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Shower Atomization

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SHOWER ATOMIZATION

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SHOWER ATOMIZATION

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Date

I dedicate this thesis to my parents, Ravishankar and Anuradha, who have been a pillar of support throughout my life. I would also like to thank to my sister, Kavana for her dedication and moral support during the entire journey. Last but not the least, all my family members for their endless support and prayers, without which it would have been impossible to accomplish the goal. Thank you all for encouraging me in all of my pursuits and inspiring me to follow my dreams.

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The research will help to design a shower for Dr. Chelson's shelter, which can control the water flow, pressure and duration of the shower, which optimizes the utilization of water. The showers could be used in drought-hit areas where water is very scarce, as daily sanitation needs are necessary to keep a person safe and healthy without wasting water. The report from, World Health Organization shows that showers consume the most water. A timed shower could help resolve this issue through eliminating the wastage. Eco-friendly environmentalists may also be attracted to the showers, as their main purposes are to save energy and water. The showers could be set according to the needs of the person. Annually, the difference in costs reflects that these showers are effective and make optimal use of the available water and energy.

Introduction

Water shortage is generally the result of two major man made causes, population growth and industrial development. There are many people wanting to make use of the available water supply even though the water is contaminated. Drought is another main cause of water shortage in places where they depend on regular rainfall as source of water. This is an irregular occurrence in arid regions of the world (Li, Chen, Chen, 2012). The idea of a water shortage is deceiving. According to a leading Soviet scientist, M.I. Lvovich (1972), the water resources on earth are adequate to meet all of the man's progressively growing needs for an indeterminate time. However, man, he says, must strictly adhere to a correct policy of using water and reshaping the hydrologic cycle, which links up all parts of the hydrosphere (the seas, lakes and streams, groundwater, soil moisture, atmospheric vapor) into a single whole; and water balance, the quantitative expression of the hydro cycle and its components. Man must practice extended reproduction of suitable water resources. According to Lvovich, the water problem cannot be solved by one-sided measures but by an integration of technological, biological and organizational measures (Lvovich, 1972). This thesis deals with the technological measures for conserving water and shows how the emergence of new technology helps to conserve water in places where water is scarce.

In many parts of the world, water supply is a problem and water may be a scarce and an expensive commodity. This may be due to climate (arid), geography (far north), location (seawater only available) or circumstance such as when you are in a (spacecraft, mobile home) and in cases of emergencies, where the water is not suitable for consumption/treatment. In all these cases, the low cost of a portable atomized shower or washing unit has distinct advantages. Existing water supplies can extend to other places, as these devices make optimal use of water, in places where water is limited. As a necessity of man not only for survival and maintenance but also for health resulting from adequate washing and showering, the atomized device would be a boon. This would lead to increasing the individual's energy and strength which in turn increases the standard and quality of life. In other respects, since the person would be free from immobility caused by the disease, the economic growth potential increases rapidly as and when water becomes plentiful.

City sewage and waste from factories are considered as the chief cause of water pollution. A lesser cause, but a growing and important one, is the contamination created by chemicals used to kill insects and to fertilize crops (Okuma, 2008). The water contaminated by these chemicals finds its way into lakes and rivers, which people rely on drinking, cooking and washing. Increasingly, radioactive wastes from factories using uranium have become a considerable cause of water pollution. Pollutants are absorbed into the beds of lakes and rivers. In groundwater, they are absorbed into the earth where they disappear but move slowly and pervasively to poison new streams and water. The result is an outbreak of disease.

In areas of scarcity, water is sold from carts. For example, In Dubai 1975, a water-seller was charging $60.00 for 3,375 liters (890 gallons). That was enough water to serve a household of 16 persons for one month. Only a fraction of this is used for washing; most of it is used for cooking and drinking. Water supply is also acute on ships where sufficient quantity must be carried for long voyages. The largest super-cargo ships never put into ports but are supplied at sea. Caravans and trailers often need to carry their water supply along into areas of arid desert or where water is polluted. Recreation vehicles such as campers also need to store water. Aircraft, too, must carry their own water, although its time away from a supply source may be short, so the need is less critical except in a case of emergency.

Of great need, also is emergency water supply in disaster zones, not only because of shortage due to broken mains but also because of the impossibility of usual treatment results in a polluted water supply. Spacecraft is the extreme example of the need for water economy. Here, compactness is most critical. The least volume and weight the water supply uses, the better. Accordingly, Martin Marietta designers contracted by the National Aeronautics and Space Administration came up with a water recyclable atomized shower which, except for its zero gravity requirement, would be applicable in any of the cases cited above (Thomas & Gallagher, 1976).

The atomizing system used on the NASA Skylab is not on the market; however, similar components are available and these could be combined for bathing and washing devices (Collins, 2012). Such atomized water devices are better off to use in places of water scarcity and pollution, which reduces the water demand and with it, relatively the water costs would be reduced.

Besides that, eco-friendly environmentalists may be attracted to these showers, as the main purpose of these showers is to save water, energy and recycle water. Water providers have indicated that long showers consume the most water; thus, reducing the duration of the showers could reduce the use of water. One can determine the temperature of the water with the help of pressure valve, which helps a person to enter the shower at the desired temperature, there by ultimately reducing the wastage of water. For this purpose, there is a knob, which helps a person to adjust or vary the temperature of the water as per the requirements of a person. For accurate results, the researcher will record the difference in money on an annual basis to notice the utilization of resources such as energy and water.

Problem Statement

Based on the available data the researcher will try to come up with a specification suitable for the design, and this must be tested to check if it is worth taking up the challenge. The most important aspect here is that the design must fulfill the needs with a cost-effective approach. The thesis will be looking into the Thar Desert area for analysis on whether or not this device could be used in the region where there is acute need to save water. By saving water, it opens an opportunity to serve much more.

Significance of the Research

Low-flow showers will help conserve water, money and energy. This would allow more people to have access to sanitation in areas where water is limited and would increase health and quality of living for those who currently have no or limited access to clean water for bathing.

Purpose of the Research

The primary aim of the research will be to determine the specifications for the design of a shower which can control the water flow, pressure, temperature and duration of the shower.

Hypothesis or Research Questions

The following objectives will help the researcher to achieve the primary aim of the research.

1. Determine what water-saving technological devices are available that could be used in the design of a low-cost water conserving shower.
2. Using the available components, give specifications for a shower design.
3. Determine the cost-effectiveness of the showers.

Assumptions

Assume that people will accept new methods of bathing. Assuming people will welcome the use of technology to the contemporary methods; will help them learn how to use them effectively and efficiently which helps in solving the water crisis.

Limitations

Exact knowledge of the number of people in the area and the water consumption rates are not available. Assumption is made without this knowledge, based on the available case study and related information.

Delimitations

The focus of this research will be for the Thar Desert region and further restrict the amount of water availability. The researcher will look for currently available products, which satisfy the needs based on the cost effectiveness.

Review of Literature

Clean Water

The WHO Guide to Sanitation in Natural Disasters describes water treatment in emergencies: "The purpose of disinfection is to kill pathogenic organisms and thereby prevent water-borne diseases. The disinfection of water can be accomplished by boiling or by chemical treatment. Chlorine and chlorine-liberating compounds are the most common disinfectants. Until the laboratory facilities of urban water supply systems can be restored to normal operations, complete tests of water samples should be made at laboratories near the disaster area. The most important tests, to be carried out under emergency and field conditions are:

1. Determination of residual chlorine (free and combined),
2. Bacteriological examination for coliform bacteria,
3. Determination of hydrogen-ion concentration and
4. Determination of type of alkalinity."

Clean water is a relative term involving chemical and bacteriological quality and quantity. The standard, for disease prevention, is the count of *E. coli* bacteria present in the typical human feces.

Bathing and health

Bathing has usually been looked upon as related to health but it is also a pleasure, a social activity, a ritual. Baths were used for cooling and washing. The Turkish steam bath, the Scandinavian sauna, the American Indian sweat, were intended to open the pores of the skin and to promote sweating, thereby removing dirt and leaving one feeling refreshed.

The bath as it is now practiced, except in Japan, uses soap, leaves the dirt in the bathwater, from which the bather emerges with some of the dirt clinging to his skin (the Japanese bather rinses, outside the tub). Showers are a relatively recent invention, and an improvement, hygienically, on the contemporary bath. In a shower, the dirt is washed away down the drain while the bather is continuously wet with clean water. Also, the shower is more stimulating to the skin, because of the impact of a needle-like spray. This mild massage leaves the bather feeling refreshed. Another advantage of the shower over the tub is the ease with which hair washing is accomplished.

In both the bath and the shower, the purpose is to use clean water (with soap) to produce clean skin. The measure between clean water and clean skin is relative, so the concept is deceptive. To understand this relativity, one must look to the science of microbiology. Clean water is often measured by the amount of E. coli bacteria present and skin cleanliness cannot be easily measured. Reports of water deficiencies seldom refer to the effects on bathing practices. Most deal with food preparation and consumption needs. In many developing countries, bathing is carried out in nearby rivers and ponds, often where floods alternate with droughts. In some cases, villages are not near bodies of water and bathing is perfunctory, most of the bought water is being used for cooking and drinking.

Most diseases are associated with drinking of unhygienic water. Diseases can also spread from bathing with contaminated water since it has the opportunity of entering all of the nine openings of the human body as well as through sores and cuts. Pores of the skin also are likely to absorb pathogenic microbes.

A case in point is seen in Hassan Fathy's book of Architecture for the Poor: Most water of Egypt is infested with cercaria or bilharzia worms, and every peasant works and bathes in this infested water. In the hot summer, everyone bathes in the channels and ponds. Children especially paddle and splash every patch of water they can find, in ditches, puddles and stagnant ponds. Since it is practically certain that anyone who stands for ten minutes in an Egyptian canal will contract bilharzia, the widespread of this disease is expected and is high. Even if the disease does not enter the body, in a way there is still the possibility of disease resulting from lack of washing (Fathy, 2010).

A USSR space flight hygiene report on prolonged restriction of washing makes this clear: “An active source of contamination of the skin is the skin itself as products excreted by sweat, sebaceous glands, particles of desquamated epithelium and hair constitute an important source of contamination to the skin.

The samples of microflora on the test subjects, skin surface and underwear consisted mainly of saprophytic species: Staphylococcus epidermis, staphylococcus Albus, diptheroid, and Sarcina. The test subjects developed (after 60 days) skin diseases, which are widespread under normal conditions of life. The most common disease encountered was folliculitis mainly in the region of the buttocks and thighs. Other diseases found were: furunculosis; streptococcal interigue; acne vulgaris; dermatitis and fungus diseases of the feet.”

Although the skin diseases found after prolonged non-washing of the subjects tested did not interfere with their work, it can be expected that over a longer period of time it would have a fatal effect on their ability to work. NASA's concern for extreme cleanliness may have to do with wanting not to leave pathogenic bacteria on the Moon or in Space.

Also, the degree of cleanliness required for surgery is understandable. Perhaps for purposes of bathing there is no need to be so particular about measuring bacteria, but have seen that viable skin destroys organisms implanted on the skin, yet excreted products themselves are a source of contamination. So, for this reason, there is a need to control bacteria. Moreover, where there are cuts or sores the individual is vulnerable to infection by the entry of pathogenic bacteria into the body.

So the main concern here is with the three things: bacteria control, removing dirt from the body, and the refreshed feeling a shower gives. Some kinds of dirt will have to be removed with more water, i.e., grease and stain, for example. But on a regular basis, the atomized water shower performs well by washing away bacteria and normal dirt and sweat. According to Dr. Vos of the McGill Medical Department of Immunology and Bacteriology, the abundance of suds in washing has no advantage in removing bacteria. This is important in considering the atomized water shower where low suds soap is preferable over a sudsy soap since the latter uses too much water.

Water Supply and Sewerage

The World Bank Report goes on to state: "Individuals need a minimum amount of water for drinking and preparation of food. Because this minimum requirement is an absolute necessity, people not being served by a piped water system resort to alternatives ranging from carrying water long distances or purchasing water from vendors, to the use of heavily polluted ponds or roadside ditches. These alternatives are not feasible physically in urban areas beyond a certain size. Moreover, in the case of water from vendors, the price is so high that only very slight quantities can be bought. Domestic consumption is one of the major uses of water in urban areas, typically accounting for 50-

75% of total consumption. Industrial, commercial, and government (schools, hospitals, etc.) consumption is frequently important. Water is vital for many industrial processes, but there is sometimes the alternative available to the large industry of developing a private supply, it is seldom cheaper than a well-run municipal system. Economies of scale are important in water and usually favor a central system where all costs are considered. The different time patterns of household and industrial demand also make a central system the least expensive way to satisfy differing peak demands. Because of the explosive acceleration of urbanization in many developing countries in recent decades, the typical experience is that service which may have been adequate at one time deteriorates as consumers are connected to the system at a faster rate than its capacity (Alkhedhair, 2013).

Once a system is operating above capacity, the quality of service deteriorates for all consumers connected to it. A good example of this “network” effect is one large South Asian city which has lagged far behind the rapid growth of the urban complex and not been properly maintained. As a result, an estimated 40% of the water put into the system is lost in distribution. Service is now available for only a few hours a day because the limited water is allocated by rotation to different areas of the city. Consequently, almost every structure has a roof tank and many have pumps to try to suck more water out of the system. The cost of these facilities is enormous and may exceed the incremental cost of a proper system. A few years ago, when the seasonal rains were inadequate, the existence of the city appeared to be threatened. Faced with the exhaustion of the reservoirs, contingency plans were made to move a part of the population out of the city, and most industries were shut down for weeks. These were the consequences of the failure of the water system to keep pace with the growth of the city.

Even in less dramatic circumstances, the cost of inadequate water facilities in terms of weakening diseases associated medical treatment and reduced productivity is undoubtedly high, but the magnitude of these costs is not easily measured. The studies, which demonstrate in developed countries the public health benefits of safe water (reduction in enteric disease), do not separate the benefit of adequate piped water from those of adequate medical services, shelter, food, etc. Public health benefits are thus rarely included in quantitative estimates of the benefits of improved water services. As a result, water projects are often penalized inappropriately when compared with the projects in other sectors for which economic returns on investment reflect the more comprehensive measurement of benefits; this may account in some degree for the widespread inadequacies of water services in most parts of the developing world."

The Case of Thar Desert

After getting to know about the water shortage in the Thar Desert area of Pakistan, there was a thought that this research could help the government in solving the crisis to an extent.

Present Thar Population: 1,308,368 (Dawn, 2017).

The atomization devices could help save water. In here, emergency nozzles could be attached to faucets, which helps in lowering the pressure of water being supplied to the town. This idea can be proposed to the Government of Sindh with literature and notes from the research. Spray devices can be demonstrated for further assistance and how it could help them solve the present situation. The following data were obtained from further research about the region:

Water is delivered by 1-meter mains from a Reservoir lake after being filtered but has not been chlorinated, but the Provincial law now requires it. Water use is mainly divided equally between residential and industrial use. The largest industry consuming water is a dairy coop. Average Individual family use is around 450 liters/day (100 gals/day for a family of 5 or 6) or more in summer in places where water is easily available.

As to solutions, the first was all industries agreed to voluntary water rationing of their regular daily use. Some of the main valves were closed off. Proposals for other action were studied and found to be expensive: for example, importing water by train tanks; drilling wells, buying water and dispensing devices. The provincial government would have liked to have known about atomizer devices before spending $3.5 million on the water plant three years ago. It has been reported that if people were careful to use the minimum amount of water necessary, it would still be around 4.5 billion liters/year (1.18 billion gals/year). It would be useful for architects to specify such devices for the conservation of water but cannot force people in the city to install them. The following data are based on the study carried out in Tharparkar by Thardeep Rural Development Program (Evaluation Report Clean Drinking Water Project-Tharparker, 2013), it shows that

1. 60 % of households wait more than one hour on wells for their turn,
2. 30% of people spend 30 rupees (30 cents) a day for two buckets of water,
3. 85% of water users get water through camel/donkey transport,

4. 25% of the population are getting water through buckets on camel/donkey and 75% on women's head,
5. 47% of population has access to drinking water source,
6. 76% of women travel an average of 3kms (1.9 mile) for fetching water,
7. It consumes 52% of working hours.

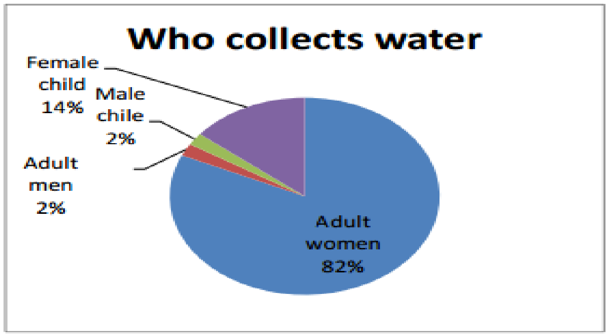

Figure 1. Who collects water. Retrieved from Reprinted from "Evaluation Report Clean Drinking Water Project-Tharparker" Retrieved from https://humanappeal.org.pk/Reports/Evaluation%20report.pdf.

Figure 2. How They Carry Water. Reprinted from "Evaluation Report Clean Drinking Water Project-Tharparker" Retrieved from https://humanappeal.org.pk/Reports/Evaluation%20report.pdf.

The feasibility of the atomizers as an emergency measure depends on how long the emergency lasts. The emergencies last around 3 weeks at a minimum. If that is the case, then there would be problems like where to get the devices; how long it would take to install them (say about 7,000 to 8,000) would arise. Finding plumbers suitable for installation of such devices could also be a problem. When looking into new constructions (both residential and industrial), it is better suited to use the atomizer devices for water conservation. Tax incentives could be provided for the industries which increase the chance of installing these devices. Based on the cost trade off, would it be beneficial to use the device, must be looked at. For a limited emergency in an established community, it would be a matter of cost, so a feasibility study should be done with a possibility of support from the surrounding industries. The installation of these devices would mean reducing water pressure and the pressure in Thar is through gravity and varies from 40 to 100 psi, which is around 2.7 atmos. (40 psi) for tips and 6.8 atmos., (100 psi) for fire sprinkler devices. The newly improved Nebia shower runs efficiently with the pressure ranging from 35-100 psi, which is the same pressure available in Thar, and using something similar to this should not be a problem. By taking into account of the available resources, a design can be developed based on the specifications and conditions suitable for the region.

Since the priority in this area is given to toilet water reduction, these devices could be used as it helps them in water reduction for alternative uses such as, shower or bathing.

Devices for Water Conservation

Since the problem of water shortage focuses on domestic use, that being the greatest area of utilization, it is mainly here that steps have to be taken towards better water management. The greatest use in the home is for flushing toilets, a use not vital to man's survival. An alternative method is to flush with less water has been proposed but only modify the situation slightly. Aerobic systems such as the Clivus Multrum moldering toilet offer a definite advantage since they use no water at all. However, difficulties arise for these systems in new urban installations, particularly in high-rise situations where the waste collection would be a problem. Devices for conserving water at the point of use have been offered, which greatly reduce waste due to inefficient devices, as well as inefficient use. In addition, reduction in the quantity of water to do the same task has been proposed. Some of these devices are –

Fordila Middle way faucet. The Fordilla Middleway faucet is primarily concerned with preventing wasteful running of unused water. It operates with a spring-loaded button, which automatically shuts off if held down longer than S to 10 seconds. It discharges approximately 1 liter per time.

Ford Meter Box Co. Inc, Wabash, Ind.

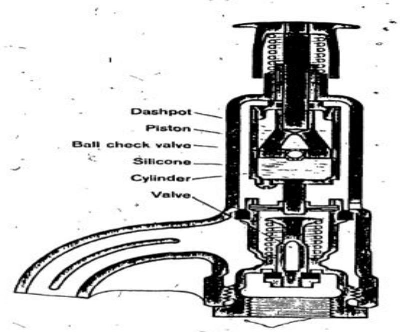

Figure 3. Fordilla Middle Way Faucet. Reprinted from “water conservation and mist experience” Retrieved from https://www.ircwash.org/sites/default/files/276-78WA.pdf.

Ultraflo plumbing system. The Ultraflo system uses an electric push-button control and mall supply pipes. Waste prevented by eliminating the running of water to get desired temperature. Solenoid valve near water heater responds to push button and delivers water at preset temperature.

Ultraflo Corp., Sandusky, Ohio.

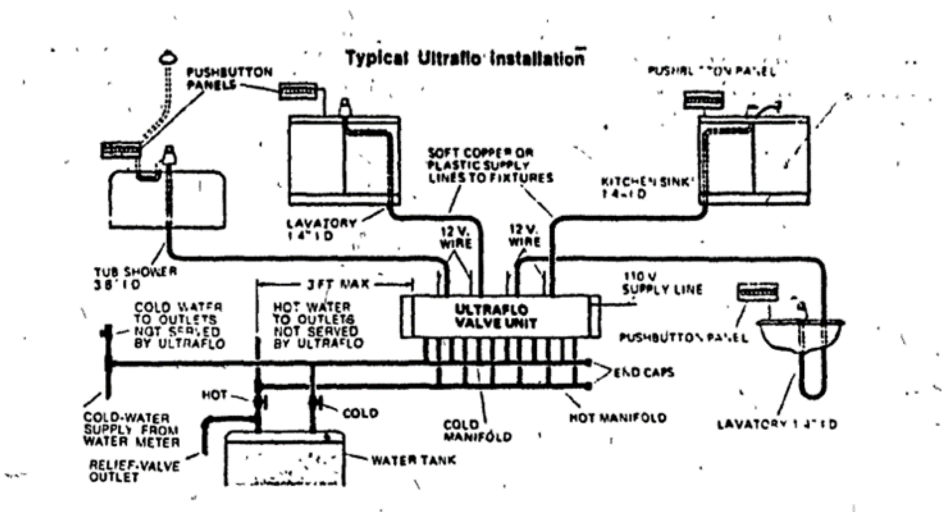

Figure 4. Ultraflo Installation. Reprinted from “water conservation and mist experience” Retrieved from https://www.ircwash.org/sites/default/files/276-78WA.pdf.

Minuse Shower. The Minuse Shower (patent pending) represents the new “state of the art” technology, which can best be described as conservation technology dedicated to solving environmental problems. The application of this technology has produced the world's most efficient shower which delivers a dramatic 90% SAVINGS in water and energy over the ordinary plumbing fixture. The Minuse Shower can be readily installed in any new construction and retrofitted in almost any existing shower. The water pressures out from three orifices in the nozzle head. An air blower imparts additional velocity, simulating a conventional shower flow. Its rate of water, consumption is 1.8 liters/minute (.5 gal/min.). Minuse Systems, Inc., Jackson, Cal.

Nova Showerhead. The Nova showerhead reduces water consumption at the point of use. Its construction allows nozzle adjustment from ufine needle" to "soft rinse" and has a button cut-off for the soaping-up period. Its capacity at 1.3 atmos. (IS psi) is 6 liters/minute (1.35 gal/min.).

Figure 5. Nova Showerhead. Retrieved http://walkinshowers.org/images/hand-held-shower-heads/A-FlowTM-5-Function-Luxury-5-Handheld-Shower-Head-System-best.jpg.

Dole pressure reducing valve. This water flow-reducing valve can be fitted onto existing fixtures. It would reduce the pressure independently of other fixtures. It is recommended for all people who tend to let water run independently during washing or bathing.

Figure 6. Dole Pressure Reducing Valve. Retrieved from https://www.picclickimg.com/d/l400/pict/201872544352_/Water-Pressure-Regulator-Brass-Lead-free-Adjustable-Water-Pressure.jpg.

Watts pressure reducing valve. The Watts pressure valve can be used to reduce pressure on independent fixtures or on the whole house system.

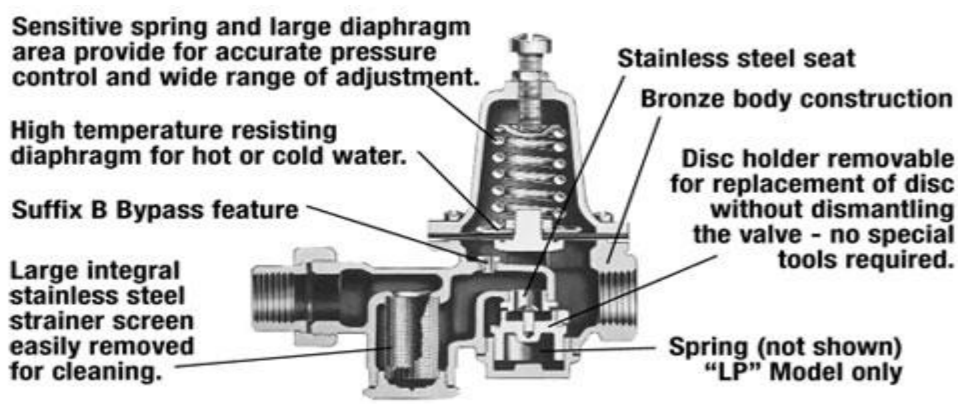

Figure 7. Watts Pressure Reducing Valve. Retrieved from https://cdn.shopify.com/s/files/1/0826/7845/files/107001-u5b-diagram.jpg.

Two other water savers, which are in regular use, are the front-loading washing machine (in preference to the top-loading type) and the pedal operated faucet. But of more relevance here is the remarkable water-saving shower in the NASA Skylab and the Nebia Shower, which uses around 2.5 liters (1/2 gallon) of water for a 9-minute shower bath. The precedent for this was first conceived by Buckminster Fuller and tested by his students at the Institute of Design in Chicago in 1948. His Fog Gun could spray at the rate of .56 liters/minute (1/8 gallon/minute).

Devices for atomization of water would make it possible to extend the water supply in developing countries. Clean water shipped in containers can overcome the shortage due to polluted water, and water atomization devices could extend the supply, while at the same time lowering its relative cost.

One such device is the Nebia shower, Nebia's design and engineering provides a significantly superior shower experience in each and every sense. Nebia is a fully self-installed shower system with an adjustable bracket and a portable wand that showers you with water like you've never experienced before?

Nebia atomizes water into millions of tiny droplets with 10 times more surface area than your regular shower. With Nebia, more water comes into contact with your body, leaving your skin clean and hydrated all while using less water than a typical household showerhead. In fact, Nebia uses 70% less water than a typical household showerhead. For the average U.S. home, Nebia pays for itself in less than two years. This is an answer to the problem of water shortage in deserts and water scarcity areas where bathing is essentaial. The Nebia sensation stays with you long after you leave your shower. For hours after finishing your shower, you feel rejuvenated. Your skin feels cleansed and refreshed. Your hair shines. Your muscles relax. This device is taken as the benchmark for the research to find the specification for the design.

Frobisher and Fuerst (1983) in Microbiology in Health and Disease describe microorganism's relation to the human body: "Numerous microorganisms find their optimum habitat in or on the bodies of man or animals. The healthy human body heaxbors millions of microorganisms on the skin, 1-4 in the mouth, eyes, ears, genitourinary tract, and in the-intestine, in short, on every surface that comes in contact with the outside world with respired air or with food. The human body is a complete ecosystem". Most of the microorganism rarely or never cause disease under normal conditions but some may under, certain circumstances (e.g. in wounds or after surgery) gain entrance to the deeper parts of the body, where bacteria are not usually present-and produce what is called an infection. Each region of the body in contact with the exterior normally has its characteristic microorganisms.

The skin carries large number of bacteria, picked up from the various things with which it comes in contact. In addition, Staphylococcus Aureus, the common cause of bolls, carbuncles, breast abscess, and other conditions is found, at times in the hair follicles and sweat glands. The skin cannot be made sterile even with the most thorough scrubbing and the application of antiseptics because although the bacteria in the outer layers of the skin can be removed, it is impossible to get rid of those in the deeper layers and in the sweat and sebaceous glands, hair follicles and so on. The mouth and throat constantly contain numerous kinds of microorganisms aided by the warmth and moisture present, and bits of food and desquamated epithelium around the teeth provide nourishment. The normal conjunctivae usually contain bacteria of a harmless kind. This is also true around the genitalia. For example, the vagina normally contains certain distinctive non-pathogenic bacteria. Prominent among the intestinal bacteria is the relatively harmless E. coli, which is viewed as an index of fecal pollution when found in drinking water. A group called enterococci, which are found to be present in faeces and fresh sewage is used as an indicator organism sometimes instead of E. coli for fecal pollution. Bacterial flora of the normal skin has been classified as “transient” and “resident”. Transient flora is subject to removal by mechanical and chemical techniques. Resident flora is limited to only a few species: acnes, micrococcus epidermis, staphylococcus, and albus aureus. Z' transient pathogenic bacteria may become residents. Viable skin has the capacity to destroy many organisms implanted on its surface. The bacterial action of the skin has been attributed to potential of hydrogen (pH) with the presence of fatty acids and soap fractions. The normal skin surface has a pH anywhere from 5 to 6. The acid reaction has been attributed to excess sweat, which has a similar pH to that of lactic acid, which accumulates as the sweat evaporates. The amino acids released or discarded in the formation of keratin may also contribute to the low pH of the skin surface. Fatty acids and soaps may contribute to the sterilizing action of the skin.

Shower

It is interesting to note the water use standards adopted by the World Health Organization in the following statement for emergency programs for disaster areas; also, their preference for showering over bathing: As soon as the early days of emergency have passed and the water supply has been increased, restrictions should be lifted, since there is a correlation between water consumption and cleanliness on one hand, and between cleanliness and the incidence of diseases on the other. With no restrictions, the use of water may approach 100 liters (22 gallons) per person per day.

Recommended standard for showers is 20-30 liters/person/day (4.4-6.6 gallons). Showers are preferable to baths both for sanitary reasons and to save water (Nasr, Yule & Hughes 2009). In hot climates, cold water should be sufficient. If hot water is provided, 20 liters

(4.4 gallons) should be supplied for each bath; over-all consumption of water for bathing should be calculated on the basis of 30-35 liters/per week (6.6-7.7 gallons).

Atomization

Atomization is defined as the mechanical subdivision of a bulk liquid. Spraying implies production of coarse drops (100 to 1000 Microns). Sprinkling suggests very coarse drops larger than 1000 Microns. The term misting is applied to the production of fine drops (10 to 100 Microns). Nebulizing is applied to very fine drops (under 10 Microns), and is usually used in inhalation aerosol therapy.

Atomization of a liquid by spray nozzles is a highly developed technology. Spray control is achieved by varying nozzle details and pressure. Finer sprays can be achieved with higher pressures and smaller orifices. But, as a result, the velocity decreases. The range of atomization is from relatively fast-moving large droplets to relatively slow-moving small droplets (Palestrant, 2008). The optimum being sought for a shower bath spray is in between i.e. fast-moving small droplets. Fast-moving, for dependable coverage and small droplets for the conservation of water.

One drawback with the atomized shower device is of course that one hand must be holding the sprayer most of the time. This is no different from the popular telephone shower, and shares its advantages, i.e., its flexibility to reach all parts of the body; and to wash children and pets with more control than is possible with the conventional fixed shower spray (Borisov et al., 2006).

Drop-production Techniques

Geometry of devices: Nozzles. “Drop-production techniques are distinguished by either the geometry of the atomizing device (i.e. nozzles), or by the source of the external motivating force employed" as mentioned in the McGraw-Hill Encyclopedia of Science and Technology (Levis, 1971). The first three categories of atomizing techniques which they list are pertinent to this study. They are: Hydraulic (pressure), Pneumatic, and Rotary. In the hydraulic atomization technique, the kinetic energy of the spray nozzles is utilized to break it into droplets. The atomization of a high velocity air stream on thin liquid films or filaments is called as the pneumatic atomization. The technique involves atomizing a liquid alloy stream by high velocity gas jets and quenching the atomized droplets by a rotating water-cooled copper drum.

The Encyclopedia goes on "Under normal operating condition's (30-200 psi) (2-13.6 atmospheres) hydraulic nozzles produce relatively coarse drops 100 to 300 Microns diameter range, the finest ones being produced by small swirl nozzles wherein pressure is converted into high relative jet velocity. Hydraulic nozzles are exemplified by garden hose nozzles, insecticide spray nozzles, and nozzles in humidification and scrubbing towers".

Pneumatic atomizers normally use compressed air (30-100 psi) (2-6.8 atmospheres) and produce drops in the 5-100 Microns diameter range. They are used in spray painting and fine misting applications, scrubbers or reactors (venturi atomizers.), and aircraft application of insecticides. Pneumatic nozzles are two-fluid, internal mix, external mix, and combination mix types. These could be, for example a mixture of liquid and air, using siphon principle (Petrovic, 2011). Rotary atomizers (spinning discs) are basically hydraulic atomizers, in which the pump and nozzle are combined and normally produce drops in the 30-300 Microns diameter range. They are widely used in spray drying because of their ability to handle viscous liquids or slurries.

The Bete Fog Nozzle Inc. of Greenfield, Massachusetts states in their catalogue (Rybczynski, 1978): “When selecting a nozzle, consideration should be given to desired capacity, pattern, fineness of the spray or fog, available pressure and orifice size where clogging may be a problem. Smaller nozzles, wider angle patterns and higher pressures result in a finer drop size.” They go on to explain spray pattern selection: There are fan or flat spray patterns for washing, applying chemicals, or flooding an area. The narrow patterns would be used where a hard scrubbing action is desired. Hollow cone nozzles are usually used in multiples where their patterns overlap for wide coverage and high capacity as depicted in the figure below:

Figure 8. Hollow Cone Nozzle. Retrieved from http://www.pnr.co.uk/products/nozzles/spray-nozzles/general-purpose-nozzles/hollow-cone-nozzles/

Full cone nozzles are most widely used and are recommended for fire protection, scrubbers, cooling and many other applications because of their uniform coverage. The exclusive patented Bete spiral nozzles, for full or hollow cone sprays, feature high efficiency and are non-clogging as they have a corkscrew-like spiral at the front of the nozzle.

Figure 9. Bete spiral nozzles. Retrieved from http://www.bete.com/pdfs/BETE_TF.pdf.

Solid cone spray patterns can be produced with nozzles which are swirl jet, impinging jet, or rotary (spinning disc). Hollow cone spray patterns can be made with tangential swirl and impinging jet types (Petrovic, 2011). The two-hole simplicity of the tangential swirl type is relatively clog proof. Flat sprays can be made with a jet on a deflector plane or planes, or with a slot orifice. Fog patterns can be made with a jet deflected by a turned back pin, interrupting the stream or combination of a small orifice and high pressure.

External Motivating Force: Pressure. The source of the external motivating force employed for atomization may be manual or mechanical. The force creates the pressure to move the liquid (Lawson, Thole, Okita and Nakamata, 2011). There are four cases:

1. Manual force makes instant pressure. For e.g. household sprayers using siphon or pump principle.

2. Manual force makes stored pressure. For e.g. garden sprayers.
3. Mechanical force makes, instant pressur. For e.g. water-pic toothbrushes.
4. Mechanical force makes stored pressure. For e.g. paint sprayer using siphon or pump principle.

Aerosols

Aerosol sprayers come under the category of pneumatic atomizing techniques and are included here only because they are a special case. They are cans containing a fluid and a propellant, which is a type of gas which compresses to a liquid. The top of the can has a nozzle which releases the fluid mixed with the propellant, but the propellant, a fluorocarbon, bursts into a gas when released from the can.

The nozzle is usually a two-fluid internal-mix pneumatic type. The contents have been mechanically stored in the container. The major objection to aerosols is the propellant's effect on the environment. The fluorocarbons when released, float up to the stratosphere and mix with the ozone layer. They then convert ozone to oxygen, thereby thinning the protective ozone shield and allowing the penetration of the earth's atmosphere. The lethal ultra violet rays which are believed not only to cause skin cancer but, perhaps more importantly, the destruction of food chains, of normal plant growth; and can, moreover, cause seasonal changes which affect our food source.

Water Spray Injected into Air Spray

The purpose of a spray is to increase the surface area of the injected liquid to promote the heat and mass transfer. In most cases, the behavior of spray can be described by spray angle, dispersion (drop size distribution) and penetration. These parameters are determined by the spray nozzle, breakup mechanism and aerodynamic effects after breakup, which in turn depends on the ambient pressure (density), injection pressure, liquid and gas properties for a particular nozzle. Since 1930, a great deal of research has been performed on the breakup mechanism and the effects of ambient pressure, injection pressure, liquid properties including extensive review works.

The aerodynamic behavior of spray was studied by Rothe and Block (1977), explained the mechanism of atomization of the jets by the drag of the ambient air; a portion of the large mass (jet) caught up by air stream and anchored at the other end is drawn out to fine drops by Rayleigh instability. Schweitzer explained the breakup mechanism by the turbulent motion which occurred inside the nozzle. The radial disturbance (velocity) tends to break the interface as soon as the restraint imposed by the orifice wall ceases. A laminar boundary layer may retard this disintegration up to certain distances. (Tanasawa & Toyoda, 1955) Studied the breakup mechanism using the photographic method, the light source being an electric spark of 0.1 micro-second duration.

The breakup regime is divided into four patterns; dripping ($Je < 0.1$), longitudinal oscillation ($0.1 < Je < 10$), lateral oscillation ($10 < Je < 500$) and atomizing ($Je > 500$). Basically, the initiation of breakup is due to the drag of the surrounding air; whereas the model of Schweitzer (Listner & Schweitzer, 1997) emphasizes the turbulent motion which originates from nozzle hole. Yet there is no definite explanation on the breakup mechanism; the effect of turbulent motion, drag of surrounding fluids, properties of liquid and surroundings (such as, viscosity and surface tension), shape of the nozzle are all considered as governing parameters of breakup. However, as far as breakup patterns are concerned, the type of classification used by Tanasawa & Toyoda (1955) is generally accepted for the purpose of application to practical systems (such as engine design), the study of sprays was conducted in a different manner. That is, the phenomena of spray were studied experimentally by changing the governing parameters; such as ambient pressure, injection pressure (flow rate) and fluid properties.

Khmelev et al., (2013) reported that the drop size distribution becomes even and initial spray cone angle increases with the increase of ambient pressure, injection pressure and decreases with liquid viscosity. Ranz introduced the concept of stress on the atomizing mechanism. In his report, the condition of atomization depends on the ratio of inertial stress (velocity of droplet) and surface normal stress (surface tension effect), which leads to a form of the Weber number. Also, the theoretical dispersion angle is predicted as a function of viscosity parameter. He suggested the possibility of modeling the spray using the Weber number as the criterion. Recently, (Bossini, 2001) used an ultra-high-speed-filming camera to study spray phenomena; such as, intact length, spray angle, etc. He found the spray cone angle increases as ambient pressure increases and decreases slightly with increasing liquid viscosity, and strongly depends on nozzle design. Most of the above studies were conducted on a solid-injection nozzle. However, in many applications, other types of nozzles - such as, swirl (centrifugal) nozzle, poppet type nozzle and fan spray nozzle are used for better atomization.

(Woolf, Pau & Shouler, 2006) Concentrated on determining the drop sizes for swirl and fan sprays as a function of injection pressure and flow number (which depends on the atomizer design). Their results show the drop size is inversely proportional to the injection pressure. In addition, (Walzel, 2010) Studied the effect of ambient pressure (at sub atmospheric pressure) on drop sizes. He also discusses the disintegration of a liquid sheet produced by fan spray nozzles. Two principal modes of disintegration were discussed; due to the growth of aerodynamic waves; and due to the perforation in the sheet. The aerodynamic instability is caused by unbalance of the aerodynamic forces and interfacial tension. This unstable wave propagates at the same velocity as the sheet with exponentially increasing amplitude (Kelvin - Helmholtz type instability) until breakup occurs (Walzel, 2010).

On the other hand, perforation occurs by the presence of non-wettable particles in the liquid or by certain turbulence characteristics in the nozzle. Coalescence of expanding perforation produces the network of unstable ligaments which eventually break into droplets. (DeCorso, 1978) Studied the effect of ambient and injection pressure on spray angle and drop sizes. Experiments were conducted with the centrifugal nozzle and diesel fuel. He concluded that the spray angle decreases markedly with increasing fuel and ambient pressure. This conclusion seems to contradict to the results reported by other researchers. This is because the swirl (or centrifugal) nozzle has different flow characteristics compared to the solid injection nozzle (Hussary & Heberlein, 2001). It is generally explained as follows; for the plain atomizer (solid injection) the axial velocity of liquid is always larger than radial velocity (5 to 15 times).

With an increase of air density (due to increase of ambient pressure), the decrease of axial velocity will be greater than the radial velocity and the spray angle will increase. However, in case of swirl nozzle, higher ambient pressure causes larger air core diameter to exist inside the nozzle. With the vortex type flow of liquid, the tangential velocity at the air core periphery must decrease, which results in decrease of spray angle. R>r a centrifugal nozzle, it is also reported that the effect of injection pressure on the spray angle turned out to be small. Rather, the large decrease of spray angle observed by DeCorso seems to originate from a different definition of spray angle used (DeCorso, 1978). He defined the equivalent spray angle which is primarily determined by the spray radius downstream. If the spray is injected into air, it will drag the air in the axial direction, induce the entrainment of the ambient air inwards in lateral direction, and then drag the droplets inwards (Panao, Rosa & Moreira, 2009). If the ambient pressure (or ambient gas density) increases, the inward drag force increases; thus the equivalent spray angle (or spray radius downstream) becomes smaller. He also reported that the drop sizes (Sauter Mian Diameter) becomes smaller up to a certain ambient pressure, and then increases above that pressure. It is conjectured that increasing the ambient pressure above a certain value causes the coalescence of droplets. However, this secondary effect has not been clearly documented experimentally (Nasr, Yule & Bendig, 2002).

(Lasheras, Villermaux & Hopfinger, 1998) proposed a one-dimensional model to obtain the spray shape assuming that the breakup is complete at injection. The continuity and momentum equation were set up for the whole spray region with the drag force on each droplet taken into account. Their solution gave the spray outline shape. In this model, the drop size is assumed to be uniform. This model greatly simplifies the actual system and from a practical point of view, it is questionable to define the boundary of spray based on a uniform drop size. The effect of condensation on a spray is not taken into account in the above research. The phenomenon of direct contact condensation of steam is important to various fields. For example, cold-water spray was injected into steam when the loss-of-coolant accident situation occurs in a nuclear reactor; cold-water spray is injected into steam in direct contact type condensers (heat exchangers); etc.

Although direct contact condensation has been a subject of importance for a long time, only very, limited research is available on the behavior of cold-water sprays in direct contact with steam (Lasheras, Villermaux & Hopfinger, 1998).

Methodology

Past quantitative and qualitative published studies including journals, books, libraries and other reliable and relevant internet sources will be evaluated to determine the existing knowledge and the feasibility of the showers. The devices currently available on the market will be analyzed so that a design can be developed that will enable the research objective to be achieved. There are many devices available but they have to be cost effective to be useful for this research. For this purpose, the researcher will establish a model which will determine the effectiveness of the device and whether it could be used in this situation. The model will focus on the availability and use of the resources used for installing and using showers. This will enable an appropriate design that will meet the standards for water conservation in a uniform manner in the Thar Desert.

Data Analysis

The first research objective was to find a nozzle of adequate capacity to ensure a given flow rate with a minimum supply of water that would be sufficient to reach the skin surface from a comfortable distance and to find if the impact was sufficient to remove soapy water in the rinsing process. To get the skin wet does not require much impact, but convenient distance of nozzle from skin is desirable to remove the suds and also requires a powerful spray. The nozzles were compared with the performance of the nozzles used in the NASA Skylab shower and Nebia shower.

The second research objective was to determine the specification and design of the nozzles as to which would work best for this research. The research would evaluate a number of nozzles, which will determine if they have the required flow and the pressure capacity suitable for the Thar Desert.

The third research objective was to check the existing products available on the market and to propose a design requirement based on cost effectiveness. An evaluation tool was developed to determine the cost effectiveness of the showers for use in the Thar Desert. This was a mathematical model that would evaluate water consumption, cost of water, sewer impact, showerhead costs, installation costs, cultural criteria, hot water usage, pressure needed, electricity usage and the effectiveness of the shower in terms of cleaning. The resulting tool helped to evaluate the variety of factors, which affect the shower in a given region.

Findings or Results

Past research was evaluated in which simple nozzles are reviewed. Complex types used in the paint and food industries was omitted, since this study has a requirement for a simple technology at low cost for developing countries. The nozzles evaluated ranged from a garden hose nozzle to household sprayer nozzles. The main aim of evaluating was to check if the nozzles satisfy the requirements,

1. A nozzle of adequate capacity to insure a given duration of flow with a minimum supply of water,
2. To determine if the spray velocity was sufficient to reach the skin surface from a comfortable distance (say about 8 inches),
3. To check if the impact was sufficient to remove soapy water in the rinsing process? (To get the skin wet does not require much impact, but convenient distance of nozzle from skin is desirable to remove the suds and also requires a powerful spray).

The NASA Skylab shower and the Nebia shower system were used as a benchmark for evaluating the nozzles and to check if they satisfy the requirements. However, the main goal here was to sustain pressure to give a 5 to 10-minute shower using as little water as possible. NASA nozzle performance was based on zero gravity and this standard could not be reached using a duplicate nozzle.

For air pressure, an electric compressor was used and the tests were repeated with a bicycle pump. The compressor had a constant pressure of 2.0 atmos (about 20 psi). Eighteen strokes on the bicycle pump produced a pressure of 3.3 atmos (about 48 psi) but after 12 minutes it was found to be around 1.7 atmos. (about 25 psi) (Massey et al., 2001).

Equipment looked into.

1. Black and Decker Paint Sprayer compressor: This was rated at 9.2 amps, 115 volts, and the pressure was Capable of reaching 4.0 atmos, (60 psi).
2. Volkswagen Teflon window washer tank: Having a volume of 2.5 liters (0.55 gallon), this was filled with 1 or 2 liters of water.
3. 1/4" vinyl hose to fit over the nodes on the VW tank. 1/8" hose was used for tests on the NIAGARA and ESTRA nozzles.
4. Chapin garden hose hand control valve with off-on device: This was adapted to receive all except the NIAGARA and ESTRA nozzles, which-had built-in hand controls.

Nozzles which were found beneficial for this reseach are.

1. Black & Decker Paint Sprayer- 5 liters/ 5mins.
2. Spraying Systems Whirl jet 1/8A – 2.17 liters/ 5mins.
3. Bete P2P- 1.8 liters/ 5mins.
4. Bete W5D80F- 7 liters/5mins.
5. Bete-F200 n- 1.92 liters/ 5mins.
6. Steinen TM051- 1.5liters/ 5mins.
7. Estra 6400- 0.86 liters/ 5mins.

Niagara 71- 0.435 liters/ 5mins.

Determinants for the proposed design based on the above specifications.

1. Capacity (flow rate) -based on Nebia Shower

2. Spray pattern - Hollow cone is preferred over solid cone because of its simplicity and reduction in clogging.

3. Material - brass selected for its durability and non-corrosiveness or steel for its strength, ductility and durabilty.

4. Connection - In some cases where nozzles are available only in a particular size, then connections can be used to make it work for the design.

5. Orifice – Small orifices produce smaller droplets, but the water pressure is low.

6. Right angle head - convenient for directing spray.

7. Spray angle - narrow angle better to conserve water and prevent overshoot.

8. Atomization - this should be between "sprinkle" which is over 1000 microns and "mist" 10-100 microns, to wet easily and quickly.

The reseach indicated that the Bete F200 has a greater impact as it has fan spray nozzles. The outcome depicts that nozzles with smaller orifices (as on the Niagara and Estra) helped sustain the flow of water for a longer period than nozzles with larger orifices; however, the quality of spray was finer with the small orifice and the impact less. Nozzles with larger outlets yielded capacities too high for a workable shower. The goal criteria of 1 liter in 5 to 8 minutes (0.25 gal/5 min.) was achieved but at the cost of very low impact.

The Bete P20 nozzle performs at .33 liters/minute (.07 gal/min) but its projecting pin would disqualify it based on safety to the bather as well as its liability to damage. However, a, protective collar-cap attached to the nozzle would be a simple corrective measure. Although having a very good capacity, the Estra's spray impact was less satisfactory in removing sudsy water. The best performance in both impact and duration were the Steinen TM501 and the Bete F200 nozzles.

Since nozzles with the required range are not manufactured, perhaps the use of standard components is impractical, and since the goal of a nozzle capacity of .25 liters/minute (.05 gal/rain) i.e., a shower using 1 liter (.22 gal.) of water and lasting about 8 minutes, is too extreme, the goal should be revised. A more practical standard would be to employ 3 or 4 liters (.6 or .8 gal.) of water for a shower lasting about 8 minutes. This would require a nozzle with the capacity of .5 liters/minute (.11 gal/min.) which is readily available from manufacturers. The water saving would still be enormous: a saving of over 90% of current average water quantity used for showering (50 liters or 11 gallons).

Summary of findings

1. The atomized shower is feasible and yields a saving at the end of the year or cycle of its usage through saving water, electricity which inturns saves money.
2. There are equipments available on the market for an atomized shower but they are expensive for this cost-based approach.
3. Low suds soap to minimize the quantity of water used for rinsing (as it needs more pressure and more water for rinsing high suds).
4. Since the focus is on reducing toilet water in the Thar Desert region, a combination of the atomized shower and the Clivus toilet would be prove beneficial for optimal use of water.
5. The atomized shower proves to be more hygienic as it creates mists to wet the body, there by reaching to all parts of the body, which is not the same when using

a regular shower.

6. Air pressure of the water should be a minimum of 1.3 atmos (15-20 psi) and in some cases; it needs to be pressurized upto 4.2 atmos depending on the type of the device used.
7. Nozzles should have a fan pattern, small orifice, under 1.58 mm (preferably 0.59 mm to 0.70 mm), (1/16"), right angle and with capacity of about .135 liters/ minute (.03 gal/min.).
8. Further research needs to done on pressure sources, hair washing, and multiple showers.
9. Shower water conservation of over 90% can been established using this design.

However, the Niagara and Estra nozzles does not provide the required mist of around 100-1000 mircrons essential for the design. This study has only explored the possibilities and merely sought to establish standards for atomized showering.

Five years ago, Nebia set out to build an amazing new shower experience and dramatically reduce water consumption. Nebia establishes an entirely new standard in water use, reducing shower water consumption by up to 70%. Nebia enables millions of people to take ownership over their daily shower, save thousands of gallons of water per year, and substantially reduce their overall environmental impact. Nebia also helps you conserve energy. Traditional household showers consume markedly more energy than a Nebia just to heat the water and the majority of that hot water goes straight down the drain. Nebia is 13 times more efficient at delivering the heat you pay for to your body, making your daily shower in a Nebia 13 times more thermally efficient. The combination of Nebia’s water and energy savings translates to lower monthly utility bills.

The atomized shower produces a different sensation from the normal shower. Although the device is similar to the handheld shower which can reach close to all parts of the body, the spray impact is much less, so the needle-like massage is missing and a softer flow of water is felt since the droplet size is finer. During rinsing, the soap comes off slowly in the proposed design, and must be wiped with the help of a cloth or sponge, since the weaker impact spray does not move the suds as fast as with the normal shower. However, on completion, one has the same joy and clean feeling as after a normal shower. Perhaps it is like a gentle rain in contrast to a driving rain.

Table 1.

Shower Parameters.

Parameters				
	Normal Shower	Nebia Shower	Bucket Shower	Proposed Design
Water Consumption (gal)	18	6	8	1.6
Electricity (Kwh)	8	4	N/A	4
Pressure (PSI)	40-80	35-100	N/A	35-100
Duration (min)	8	8	4	6
Maintenance	Needed	Self	N/A	Self
Wastage (gal)	12	Optimum usage	4	Min usage
Facility required	Yes	Yes	Not needed	Yes
Water Supply	Needed	Needed	Not needed	Needed
Installation costs($)	150	Self-done	N/A	Add-on to existing
Consumption per/min(gal)	2.25	0.75	2	0.256
Water Saving	None	70% of normal shower	None	90% of Normal shower
Plumbing ($)	150	Add on to an existing	N/A	Add on to the existing
Effectiveness of Shower	Good	Soft and keeps you hydrated	Not so effective	Soft and good

Note. Parameters specifications.

The water-saving shower and the elimination of water discharge to a sewer serve as environmental protection and energy conservation. Less fresh water per showering saves energy in treatment and plumbing. Less hot water is used; and less sewage is generated which conserves energy used in heating and treatment. Considering the increasing demand for water, the increasing cost of energy, and increasing water quality requirements demanding better treatment, the implications for conservation by the wide use of such a shower system are very significant, especially when projected over the next few decades.

It was visible that there are certain barriers that exist in the Thar Desert. To convince users to convert would require demonstration, mainly of cost savings. In localities where bathing is minimal and disease a common condition, only a long-range educational program can help in the acceptance of any new technology. Richard Feachem reports on introducing new technology into the New Guinea Highlands clan (Freachmen, 1973). He reports that cultural habits inhibit improvement of the water supply. These accounted for minimal water use, for example, total per capita usage being 0.68 liters daily of which 79% is for drinking.

Table 2.

Shower Attributes.

Shower Attributes				
Shower Attributes	Normal Shower	Atomized Shower	Bucket Shower	Proposed Design
Pressure (PSI)	40-80	35-100	N/A	35-100
Duration (min)	8	8	4	6
Maintenance	Needed	Not required	Not required	Not required
Wastage (gal)	12	Optimum usage	4	Min usage
Facility required	Yes	Yes	Not needed	Yes
Water Supply	Needed	Needed	Not needed	Needed
Consumption per/min(gal)	2.25	0.75	2	0.256
Water Saving	None	70% of normal shower	None	90% of Normal shower
Effectiveness of Shower	Good	Soft and keeps you hydrated	Not so effective	Soft and good

Note. Attributes for Thar Desert.

The Anticipated costs for a year are shown below, which takes into account the water consumption, electricity, usage costs, equipment costs, wastage etc for 300 showers. This helps in determining the overall costs per product which will help in determining the end result.

Table 3.

Anticipated Costs.

		Costs			
Anticipated years of Service	1				
Anticipated Showers/year	300				
Usage Costs	Normal Shower	Atomized Shower	Bucket Shower	Proposed Design	Costs
Water Consumption (gal)	18	6	8	1.6	$0.05
Electricity (Kwh)	8	4	N/A	4	$0.11
Heating Costs($)	0	0	0	0	$1
Waste(gal)	12	Optimum usage	4	Min usage	
Maintenance ($)	25	20	10	20	$1

Note. All costs are in US Dollars.

Early familiarity with atomizers may reduce cultural resistance to new technology, which can help prevent future water shortage. Despite potential cultural resistance and the time lag for new technology to be accepted, the concept makes sense. If the world is to sensibly organize its water use with an integrated program of technological, biological and organizational measures, a water crisis can be averted (Lvovich, 1972). The atomized shower is offered here as a technological measure for saving water in places where water is hard to get, yet daily sanitation needs are essential for one to remain healthy.

Table 4.

Overall costs.

	Costs			
Anticipated years of Service	1			
Anticipated Showers/year	300			
Usage Costs	Normal Shower	Atomized Shower	Bucket Shower	Proposed Design
Water Consumption (gal)	0.9	0.3	0.4	0.08
Electricity (Kwh)	0.88	0.44	0	0.44
Heating Costs	0	0	0	0
Waste	0	0	0	0
Cost per Shower	1.78	0.74	0.4	0.52
Maintenance	25	20	10	20
Total Cost per/year	559	242	130	176
Initial Costs($)	150	250	2	30
Plumbing Installation costs($)	150	150	100	150
Septic Installation	300	400	102	180
Total Initial Costs($)	$859	$642	$232	$356

Note. All costs are in U.S Dollars.

Recommendations

The concept of the Grey tank derives from current studies of the Clivus Multrum toilet. This toilet utilizes aerobic decomposition of fecal matter in its operation to produce a compost. The system uses or requires no water. The waste deposited in the Clivus Multrum toilet can be withdrawn as fertilizer, while the grey water collected in a container under the shower serves as garden irrigating water or as reserve water for firefighting. This could provide a more optimal approach to saving water as most water is being wasted through flushing the toilet. Since studies show that flushing takes up most of the water, the Clivus Multrum toilet would be a good addition to this research in trying to extend the current water supply to many more.

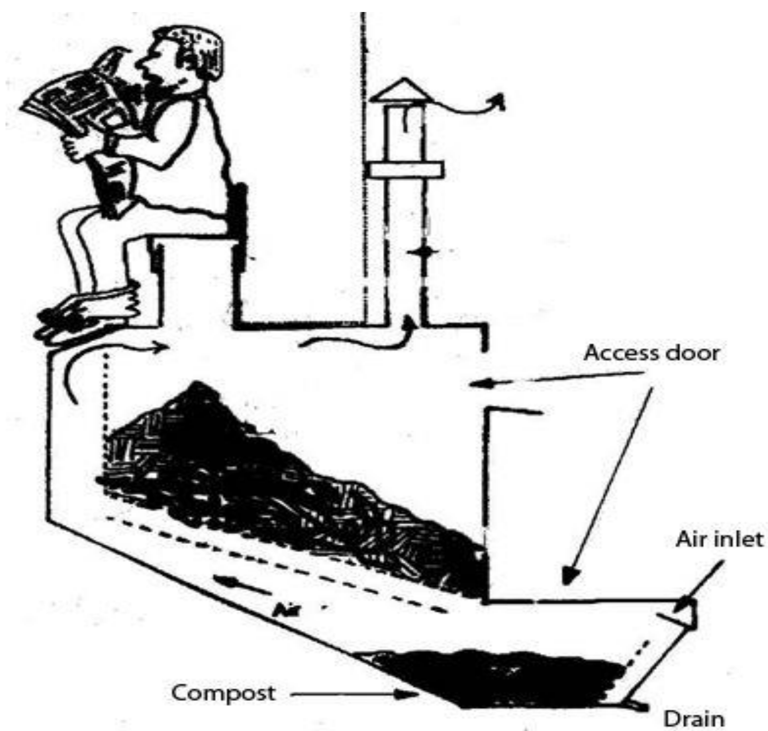

Figure 10. Clivus Multrum toilet.

Retrieved from https://www.pinterest.com/pin/325948091762167395

Conclusion

Specifications for the proposed design

Specifications derived from the above determinents for selecting a nozzle:

1. Capacity (flow rate: .35 liters/minute (.1 gal/min.)
2. Spray pattern: hollow cone as it helps in reduction of blockage.
3. Material: Brass/ 303 Stainless steel/ 316 Stainless steel
4. Connection: 1/2" ' o.d. male
5. Orifice: 0.59 mm to 1.58 mm (for optimum usage the less the orifice the better).
6. Right angle head
7. Spray angle: 70 - 90°
8. Atomization (droplet) size; "Spray"-100 - 1000 microns.

The nozzle performance range affects bathing. The more forceful and larger droplet-nozzles use water too fast for a satisfactory shower, while the finer droplet nozzles produced a spray too weak to remove the soap in the required time and amount of water (desired droplet range 0.59 mm to 1.58 mm). However, the Steinen TM051 nozzle achieved a good compromise obtaining a 6-minute shower with 2 liters of water. In addition, its right angle head proved most comfortable for handling and for reaching all parts of the body. Another nozzle, which was found to satisfy the requirements, was the Bete F200. Its greater impact proved more effective than the Steinen TM051 V in removing soapsuds. This was due to the concentration of droplets in a fan pattern. The drawback of the Bete F200, however, was that it does not have a right-angled head. Ofcourse, this advantage or disadvantage depends on the type of control valve handle used.

The regular shower uses about 65 liters (17.2 gal.) of water and takes about 5 to 9 minutes. This design uses approximately 2 liters (0.5 gal.) of water for 5 to 8 minutes. This is a water saving of around 90%. There are tests to demonstrate the feasibility of the atomizing devices and to show how they help in satisfactorly cleansing of the body. Since this reseach required working with a low cost budget, new technologies are not feasible, until further refinement of these technologies for optimum recital based on the cost effective nature for this research. There are devices that are availabe in the market to be readily used, but exceed the required budget. Hence this research has come up with a design specification for the Thar Desert region based on the available parameters for the region.

There are millions of people living in poverty without the supply of clean water. Women and young girls are subjected to water collection in most developing countries. Often, these women and girls spend hours a day traveling to collect water to meet their family's needs. This task consumes most of their time and is the reason for them not to pursue their education, focus on domestic duties and find other job opportunities. Providing a close water supply and teaching them to use the resources effectively, permits these girls to save time, which they can work on their education. Education allows females to improve their prospects and the future of their societies.

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