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Point-of-Use/ Entry Drinking Water Strategy for Arab Countries

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Abstract

This paper investigates the potential for incorporating point-of-use and point-of-entry treatment alternatives in drinking water supply strategies of Arab countries. The increase in the adoption of these treatment alternatives in Arab countries and the drivers for this increase are discussed. The paper then outlines the required elements of a strategy to be considered in the incorporation of such alternatives. Finally, a conceptual framework for the selection of sustainable point-of-use and point-of-entry systems is described. This framework encompasses indicators used to select and rank treatment systems. This is considered a timely intervention to describe a strategy to control the growing market for point-of-use and point-of-entry systems.

Keywords: Drinking Water, Water Treatment Strategies, Point-of-use, Arab Countries

Introduction

The Arab region is currently facing serious challenges from the implications of economic development. A major challenge is to provide safe drinking water to all while ensuring minimum environmental, economic, and social adverse effects. Drinking water strategies and policies have evolved over the years to face this challenge. A promising, yet often overlooked, strategy is that of point-of-use (POU) and point-of-entry (POE) water treatment.

The current practice in Arab States is using large centralized treatment plants and long distribution networks to serve consumers. In the past two decades several concerns with this practice have emerged: 1) the elevated costs of upgrading central plants to cope with stricter drinking water regulations and degrading water quality; 2) the multiplicity of emerging contaminants and the call for setting new water standards; and 3) the difficulty in controlling contaminants introduced in the distribution system such as disinfection byproducts and lead. Similar concerns are present worldwide and this has prompted the consideration of POU and POE treatment systems as an end of pipe solution and a last line of defense against water contaminants (McEncroe, 2007).

POU and POE systems have been the subject of several studies and investigations of their capabilities and risks in complying with drinking water standards. However, the challenge of implementing a new strategy is ensuring its sustainability by carefully balancing the use of environmental, economical, and social-cultural resources in such a way that the contribution to local and global problems is minimized or are at least known and accounted for. A sound strategy is needed to ensure the sustainability of implementing POU/POE systems.

Furthermore, the worldwide growing interest in POU/POE devices has led to an overwhelming increase in the number of commercial devices that are marketed as potential solutions to drinking water problems. This leaves consumers and community water suppliers with the difficult task of choosing from these devices. This paper investigates the feasibility of POU and POE water treatment as a strategy alternative for drinking water supply in Arab countries. In addition, a framework for selecting a sustainable POU/POE treatment system is presented.

Distributed Water Treatment Systems

Large scale centralized water treatment may be preferable with respect to robustness and economy of scale. However, as regulations become stricter water treatment becomes increasingly sophisticated, making it increasingly expensive. An advantage of centralized treatment is the fact that monitoring and control of one single plant is easier than a large number of small ones. On the other hand, the effect of failure in a small-scale plant produces less widely distributed health effects. The main advantage of decentralized systems is that they offer the potential to use different treatment techniques best suited to their respective source water. In addition the expensive and risky transport of water over large distances is eliminated (Norton and Weber, 2006). However, the success of decentralized solutions demands consumer acceptance and participation.

The economic and technological merit of distributed water treatment systems as alternatives to centralized water treatment has been the subject of investigation by many researchers (Adriaens et al., 2003). The breakeven cost of distributed water treatment units used to remove disinfection byproducts compared to enhanced centralized treatment was found to slowly decrease as service population size increased, indicating that, in this respect, only centralized treatment can be feasible for large communities (Norton and Weber, 2006).

The smallest scale of distributed drinking water treatment systems is that of point-of-use devices. These are devices that only treat water intended for direct consumption (drinking and cooking), and are typically installed at a single outlet or limited number of water outlets in a building. A slightly larger scale is the point-of-entry treatment level, where devices are typically installed at the inlet to treat all water entering a single home, business, school, or facility (Figure 1) (AquaVic, 2007, USEPA, 2006a, USEPA, 2006b).

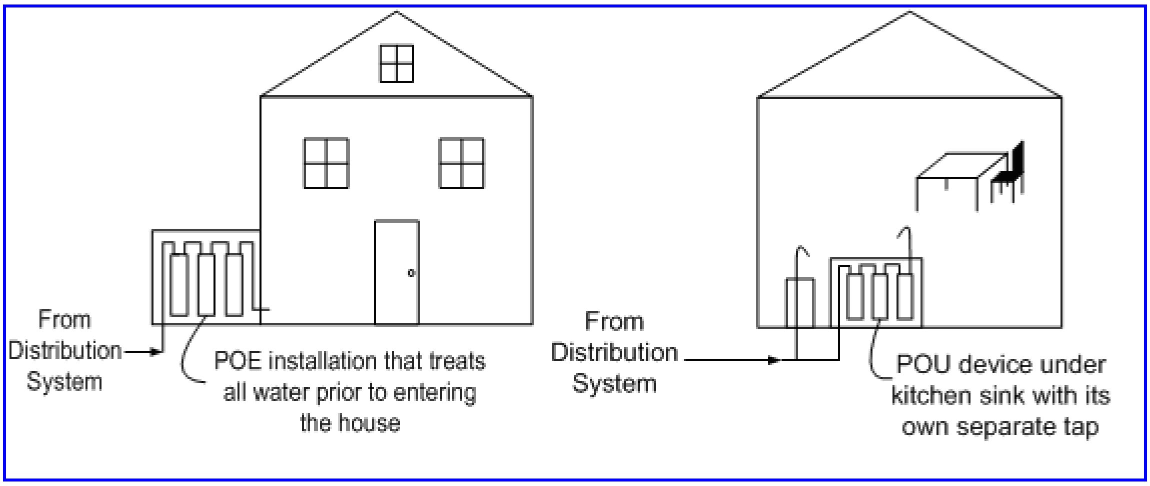

Figure 1 Typical installment of POU and POE systems

POU/POE systems are typically designed to reduce specific contaminants in drinking water, including heavy metals, pesticides, particulates, and pathogens (Chaidez and Gerba, 2004). Most treatment technologies can be implemented on a POU/POE scale including: activated carbon and other adsorption resins, distillation, membrane filtration, and others (Table 1). Some treatment packages consist of several processes in series depending on the level of treatment needed and the quality of the feed water. Some, such as reverse osmosis units, even have prospects for small scale desalination that is being recommended by Arab researchers (Bouchekima, 2003, Ayoub and Alward, 1996).

Arab Water Supply and Role of POU/POE Systems

There are many changes on the drinking water supply horizon in the Arab region. These changes will influence future water supply strategies. This section discusses some of the changes that are directly related to the use of POU/POE systems.

Consumer awareness and concerns

Consumers in many Arab states use bottled water as a perceived healthier alternative to public treated water (Al Fraij et al., 1999). The most important factor for the worldwide rise in the use of POU/POE treatment is the increase in consumer awareness about water issues and their concerns about the safety of centrally treated water. Although there are no confirmed statistics on consumer trends towards drinking water, it is apparent that there is a growing concern among Arabs regarding the quality of their home drinking water, and that more Arabs are looking for a home drinking water solution (Smith and Emam, 2006, Smith and Komos, 2008).

A recent analysis of consumer acceptance of centrally treated water stored in roof storage tanks in Amman, Jordan showed that 54% did not use the water for drinking (Al-Omari, 2008). In general, consumer concerns about their tap water include: source-water of perceived high risk, a perceived insufficiency in water treatment, and unpleasant taste or odor (Smith and Emam, 2006, Smith and Komos, 2008). Alternative water sources are often sought due to perceived improvements in quality and safety over regular tap water.

Table 1 Performance of some POU/POE technologies

Technology	Removes				Notes
	Viruses	Bacteria	Cysts	Organic Compounds	
Solid Block Activated Carbon (SBAC)	no	some	yes	most	Limited removal capability for some pesticides; can remove methyl tert-butyl ether and selected disinfection byproducts; also removes chlorine and can be formulated to remove metals
Granular Activated Carbon (GAC)	no	no	no	most	Limited removal capability for atrazine, aldicarb, and alachor; shows promise for removal of biotoxins; removes chlorine; and is moderately effective at removing some metals
Ultraviolet (UV) Light	most	yes	yes	no	Requires prefiltration; used alone or in combination with other technologies
Microfiltration (MF)	no	yes	yes	no	Used as prefilters in combination with RO
Ultrafiltration (UF)	some	yes	yes	some	Cannot remove low-weight (less than 100,000 daltons) organic compounds
Nanofiltration (NF)	yes	yes	yes	some	Can be configured to remove arsenic
Reverse Osmosis (RO)	yes	yes	yes	most	Not effective at removing low molecular weight organic compounds; removes many metals and radionuclides; can be used for small scale desalination

Source (USEPA, 2006a)

Distribution system contaminants

Concerns regarding contaminants introduced in the distribution system in the Arab region have been sounded by many researchers (Abdel-Monem et al., 1991, Abo-Shehada et al., 2004, Alforeij et al., 2001, Almohaithaf, 2001, Al-Mudhaf et al., 2007, Al-Omari, 2008, Al-Rawajfeh and Al-Shamaileh, 2007, Elshorbagy and Abdulkarim, 2006, Smith and Emam, 2006, Smith and Komos, 2008). These contaminants include mainly disinfection byproducts (DBPs), copper, aluminum, cadmium and lead concentrations in cities that use lead pipes and lead containing materials in the distribution system and household plumbing (Mohamed et al., 1998, Lasheen et al., 2008).

Moreover, in some parts of the Arab region (e.g. Gulf countries, and Jordan) operating the water distribution network to ensure continuous water supply is non-achievable due to economic or physical circumstances. In such cases, intermittent water supply is often adopted (Alshbool, 2003). This means that water is supplied on periodic basis based on assessment of demand at different areas of the distribution network. Among the associated water problems with intermittent supply is the low pressure in the distribution system. This, in turn, elevates the risk of biofilm growth and microbial contamination; in addition soil water seeping from cracks and weak joints may create hazardous contamination of water.

Another potential contamination source is by collecting and storing water at the household. The risk of microbial and chemical contamination depends on the type of water stored whether it is treated water, rain water, or groundwater; another factor is the type of storage reservoir, cisterns are more risky than steel or concrete tanks (Abo-Shehada et al., 2004, Al-Omari, 2008).

Realizing the risks from distribution system contaminants prompts the consideration of the “multiple barrier” approach in drinking water treatment. This approach includes the protection of source water quality, multi-level treatment applied at the water treatment plant, distribution system monitoring and protection, and finally using POU/POE systems as the last barrier for consumer protection (Abbaszadegan et al., 1997, Baker et al., 2006, McEncroe, 2007). In cases where the contaminants enter in the distribution system through cross-connection, back flow, or contamination of reservoirs; POU and POE alternatives may be the only options to respond to such contamination.

Emerging contaminants

Many contaminants that were not of concern a decade ago are now considered a health hazard and their removal or concentration reduction is required by regulations of many developed countries. Increasing consumer awareness may motivate the use of POU/POE systems to remove contaminants of potential health significance, even though they might still be unregulated.

Several emerging contaminants are still unregulated in many countries. These include: natural radionuclides, disinfection by-products, perchlorate, methyl tertiary butyl ether (MTBE), and newly discovered endocrine disruptive chemicals (Raucher et al., 2004). Radium 226 and radon are common natural nuclides in groundwater. They have been found in groundwater and even in the distribution network of some Arab cities (e.g. Qena, Egypt, and Riyadh, Saudi Arabia) although not exceeding the acceptable limits (Ahmed, 2004, Alabdula'aly, 1997).

Often it is not economically feasible to modify water treatment plants to remove these emerging contaminants, especially when there are about 45 million people still lacking adequate access to safe drinking water. Additionally, most of them are in rural areas and poor urban neighborhoods (Saghir, 1999, Shawky, 2001). Thus, a good approach, especially with contaminants of unproven or minor health hazard, is to remove these contaminants by additional treatment at the point-of-use.

Remote areas and small water systems

For decades the compliance of small water systems to regulations seemed to be an impossible task, especially in remote and rural areas where the necessary expertise and financial resources are often unavailable. This has led to numerous incidences of outbreaks caused by waterborne pathogens and other adverse health effects resulting from water contaminants in small communities. Many rural areas in the Arab region suffer from higher drinking water contamination due to insufficient treatment, or unhygienic water storage (Abo-Shehada et al., 2004, WHO, 2005).

POU/POE represents an alternative for small water systems with limited financial resources and expertise to comply with regulations. Furthermore, small and rural water systems are distributed by nature where houses are too far apart to be connected with water networks thus making a decentralized or distributed water treatment system more feasible.

Water demand management and consumer participation

One of the main paradoxes in the Arab region, is that although water scarcity is acknowledged as a fact, over-usage of domestic water is shockingly prevalent (Abderrahman, 2000). The notion of water demand management (WDM) evolved from a conviction that it is the way we use water that affects consumption trends, rather than simple projections of the increase in the number of consumers. POU/POE water treatment inculcates a sense of ownership and responsibility towards drinking water in consumers. Water consumption is no longer accounted for in a bill you get every month that, in many cases, charges a consumer for a fraction of the cost of what he actually consumed. POU/POE water systems demand consumer participation and involvement in decision making.

While adopting a POU/POE water treatment strategy can have a number of benefits it is not without its challenges. The following benchmarks previous experiences in other countries and describes a strategy for implementing POU/POE water treatment systems in the Arab region.

Aspects of a Strategy towards POU/POE Water Treatment

As with any new system, the consideration of POU/POE systems as treatment alternatives requires a well designed strategy. Benchmarking progress in developing such a strategy is important to learn from others successes and mistakes. This section investigates the various aspects of a strategy needed to successfully implement POU/POE systems. Figure 2 shows a summary of the strategic aspects discussed below.

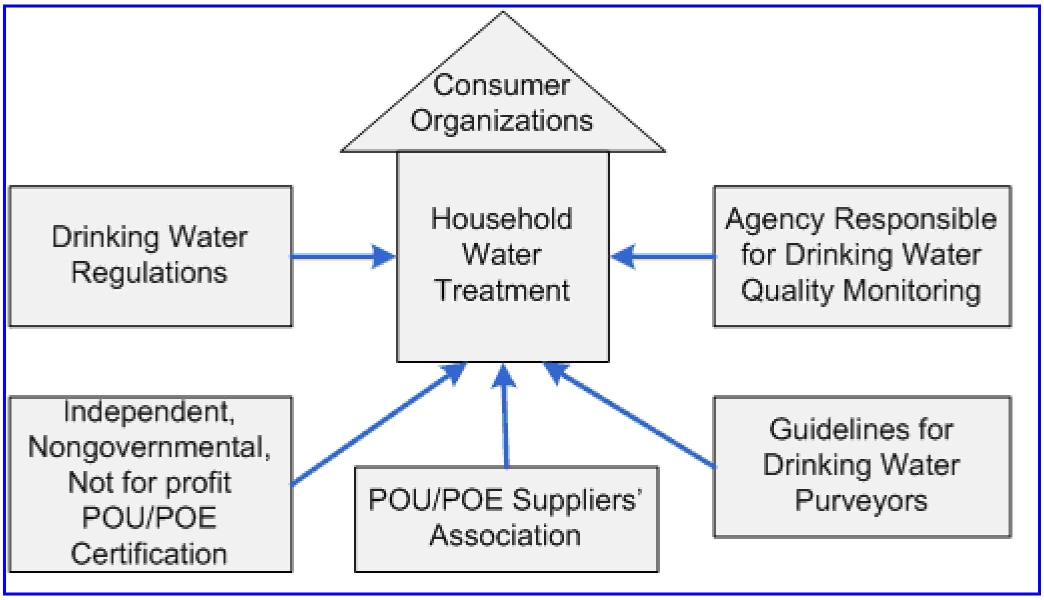

Figure 2 Aspects of a strategy for POU/POE water treatment

Drinking water supply regulations and guidelines

Complying with regulations, standards, local plumbing, electrical, and/or building codes are important to ensure the safety of the drinking water and the quality of the service provided. This is accomplished through the development of guidelines which are issued by responsible agencies to help implement systems that are in compliance with regulations.

Some of the important aspects that should be outlined in regulations and guidelines for drinking water purveyors are:

1. Updated drinking water quality standards. A survey of Arab water legislation revealed that actual water quality standards are not explicitly included in any of the countries' water laws, provisions in the laws vest either a ministry or an agency with the responsibility of setting drinking water quality standards via the issuance of regulations (Bruch, 2007).
2. Conditions where POU/POE systems can be approved as treatment alternatives. For example, The United States Safe Drinking Water Act (SDWA) Section 1412(b)(4)(E)(ii) identifies POU and POE devices as options for small systems (defined as systems serving less than 10,000 individuals) to comply with a maximum contaminant level (MCL) (SDWA, 1996). However, the same section stipulates that POU devices cannot be used to achieve compliance with a maximum contaminant level or treatment technique for a microbial contaminant or an indicator of a microbial contaminant (Cotruvo and Cotruvo, 2003).
3. Assign responsibilities for systems installation, operation and maintenance, and monitoring and evaluation.
4. POU/POE compliance restrictions and required permits. Systems that implement a POU or POE treatment strategy must dispose of the wastes

generated by these units. Spent cartridges, media, membranes, bulbs, and filters must all be disposed of at the end of their useful life. Furthermore, in many of the reviewed regulations there are many strict requirements for water purveyors to ensure the safety of drinking water, including: POU devices cannot be listed as a compliance technology for a microbial contaminant, units have to be owned, controlled and maintained by a water purveyor, mechanical warnings should be present (alarm, light, auto-shutoff, etc.), and only certified units can be used.

5. Further, codes may be required to define procedures for installation, repair, and/or maintenance of POU and POE treatment units; including the need for licensed plumbers and/or electricians.

Certification of POU/POE devices

Unlike central water treatment, POU/POE systems are implemented through a business market based model rather than public service oriented model. A certification process is needed to avoid misrepresentation such as fraudulent advertisement and the distribution of faulty treatment devices. Any marketed device has to go through this process to confirm its treatment claims.

The North American experience in certifying POU/POE devices is a good benchmark. Currently, standards are developed by consensus through an independent, non-governmental, not for profit organization, NSF International (NSF) (Table 2). NSF certification process requires a water treatment system to meet the following requirements (NSF, 2008):

1. The contaminant reduction claims being made for the product must be true.
2. The materials and components in the system cannot add anything harmful to the water.
3. The system must be structurally sound.
4. The advertising, literature, and product labeling must not be misleading.
5. The materials and manufacturing processes used cannot change.

Table 2 POU and POE treatment units’ certification standards

Standard	Title	POE	POU
NSF/ANSI 42	Drinking water treatment units—aesthetic effects	Yes	Yes
NSF/ANSI 44	Residential cation exchange water softeners	Yes	No
NSF/ANSI 53	Drinking water treatment units—health effects	Yes	Yes
NSF/ANSI 55	Ultraviolet microbiological water treatment sys.		
	Class A systems designed to inactivate pathogens from contaminated water	Yes	Yes
	Class B systems designed for supplementary bactericidal treatment of disinfected water	Yes	Yes
NSF/ANSI 58	Reverse osmosis drinking water treatment systems	No	Yes
NSF/ANSI 62	Drinking water distillation systems	Yes	Yes
NSF/ANSI 177	Shower filtration systems—aesthetic effects	No	Yes
NSF/ANSI P231	Microbiological water purifiers	Yes	Yes

Governance

'Water Governance' can be understood as procedures, approaches and measures enshrined in legal, policy and institutional frameworks to manage water resources (Bruch, 2007). For implementing POU/POE systems a decentralized framework is required, in which management occurs at multiple levels.

At present, few of the Arab countries have had experience in decentralized water governance. For example, Morocco and Yemen possess the most decentralized legal frameworks of water governance, whereby their laws and regulations mandate the transfer of authority from a centralized government to local governmental agencies (Bruch, 2007). As with any decentralized approach the main challenges in implementing a POU/POE system are of logistic nature. Clearly defined responsibilities among stakeholders are important to avoid competition and confusion and enhance cooperative water management.

Four main entities are important for governing the implementation of POU/POE drinking water treatment:

1. Government monitoring agency: the overlooking agency ensuring the proper functioning of the implementation strategy. This agency is commonly either the Ministry of Health or the ministry responsible for drinking water provision.
2. Water utility (government owned or privatized): the one responsible for the operational plan for implementing POU/POE treatment systems on a local scale.
3. POU/POE systems suppliers/manufacturers association: in North America this is the Water Quality Association (WQA), which is a not-for-profit international trade association representing the residential, commercial, industrial, and small community water treatment industry. It guides and represents suppliers on the national level and can also address illegal practices (including monopoly).
4. Consumer/community organizations: the one representing consumer concerns and interests. Moreover, it is responsible for consumer awareness regarding new strategies and the responsibilities they entail.

As mentioned earlier, regulations (in USA) assign most of the responsibilities to the water purveyor or water utility. Nevertheless, educating all the interested parties on their roles and responsibilities is a crucial factor for the success of POU/POE treatment systems. There are two approaches of a water utility to implement a POU/POE service strategy (Raucher et al., 2004):

1. Regulatory compliance approach, where the systems are designed and implemented to reduce contaminant concentrations to levels less that those assigned by drinking water regulations. In this case, the utility will need to maintain all issues related to water service including financially supporting this option, unless there is a political decision favoring privatization of water services.

2. Supplemental service approach, where the systems are implemented to enhance the quality of water substantially beyond regulatory limits, or to remove contaminants that are not a direct threat unless ingested. In this case, subsidies can be avoided. Supplemental service includes systems that improve the aesthetic quality of water such as taste and odor removal or reduction of hardness.

Utilities also have the option to contract out all or some installation and maintenance activities to contractors in the form of Public Private Partnerships (PPP). In general, POU/POE strategies have the potential to distribute the cost (all or a part) of water treatment to consumers. Furthermore, since maintenance costs will be directly proportionate to the rate of use, it ensures equality and fairness. One major advantage that many of the Arab states have is the availability of cheap labor. Most decentralized systems, and POU/POE systems are no different, are labor intensive and provide many average income jobs for installing and maintaining the systems. Nevertheless, the option of addressing water quality issues with POU/POE technologies raises considerations about the water utility's capabilities to implementation challenges and concerns.

Challenges and concerns with adopting POU/POE systems

There are several concerns when it comes to the implementation of POU/POE systems; we mention a few of them here:

1. Utility visibility: most utilities are mostly invisible to consumers under centralized water treatment. POU/POE treatment alternatives demand increased visibility and transparency from water utilities, this will require new expertise in customer relations that most utilities lack.
2. Inconvenience of the in-home intrusion of utility (or water purveyor) personnel for installation, monitoring, and maintenance of water systems.
3. Confusion resulting from system ownership whether it is owned by the customer or by the water utility.
4. How to deal with reluctant community members, in case of community wide implementation of POU/POE systems?
5. Certification of personnel for POU/POE installations and maintenance maybe a cumbersome and delaying task, given the lack of expertise.
6. If POU/POE systems are offered as a basic water treatment service by Arab water utilities, this could be perceived as direct privatization of water services and may cause an alarm among water stakeholders in the region.
7. If POU/POE systems are offered as a general supplemental service by Arab water utilities, customers will see this as a valuable option from a trusted and knowledgeable entity rather than a business oriented company. On the other hand, this may be perceived as a biased strategy towards the higher income segment of the community. Ultimately, consumer views are important in the design of the governance system.
8. Perhaps the biggest concern of all is that of selecting a cost effective and sustainable system that fits the needs of a particular customer or community.

POU/POE Systems Market

Water treatment devices certified according to NSF/ANSI standards include: softeners, distillation systems, filtration systems, reverse osmosis systems, microbial purifiers, and UV systems. Worldwide, there are around 376 manufacturers of certified POU/POE devices listed by NSF producing around 5,840 drinking water treatment products. Only 3,354 of these products are treatment devices, the remaining 2,486 products are accessories and replacement elements such as: faucets, filter cartridges, housing adapters, membranes, media, valves, pumps, and tanks.

A quick analysis of the distribution of certified drinking water treatment units among the various standards shows that the majority of the certified products (55%) are for aesthetic effects only. Table 3 shows the different configurations of POU treatment devices. It is clear from Figure 3 that certified plumbed-in products represent more than 75% of the total (NSF, 2008).

Table 3 Main configurations of POU treatment devices

Configuration	Description	Advantages	Disadvantages
Countertop Manual Fill	Placed on a counter, filled by pouring water into the system and activating it for a batch of water	Easy to install Longer filter capacity No lumbing	Uses up counter space
Countertop Connected to Sink Faucet	Placed on a counter and connected by tubing to an existing kitchen faucet	Easy to install Longer filter capacity	Uses up counter space
Faucet Mount	Mounts on kitchen faucet. Uses diverter to direct water through filter	Easy to install	Frequent filter changes
Built-in Faucet Filters	Replacement kitchen faucet that comes with a built-in filter	Does not require separate faucet	May require professional installation
Plumbed-In	Installs on cold water line under sink. Filtered water is dispensed through existing faucet(s)	Longer filter capacity	May require professional installation
Plumbed-In to Separate Tap	Installs on cold water line under sink. Filtered water is dispensed through an auxiliary faucet	Longer filter capacity	May require professional installation
Pour Through	Water drips through by gravity through a filter	Easy to install No plumbing	Frequent filter changes
Shower Filters	Install directly to the existing pipe before the homeowner's showerhead	Easy to install	Limited contaminant reduction

Source (NSF, 2008)

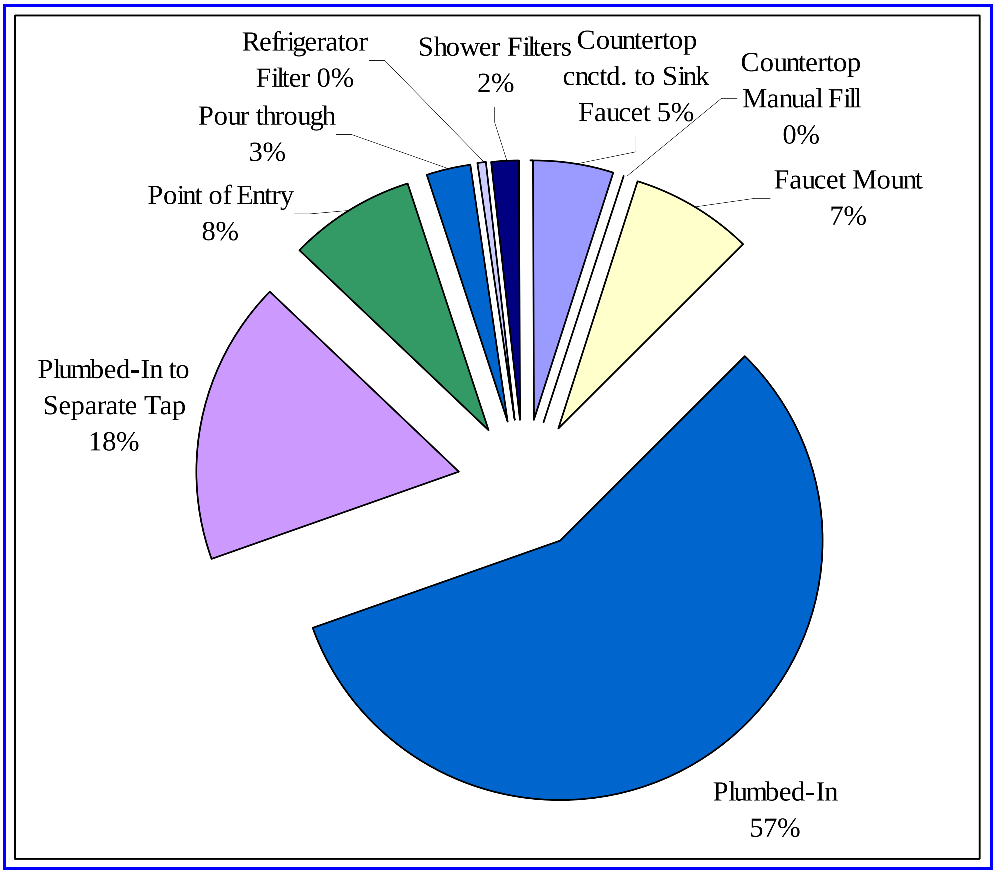

Figure 3 Percentage distribution for various configurations of NSF certified water treatment products

POU and POE treatment not only vary in their efficiencies but they will also vary considerably in how much they cost depending on the level of treatment required and the quantity of water treated (Table 4). The prices range from less then US$100 for tabletop units, to several hundreds of dollars for under the sink units, to over a US$1000 for POE units (Craun and Goodrich, 1999).

A Framework for Selecting Sustainable POU/POE Systems

We have developed a conceptual framework to aid in the selection of sustainable POU and POE drinking water treatment systems (Figure 5). The framework encompasses several stages explained in the following paragraphs.

The first stage includes analyzing and structuring the POU/POE water treatment selection issue. A suitable and often used methodology for sustainability assessment is systems analysis. The advantage of using the systems analysis approach is that it assesses and integrates systems processes, thus accounting for heterogeneity, interactivity, and multidimensional character of the sustainability. Results of the systems analysis will comprise POU/POE technology characterization in terms of removal efficiency, cost, cultural acceptance, and other characteristics. Furthermore, systems analysis is necessary to define rules and constraint for constructing alternative treatment trains; selecting among these alternatives; and assigning importance to the various criteria used in the selection process.

Table 4 Summary of POU/POE treatment technologies and their costs

Technology	Contaminants Removed	Initial Cost	Operating Cost	Operation & Maintenance Skills
Chlorine / Iodine	Microbial	+	+	+
UV / Ozone	Microbial	++	+	++
Submicron cartridge filter	Protozoa, bacteria	+	+ to ++	+
Reverse osmosis	Microbial, inorganic chemicals and metals, radium, minerals, some organic chemicals	++	+++	+++
Distillation	Microbial, inorganic chemicals and metals, radium, uranium, minerals, some organic chemicals	++	++	+
Activated carbon	Organic chemicals, radon, odors (carbon block can filter protozoa and some bacteria)	++	++ to +++	+
Ion exchange	Inorganic chemicals, (e.g. radium, nitrate)	++	++ to +++	++
Activated alumina	Arsenic, selenium, fluoride	+++	+++	+++

+ Low ++ Moderate +++ High   Source:(Craun and Goodrich, 1999)

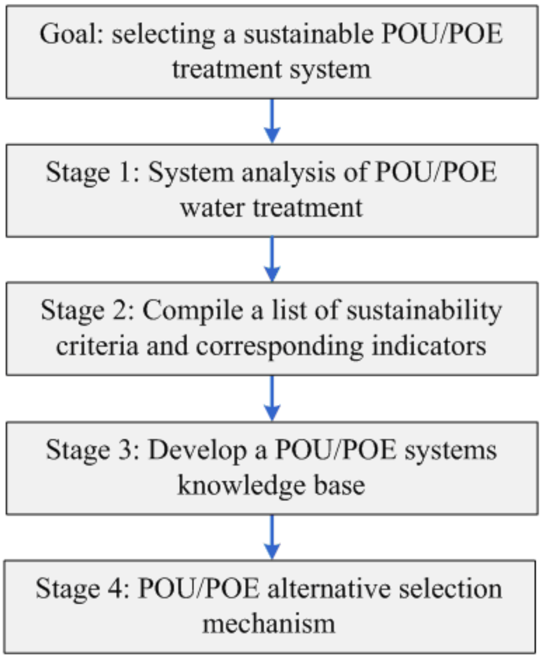

Figure 5 A conceptual framework for the selection of a sustainable POU/POE treatment alternative

The second stage includes an investigation of criteria used in assessing the sustainability of the treatment alternatives. Bearing in mind the difficulties of defining and quantifying sustainability criteria, relevant proxy indicators can be designed to assess the sustainability of various alternatives. In general, sustainability in this study encompasses several aspects as shown in Table 5. Several conditions must apply for the system to be considered 'sustainable'. These are as follows: (i) the system must be technically effective, reliable, and robust, (ii) it has to be economically feasible, (iii) pollutants, emission, and residuals should be kept to minimum and persistent/hazardous compounds should be absent from the operation and maintenance of the system, and (iv) the system should be culturally acceptable and manageable. The evaluation of these conditions can be based on information available on the various treatment devices in literature.

Table 5 Examples of sustainability criteria and proxy indicators

Criteria	Subcriteria	Proxy Indicator
Technical	System performance	Removal efficiency matrix for a spectrum of water contaminants
Economic	Cost	Capital cost can be presented as a cost category or cost function
Environmental	Resource consumption	Energy consumed by the treatment kWh/m^3
Socio-cultural	Cultural acceptance	Technology sales in units as percentage of the market

Treatment alternatives and the evaluation of their indicators of sustainability are used to construct a knowledgebase in the third stage. The knowledge base provides decision makers with a complete overview and enables adaptation of the data. The knowledge base can include:

1. Treatment unit type and description
2. Reduction claims and target contaminants
3. Incidental effects (other contaminants removed, variation in pH, etc.)
4. Maximum and minimum feasible flow
5. Conditions that increase/decrease efficiency e.g. presence of a specific contaminant that impedes the efficient performance of the device
6. Service life
7. A document that includes:
    a. Installation instructions
    b. Required permits for construction, operation and pilot study
    c. Water quality monitoring and reporting procedures

The forth stage uses a designed selection mechanism to rank the treatment alternatives in terms of their respective sustainability rating. The output provided by the selection framework will rank the best systems from the alternatives knowledgebase, and will give a detailed overview of the sustainability assessment of these alternatives. The output can include:

1. List of ranked treatment alternatives with the following:
    a. Their respective scores and sustainability rating
    b. Technical fact sheet for each alternative
    c. A cost estimate for each alternative
2. A summary sheet of the case under analysis: water quality, quantity, etc.
3. A list of companies producing the top devices on the list.

Conclusions and Recommendations

The drivers for the increase in the use of POU/POE systems in the Arab region were described. The various aspects of a strategy to adopt POU and POE treatment systems were discussed to alleviate some of the challenges commonly faced when implementing such a decentralized system. In general, some observations and recommendations for a future course of action regarding POU/POE systems in the Arab countries can be summarized in the following (NSF, 2008):

1. Consumers in many Arab states use bottled water and POU/POE treatment devices as perceived healthier alternatives to public treated water,
2. Consumer involvement and the consideration of the POU and POE alternatives require a redefinition of the role of government and setting up a sound regulatory framework,
3. POU/POE systems can help water utilities with the difficult task of striking a balance between ensuring the safety of drinking water for all and the desire to recover a portion of the water treatment costs,

4. Privatization and decentralization of water services can only be successful if responsibilities are assigned properly. POU/POE systems are structured in a way that responsibilities can be easily broken down. This also helps in cases where a Public-Private Partnership is sought. Implementation and management aspects of POU/POE systems can be assigned to a private company, whereas monitoring the quality of the service can be assumed by the utility.
5. POU/POE systems are small systems by design and can result is many associated jobs and small businesses in the Arab region.

There is a need for a standardized process for selecting sustainable POU/POE treatment systems. A conceptual framework for such a process has been provided. The main difficulty in the selection process comes from the large number of marketed treatment devices and of treatment alternatives that can be formed from these devices. However, existing standards, reports and guidelines provide a wealth of knowledge on selecting and implementing POU and POE treatment systems. This research is expected to assist Arab drinking water policy makers, water purveyors, consultants, and even consumers in selecting sustainable POU and POE treatment systems.

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