using nanotechnology filters

6. RISK OF NANOTECHNOLOGY IN PRODUCING DRINKING WATER :

Though nanotechnology shows potential opportunities for developing devices for water-treatment, there is also a need to do further research to assess the possible human health and environmental risks. There are only a few studies have been carried out, and it is expected that the unique properties of nanomaterials (for example, size, shape, reactivity, conductivity) may convert water to be toxic [81]. Thus, it is imperative that information about possible risks and risk-management approaches should be developed and monitored systematically and need to be weighed up against the potential benefits [82-84].

7. ABCD LISTING OF USE OF NANOTECHNOLOGY BASED UNIVERSAL WATER PURIFIER :

Many analysing frameworks are used to study any system or a model which include, SWOT [85], SWOC [86], PEST [87], ABCD [88-89], Competitive Force Model [90] etc. In this paper, for analysing a practical water purifier system using nanotechnology, we felt that ABCD qualitative analysing framework is found suitable. In ABCD qualitative analysing framework [91-100] lists the Advantages, Benefits, Constraints, and Disadvantages of realizing such a system from various stakeholder's point of view are discussed.

7.1 Advantages :

(1) Nanotechnology based filters are small in size and high mechanical strength.
(2) Nanotechnology based filters can be cascaded for filtering different types of impurities.
(3) Nanotechnology based filters can be fabricated to any structure so that it can be scaled to any extent.
(4) Filters any type of input impurity 100 %.
(5) Nanotechnology based filters remove both undissolved and dissolved impurities completely.
(6) Nanotechnology based membranes filter water instantly.
(7) Nanotechnology based filters do not consume any external power for filtering process – self reliable system.
(8) Nanotechnology based filters do not consume any resources for its operation.
(9) Nanotechnology based filters have very low investment cost/per filter for large scale production.
(10) The technology behind nanotechnology based universal filter is simple.
(11) Nanotechnology based universal water purifier has a long working life.

(12) Nanotechnology based universal water purifier can be programmable to decide the quality of output.
(13) Nanotechnology based water purifier is not producing any impure water outlet.
(14) Nanotechnology based universal water purifier separates by-products at individual filters.
(15) Nanotechnology based universal water purifier has provision to add minerals at output.
(16) It is assumed that nanotechnology based universal water purifier does not make environmental degradation.
(17) The performance of nanotechnology based universal water purifier is location independent.

7.2 Benefits :

(1) Nanotechnology based universal water purifier light in weight.
(2) Nanotechnology based universal water purifier filters all kind of impurities.
(3) Any amount of input water can be purified at a time.
(4) Purity of output water is 100 %.
(5) Nanotechnology based filters are useful for removal of both undissolved and dissolved impurities completely.
(6) The instantaneous filtering property gives the benefit of no time lag between input and output.
(7) Since there is no external power required for filtering process, nanotechnology based universal filter is a self-reliable system.
(8) Nanotechnology based filters has no operating cost.
(9) Nanotechnology based filters have low maintenance cost.
(10) Nanotechnology based filters are easy to use.
(11) Nanotechnology based universal water purifier is reliable for long duration.
(12) Nanotechnology based universal water purifier has facility to decide the output water quality.
(13) Nanotechnology based water purifier produces no wastage of water.
(14) Separated by-products can be used for respective applications.
(15) Mineral water can be also produced at the output of nanotechnology based universal water purifier.
(16) Safe to use provided the required precaution is taken.
(17) The location independence makes it portable.

7.3 Constraints :

(1) Technology development
(2) Water management
(3) Construction of mega plant for water purification
(4) Maintenance
(5) Creating awareness

7.4 Disadvantages :

(1) Predicted risk on human health
(2) Predicted Environmental risk

The characteristics of ideal water purifier can be comparable with the predicted characteristics of nanotechnology based universal water purifier and is listed in table 3. It is observed from table 3 that nanotechnology based universal water purifier is almost in par with the expected qualities of ideal water purifier for all practical purpose.

Table 3 : Comparison of ideal water purifier properties with nanotechnology based universal water purifier

S. No.	Water Purifier Characteristics	Ideal water purifier System	Nanotech based Universal water purifier system
1	Any kind of impure water	Can be purified 100 %	Can be purified to pure water level
2	Any amount of input water	Can be purified instantaneously	Can be purified to desired level
3	Scalable system to any level	Zero to Infinity	Small scale to large scale

4	Output water quality	Always 100% pure	Required purity level
5	Type of filtration	Removes both undissolved and dissolved impurities completely	Removes both undissolved and dissolved impurities to the required level
6	Time for filtration	Filtration of water instantly and there is no time lag between input and output	Filtration of water in real time and there is no considerable time gap between input and output
7	Power for filtering process	No consumption of any external power	Can use renewable power from Sun or Wind
8	Operating cost	Zero operating cost	Low operating cost
9	Investment	Zero investment	Low investment
10	Type of technology	Ideal technology	Nanotechnology
11	Life & Reliability	Infinite life and reliability	Long life and reliability
12	Programmability to decide the output quality	Yes	Yes, for a certain extent
13	Wastage of water	Zero	Minimum or zero
14	By-products	Automatically separable and reusable for their applications	Easily separable and reusable for their applications
15	Environmental degradation	Absolutely not	Yet to be decided
16	Portability	Yes	Possible
17	Safe to use for living beings	Yes	O.K. but questionable

8. CONCLUSION :

Developing capability of producing an abundant amount of potable water is one of the basic requirement of civilized society and can be addressed using nanotechnology. In this paper, we have used a method of research where the ideal system is predicted by means of its various characteristics and analysed the possibility of improving the real systems towards ideal systems using suitable technology. Accordingly, the ideal water purifier system is proposed based on its anticipated input, system, output, and environmental characteristics and discussed how these characteristics can be achieved using a practical system developed using nanotechnology. The advantages, benefits, constraints, and disadvantages of such nanotechnology-based system are analysed from the user point of view using the ABCD listing framework. Based on the analysis, it is found that a practical water purifier system using nanotechnology-based filters are capable to improve the performance towards ideal water purifier performance.

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