Science Q
JOURNAL OF PHYSICAL AND CHEMICAL SCIENCES
Journal homepage: http://scienceq.org/Journals/JPCS.php
Review Open Access

A Review of Strategic Management of Water Resources

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Received: August 15, 2017, Accepted: September 09, 2017, Published: September 09, 2017.

ABSTRACT
Access to improved water has been considered as the most important condition for human sustainability, sustainable development as well as ecosystems maintenance. Water is a critical component of cultural, spiritual, economic and social well-being for any society hence, the need for portable water supply. This work examines the application of knowledge of fluid mechanics in strategic water management. Water pollutants such as refuse and sewage, oil spills agricultural and industrial waste were identified as causes of shortage improved water supply; sources of improved and unimproved water supply were also identified. The knowledge of fluid mechanics were prescribed for water sustainability and in solving challenges relating to type of flow and the determination of parameters like pressure, speed, density, volume and other flow parameters that will ensure safe flow rate of water to prevent spills while ensuring even distribution of improved water.

Keywords: *Water, Resource Management, water Management, water consumption and contamination,*

INTRODUCTION
Water is essential for human health and well-being, and for all types of ecosystems and a robust economy. The production of many goods and services, such as agriculture, energy, manufacturing, transportation, fishing, tourism and others, depends on the availability and quality of water [1]. There have been increased concerns for water resource management as a result of Increasing water-related pressures from industrial development and trans-boundary influences, Climate change; and changing global economy. One of the most basic human needs and prerequisites for health and sustainability is access to safe drinking water [2]. World Health Organization (WHO) and United Nation's International Children Emergency Fund (UNICEF) [3], identified improved water sources as: household connection, public standpipe, bore hole, protected dug well, protected spring and rain water collection while unimproved sources are unprotected well, unprotected spring, river or pond, vendor-provided water, bottled water and tanker-truck water. About 1.1 billion people representing 18% of the world's population lack access to safe drinking water [4]. The consequence of the failure to provide safe water is that a large proportion of human beings have resorted to the use of potentially harmful sources of water. The implications of this collective failure are dimmed prospects for the billions of people locked in a cycle of poverty and disease [5]. At any time, more than half of the hospital beds in the world are filled with people suffering from water-borne diseases [6]. About 80% of all diseases and more than one third of all deaths in developing countries are caused by contaminated water [7]. It has been confirmed that with adequate supplies of safe drinking water, the incidence of some illness and death could drop by as much as 75% [4]. The quantity of water and the proximity of the supply point to the home are more important than actual water quality in improving health since the quantity collected from such distant source is likely to be too small for effective hygiene [8]. Studies indicate that clean water within a distance of not more than 1 km from the house tends to lead to improved health status, since people tend to use substantially more water for cleaning and washing [9,10]. WHO and UNICEF view improved water source as water available from a defined list of technologies, with access to at least 20 litres of water per person per day from source within 1 km of the user's dwelling. The purpose aim of this work is to identify the roles of fluid mechanics in enhancing strategic water management. An understanding of this will definitely enhance the formulation of policies aimed at ensuring the development of improved and sustainable water system in Nigeria. Seminar, conferences, discussions and workshops held globally aimed at determining the key elements for strategic water management and how related actions can be effectively implemented for water sustainability while addressing the challenges of impaired water quality, diminished water availability, decayed water infrastructure which threaten safe and sustainable water resources.

2.1 Strategic Water Resource Management
Strategic water resource management refers to all the competing demands for water and seeks to allocate water on an equitable basis to satisfy all uses and demands. Water treatment and re-use will have a decisive role in sustainable development in the public, industrial, and agricultural sectors. In the public sector, securing public health will remain the basic feature of urban water systems; water transportation and treatment technologies must be chosen accordingly. Technologies now exist for controlling many types of pollutants. The future challenge will be the control of organic micro-pollutants and heavy metals. For the water-intensive industries, minimizing water consumption will become a necessity, and it will be a key factor determining the market compatibility of industrial products. For the agricultural sector new technologies for irrigation will be needed that minimize water consumption and prevent unsustainable groundwater extraction. Strategic water management are activities relating to planning, developing, distributing and managing for optimum use of water resources. An assessment of water resource management in agriculture was conducted in 2007 by the International Water Management Institute in Sri Lanka to see if the world had sufficient water to provide food for its growing population. It assessed the current availability of water for agriculture on a global scale and mapped out locations

suffering from water scarcity. It found that a fifth of the world's people, more than 1.2 billion, live in areas of physical water scarcity, where there is not enough water to meet all demands. A further 1.6 billion people live in areas experiencing economic water scarcity, where the lack of investment in water or insufficient human capacity make it impossible for authorities to satisfy the demand for water. The report found that it would be possible to produce the food required in future, but that continuation of today's food production and environmental trends would lead to crises in many parts of the world [11]. Table 1 identifies common water borne diseases and their symptoms.

Table 1: Common Water Borne Illness

Disease and Transmission	Sources of Agent in Water Supply	General Symptoms
Anebiasis (hand to mouth)	Sewage, un treated water, flies in water supply	Abdominal discomfort, fatigue, weight loss, diarrhea, gas pains
Cholera (Oral fecal)	Untreated water, sewage, poor hygiene, crowded living condition with inadequate sewage facilities	Diarrhea, vomiting, occasional muscle cramps
Crytosporidiosis (Oral)	Collects on water filters and membrane that cannot be disinfected, animal manure, seasonal run off of water	Diarrhea, abdominal discomfort
Hepatitis (Oral fecal)	Raw sewage, untreated drinking water, poor hygiene, ingestion of shell fish from sewage flooded beds	Fever, chills abdominal discomfort and jaundice
Shingellosis (Oral fecal)	Sludge, untreated waste water, ground water contamination, poorly disinfected drinking water	Fever, diarrhea, bloody stools
Typhoid (Oral fecal)	Raw sewage, water supplies with surface water source	Fever, headache, constipation, appetite loss, diarrhea, vomiting, abdominal rash

Source: [12]

2.2 Water Pollution

Water pollution is a big problem in the present day world. It threatens aquatic life and changes water bodies into unsightly, foul-smelling scenes. It also affects health and prevents accessibility to portable water supply. The common water pollutants are: Refuse and sewage; Industrial and agricultural waste; Crude oil spills.

2.2.1 Refuse and Sewage

It is a common practice to dump refuse and human wastes into river for easy disposal. Nowadays, many homes have water closet lavatories. The human waste and liquid from lavatories are emptied either into septic tanks or sewers. (Sewers are large underground pipes for carrying waste or sewage). In many cases, sewers empty the waste directly into rivers and seas without any treatment. The waste or sewage is mostly inorganic matter. It is broken down into simple substances by decomposers mainly bacteria. In the process, the bacteria use up the dissolved oxygen. Too much sewage in water body causes an increase in bacteria population. This reduces the oxygen level of water. If the oxygen level falls too much, the aquatic organisms start to die and eventually the water body becomes clogged up and foul-smelling. Water polluted by sewage contains many disease-causing organisms.

2.2.2 Industrial and Agricultural Waste

Many industries empty their chemical waste directly into rivers and seas without converting them into harmless substances. These chemicals include: acids, alkalis, mercury compounds, organic compounds and detergents. Fertilizers and insecticides used in agriculture are washed by rain into soil and eventually reach the lakes, ponds and rivers. Many harmful chemical wastes like detergents and insecticides are non-biodegradable (they cannot be broken down into harmless compounds by living organisms). They remain in water and harm aquatic life. Mercury compounds tend to accumulate in the body of aquatic organisms like fish. This can lead to mercury poisoning when such fish is consumed. Also, several industries like oil refineries, steel mills, and breweries use water for cooling. Usually water from nearby river or lake is pumped in and used for the cooling process. The resulting warm water is then emptied back into the river or lake. This causes an increase in temperature of the water, thereby resulting in death of aquatic life.

2.2.3 Water and Crude Oil Spills

Poor water treatment and delivery systems pose increasingly greater challenges for delivering adequate supplies of safe drinking water. Leaking pipes and water main breaks are responsible for inadequate treated drinking water. Furthermore, decayed infrastructure can contaminate treated drinking water, surface water and groundwater. In addition, accidents and carelessness in oil rigs and tankers cause crude oil spills mainly in coastal areas. The oil floats on water and kills most of the aquatic life in the affected areas. The oil is then washed up on the beach temporarily preventing people from using the water and the beach for recreation. Cleaning up of large spills is a relatively expensive process and rehabilitation of affected areas may take several years.

3. METHODOLOGY

Strategic management of water resources involves establishing more protective water quality standards, increasing funding for wastewater treatment plant construction, and educating local officials, engineers, and the public on best management practices.

3.1 Strategic Management of Water Resources through the Knowledge of Fluid Mechanics

Almost all water and wastewater treatment equipment rely on continuous through flow of water. Some equipment requires this flow to be well-mixed, whereas other equipment requires plug-flow. Examples of well-mixed systems are activated sludge plants, chemical dosing zones and anaerobic digesters while sand filters (in both filtration and back-wash modes), clarifiers, adsorption columns (ozone, activated carbon and ion exchange) and dissolved air flotation cells are examples of the plug-flow systems. Some processes such as nutrient removal activated sludge plants require the combination of both plug flow and completely mixed reaction zones. The laboratory-scale experiments that are used to obtain design data for a plant are usually operated under ideal flow conditions; unfortunately it is usually not feasible to carry this through to full-scale plants in this work. The complexity of the flow patterns, and the uncertainties about how they affect the relevant performance indicators for the process involved have led designers of equipment to use safety factors based on experience to ensure that the process achieves its required objectives. This means that equipment that is installed is often larger and more expensive that it needs to be. Computational fluid dynamics (CFD) is a numerical procedure to calculate the properties of moving fluid. Most water treatment processes involve the movement of water. This motion is often complex and difficult or very expensive to observe. The prediction of the flow patterns and other properties of flowing fluids would provide insight into processes which otherwise would not have been possible. CFD modelling of clarifiers and an anaerobic compartment will both logically explain the unexpected behaviour of the clarifier and in designing features to modify the undesirable flow pattern. Apart from its use in design of water treatment equipment, CFD modelling can also assist in research into water treatment processes.

From Bernoulli's equation,

$$\frac{P}{W}+\frac{V^2}{2g}+z=constant \quad (1)$$

Where:

P/W is the pressure head

$V^2/2g$ is the kinetic head

Z is the Potential head or datum (m)

The knowledge of fluid mechanics can be employed in strategic water management and control of water pollution so as to enhance availability and distribution of improved water supply. This can be achieved through the followings:

i. Safe water treatment process and distribution
ii. Safe refuse and sewage disposal
iii. Prevention of crude oil spills
iv. Control of water pollution by companies and individuals

3.2 Batch Settling of Secondary Sewage Sludge

The modelling of solids settleability is essential for modelling settling tanks in water and wastewater treatment. Until the advent of hydrodynamic models, the focus of modelling solids settleability was on describing the behaviour of the solids in the water while the water itself was considered a stationary or ideally moving medium in which the solids settled. Hydrodynamic models now allow the behaviour of the water in the settling tank to be modelled. While the modelling of the water flow has made extraordinary advances in the past 20 years, modelling the settleability of the solids has not improved much over this time. In fact, the weakest part of hydrodynamic models of settling tanks may be the modelling of settleability of the solids. This investigation explored methods for measuring and modelling solids settleability with the view of improving these for hydrodynamic models of settling tanks.

The design and operation of secondary clarifiers is commonly based on the solid flux theory. The basic data required for the application of this theory can be obtained from multiple batch tests by which the stirred zone settling velocities over a range of sludge concentrations are measured (dilution experiments). Many CFD modellers of settling tanks have used the Takács equation to describe the settling velocity of the solids, however the equation is not well formulated for experimental calibration. It contains 4 constants that require measurement to calibrate it. Only 2 of these constants are readily measurable from laboratory scale tests, the remaining 2 usually have to be inferred from measured values of the suspended solids in the effluent from the full-scale clarifier. This is unsatisfactory, in that the clarifier cannot be properly modelled without using its own operating data.

3.3 Safe Water Treatment Process and Distribution

Pipe borne water is prepared in a water treatment plant. This water is usually germ- free but it contains mineral solutes like sodium chloride. Water from rainfall, river or lakes is stored in reservoirs. This water is purified by various methods which include: coagulation, sedimentation, filtration and disinfection. The water purified is then distributed to towns and cities via underground pipes for domestic and industrial uses. The knowledge of fluid mechanics helps to fix type of flow and the determination of parameters like pressure, speed, density, volume and other flow parameters that will ensure safe flow rate of water to prevent spills while ensuring even distribution of improved water.

The treatment of water to make it fit for use can be done in the following ways: First, the untreated water is passed through large settling tanks where chemicals like potash alum $(KAlS0_4)_2$, or sodium aluminate (III), $(NaAlO_2)$, are added to cause coagulation or flocculation. The impurities clump together to form big particles of dirt or flocs which settle down rapidly. Next, the water is passed through a filter bed to remove other impurities like fine particles of dirt. The water is then treated with chemicals like chlorine to kill germs. Other chemical such as iodine and fluorine may be added in the right amount as food supplements to prevent goitre and tooth decay respectively. Finally treated water is now germ free and can be stored and distributed for use. Pure water is essential in different applications like laboratory experiments, cosmetics, electronics manufacturing, food processing, metallurgy, and other industrial processes. Impurities in water may cause interference which may cause undesirable results.

Water contaminated with ions (calcium, magnesium, iron, salts or other ions) is also more electrically conducive and may not be suitable for some applications [13]. Active ions and minerals in tap water causes scale build up, inaccurate readings of lab equipment, contamination of finished products and shortened shelf life of organic items, not to mention down time, cost of part replacement or complete machine replacements. Some common applications of deionized water are;

i. Cooling systems: With low conductivity, deionised water is also a good cooling agent for equipment such as high power lasers. It can stop such devices from overheating
ii. Laboratory tests: When carrying out a lab test, getting accurate results is essential. However, using ordinary water might result in the test being skewed as contaminants might impact the result. This why deionised water is a preferable option. Not only is it used in experiments, but also to clean instruments.
iii. Industrial machinery: Industrial machinery is subjected to heavy use and must be cleaned regularly to avoid dirt and grime from building up. Regular water, however, might cause parts to corrode too quickly which would negate the need to clean it, as the purpose

of doing so is to avoid properties such as salt from building up. As a result, deionised water is used to cool, lubricate and manufacture certain products.

iv. Car Engines: To increase the service lifespan of lead-acid car batteries or the engine's coolant system, deionised water is widely used as the best alternative water. This is because normal water might have corrosive contaminants that will lead engines to rust, therefore shortening their lifespan. Furthermore, it's essential diluting concentrated anti-freeze.

v. Fire Extinguishers. Putting out fires that erupt around electrical equipment using normal water is not recommended due to the high conductivity. Deionised water, however, has a low electronic conductivity. This means that, in case of fires, it will put them out and not damage equipment as much as normal water would.

vi. Aquariums: Fish tanks must be a conducive environment for marine life to flourish. However, regular water might be so impure that it results in unwanted algae developing. As a result, some prefer using deionised water to, as it contains less impurities.

The two major types of treatment applied to water are water softening involving the replacement of hard ions such as Ca2+ and Mg2+ by Na+ and demineralisation which is the complete removal of dissolved mineral. In water softening a cation resin in the sodium form is used to remove hard metal ions (calcium and magnesium) from the water along with troublesome traces of iron and manganese, which are also often present. These ions are replaced by an equivalent quantity of sodium, so that the total dissolved solids content of the water remains unchanged as does the pH and anionic content. At regular time intervals the resin is cleaned. This involves passing influent water back up through the resin to remove suspended solids, passing a regenerant solution down through the resin to replace the ions that have bound to the resin and then rinsing again with water to remove the regenerant solution. In water softening the regenerant is a strong solution of sodium chloride.

Table 2 shows the contaminants that can be removed with ion exchange, and some that must be removed with other processes.

Contaminant	Comments	Ion exchange removal
Hardness	There is no prescribed limit for hardness in drinking water.	The process is a normal softening, using special resins agreed for the treatment of drinking water.
Nitrate	Nitrate is not a problem for adults, but it is harmful for infants. The recommended level is less than 50 mg/L.	Nitrate can be removed with special, selective resins.
Perchlorate	Perchlorate contaminates some water wells close to production sites of rocket fuels. The recommended level is less than 6 µg/L.	Perchlorate can be removed with special, selective anion exchange resins. Resins used for nitrate removal are also effective for perchlorate.
Boron	Boric acid is present in sea water RO permeate. The recommended level is 5 mg/L.	Boron can be removed with special, selective resins.
Lead	Excessive Pb levels may be due to old lead pipes.	Lead can be removed with carboxylic (WAC) resins. Softeners also remove Pb.
Barium	Barium is a component of hardness, and forms insoluble salts. The recommended WHO limit is 0.7 mg/L.	Sulphonic (SAC) resins have a high selectivity for barium.
Chromate	The presence of chromate in underground water is mostly due to industrial pollution. The recommended limit for Cr(VI) is 50 µg/L.	Special WBA resins can be used to remove chromate from water.
Radium	Radium is a component of hardness, but it has natural radioactivity. The American EPA has set a limit for a maximum combined value of 5 pCi/L (0.185 Bq/L). Ra is found in trace amounts in uranium ores.	Radium can be removed with sulphonic (SAC) resins.
Uranium	The toxicity of uranium is not due to its radioactivity, it is purely chemical. The WHO guideline is 15 µg/L.	Uranium (VI) is present in nature as the uranyl ion UO_2^{++} and can be removed with WBA or SBA resins.
Other heavy metals	Heavy metals may be present in underground water, either naturally or due to pollution.	Many metals can be removed with chelating resins, but those are not authorised in all countries.
Arsenic	As is found in some natural water sources. The recommended limit is 10 µg/L.	There is no proven ion exchange process to remove arsenic selectively. Other media, such as granulated iron hydroxide or titanium oxide, can be used.
Fluoride	Ground water is sometimes contaminated with fluoride originating from industrial waste, e.g. aluminium mills. The recommended WHO limit for the F^- anion is 1.5 mg/L.	Anion resins have a low selectivity for fluoride, so that selective removal is not practical. The usual process involves activated alumina.

Source: [3]

Virtually all the dissolved matter in natural water supplies is in the form of charged ions. Complete deionization (i.e. demineralisation) can be achieved by using two resins. The water is first passed through a bed of cation exchange resin contained in a vessel similar to that described for softeners. This is in the hydrogen ion form brought about by the use of a strong acid regenerant (either hydrochloric or sulphuric). During service, cations in the water are taken up by the resin while hydrogen ions are released. Thus the effluent consists of a very weak mixture of acids. The water now passes through a second vessel containing anion exchange resin in the hydroxide form for which sodium hydroxide is used as the regenerant. Here the anions are exchanged for hydroxide ions, which react with the hydrogen ions to form water. Such twin bed units will reduce the total solids content to approximately 1-2 mg L-1. With larger units it is usual to pass water leaving the cation unit through a degassing tower. This removes most of the carbonic acid produced from carbon dioxide and bicarbonate in the feed water and reduces the load on the anion unit. Without degassing the carbonic acid would be taken up by the anion bed after conversion to carbonate. If complete demineralization is required this is achieved by passing the twin bed effluent through a third vessel containing either cation resin in the hydrogen form or a bed of mixed resin consisting of both anionic and cationic resin which has been intimately combined. Mixed resin is a very efficient demineraliser and can produce water with much lower levels of dissolved material than can be achieved by distillation. For small supplies, such as in laboratories, mixed resin is often used in disposable cartridges. These are only used once, but larger mixed resin units can be regenerated. After exhaustion the bed is subjected to an up flow of water. Anionic resin beads are less dense than the cationic ones and they rise to the top so that the bed is separated into two layers of resin. Each is regenerated in situ with the appropriate regenerant then rinsed with clean water. The internal pipe work of the vessel is arranged so that regenerants and washes enter at the point separating the two resins and flow either up or down as required. An up-flow of compressed air then mixes the resins up again.

Other ways of enhancing improved water supply are:

3.5 Control of Water Pollution by Companies and Individuals

Refuse should be burnt in an incinerator with in-built devices to prevent air pollution. Sewages should be processed, treated and converted to useful fertilizers in sewage plants. Through the knowledge of fluid mechanics and strength of materials, storage vessels, oil pipes are designed with satisfactory rigidity and strength to prevent oil spills. Strict laws must be passed to control water pollution by individual and companies. Governmental plans should address pollution from point sources coming from a discrete source or pipe. These include: combined sewer overflows, excess wastewater flows, management of municipal point source discharges, operation and maintenance of wastewater facilities, treatment of industrial wastes in municipal systems, industrial wastewater treatment plant effluent standards. In addition, governmental plans should also address pollution from nonpoint sources such as: urban storm water runoff, agricultural runoff, septic wastes, surface waste disposal, air deposition and other nonpoint sources

4. CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

Access to improved sources of domestic water supply is largely influenced by the main source of domestic water. Water pollutants such as refuse and sewage, oil spills agricultural and industrial waste were identified as causes of shortage improved water supply; sources of improved and unimproved water supply were also identified. Inadequate water supply points and fluctuating release of water to populace by Water Corporation is manifested in overcrowding around public standing pipes. Other determinants of access to improved water include: distance from improved source to house, average time spent to fetch from main source, average number of trips per person per day due to main source, adequacy of supply from main source and quantity of water used per person per day. Efforts should therefore be made to bring piped water close to the homes.

4.2 Recommendations

This strategic research action plan maps out the targeted steps that should covers the next four years;

i. It is rational to consider the construction of more dams as a viable option and if cost will be prohibitive, it is suggested that the capacity of existing dams be upgraded
ii. The conventional centralized water supply and distribution systems can no longer be effective in rapidly growing cities hence, water supply and distribution should be decentralized in towns and cities.
iii. Efforts to meet the water need of city dwellers must therefore consider the atomization of sources through linking the city with other dams and construction of large scale water distribution centres as a priority. The objective of this strategy is to create sectional water works that would have defined spheres of influence and coverage to be known as Water Supply Area.
iv. To ensure strategic management and availability of water supply, it is urgent for Water Corporation to expand piped water network close to homes, hence they must ensure ceaseless flow of water from pipes, regular maintenance of the system and quick response to leakages.
v. Improved education to schools, local officials, and the public regarding the relationships between water quality, use attainment, and the causes and sources of impairment, as well as effective strategies for improving water quality locally.

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Citation: I. A. Daniyan *et al*. (2017). A Review of Strategic Management of Water Resources. j. of Physical and Chemical Sciences. V5I4. DOI: 10.15297/JPCS.V5I4.02