Water Management on Islands – Common Issues and Possible Actions

A concept paper in preparation to the international workshop: "Capacity Building in Water Management for Sustainable Tourism on Islands"

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1. Introduction

Island states/communities depend, as other mainland countries, upon the quality and quantity of their water for their existence and economic activities. However, water management on islands is unique as it is constrained by their size, isolation from the mainland, fragility, and limited human, natural and financial resources (Pacific Islands Forum, 2005; Khaka, 1998).

Although different in many features (size, isolation, geology and topography, climate and hydrology, economic development, etc.) - all influence water resources and management, islands share common water-related problems and challenges. Management of water on islands is extremely crucial because its finite feature. The size[1] of islands limits the availability of resources, including water resources. Limited resources (such as water resources) mean that any resource development in islands requires sustainable management approach. Narrow resource base also limits the possibility of diversify economy thus very often economy on islands rely on a single or very few economic sectors, such as tourism. Size also effect shortage of space, especially in coastal areas where most of the local population as well as tourist activities, concentrate. This is especially the case in small islands. Isolation also affects water management on islands as they must rely on their own resources, as transfer of water has to overcome distance and sea. While some islands are located near the continent or are part of archipelago thus can

[1] Islands' size is classified as large (above 2000 km²), small (less than 2000 km²) and very small (less than 100 km²), Asian Development Bank, (2006)

use this relative proximity to overcome the distance, others are very isolated and water importation may not be possible (Kliot, unpublished A). Water importation may not be desirable even in less remote islands as it increases their dependency in external sources. All this means that water management on islands is faced by unique challenges and requires unique solutions.

These challenges are further stretched by developed tourism. Due to the above mentioned limited resources, many islands rely on tourism as the major source of income. For many islands tourism is the most important industry in the economy (e.g. Barbados, Bahamas, Malta, etc) and for others it is the second important economy (e.g. Maldives, Western Samoa). Tourism affects water management as it is a great user of water as well as a producer of wastewater. To meet water demands of tourists water withdrawals are rapidly increased. In Mediterranean islands, for example, water withdrawals can double and triple to meet demand in tourist season. Tourism also increases pollution of water resources. As water consumption increases, so is the production of wastewater, and without proper treatment, an increase of the pollution load occurs. Tourism contributes about 7% of wastewater pollution in the Mediterranean, by generating up to 180 liters of wastewater per tourist/day, according to the European Environmental Agency. In the late 80s, the coastal Adriatic Sea was heavily polluted by agricultural and tourism-related wastewater, and this had a serious impact on hotel occupancy rates in Italian resorts as visitors preferred to avoid them. It took all the efforts of the tourism industry and local authorities to solve the problem and offer visitors the clean beaches they expect. The tourism industry can thus play an invaluable role, by acknowledging its part in the problem and confirming its commitment to the solution. However, water management strategies will only be successful when there are joint efforts between the tourism industry and local and national government policies and regulations (UNEP, 2003).

In this paper main water problems on islands, as well as potential solutions, are described. In general terms, water related problems on islands relate to two main issues: water availability (quantity) and quality, as well as related policy, institutional, and managerial issues. These can be addressed on different levels: at the island level; at the

local/city level; and at the individual unit level (e.g. hotel, small tourist resort, or individual user).

2. Water related problems on islands

2.1 At the island level

2.1.1 Water scarcity is common on islands, and many islands are water scarce with water withdrawals of less than 1000 m^3 per person per year (e.g. Bahamas, Bahrain, Barbados, Cyprus, Malta, Maldives, etc.) (UNESCO, undated).

Water scarcity is common, but can result from different conditions, mainly climatic and physical. In some islands the problem is related to low precipitation rate. Mediterranean islands often have semi-arid climate and are largely dependent on the availability, timing and amount of precipitation. At least in some parts of the Mediterranean, the amount of precipitation has steadily decreased and the main precipitation period has shortened over the last few decades resulting in diminished water resources (Manfred, undated). In Cyprus, for example, despite implementation of several measures to increase water availability (e.g. increasing storage, introducing water treatment plants, improving irrigation systems, etc) available water was still not enough to satisfy the water demand for domestic and irrigation needs, mainly due to the climatic change, which caused a reduction of approximately 20% in the precipitation and resulted in a 40% reduction in surface runoff, as well as frequent occurrence of extreme drought events (Anonymous, 2006). Islands in other geographical regions experience similar situation. The Lopez Island, for example, (Washington State, USA) has relatively little precipitation, lacks surface water resources, and relies mainly on groundwater as its freshwater source (USGS, 2000).

However, even in islands with high rainfall, water resources can be scarce due to relatively limited surface area and capacity to store water for use in the dry season. Steep topography – not suited for the development of surface water resources, easily eroded soils, and short river channels make it even more difficult to effectively store enough

freshwater (Khaka , 1998). Highly impermeable rock without significant storage potential can limit groundwater storage, and on most islands, river basins (catchments) are often present in large numbers but they are small in size and have limited regulation capability (UNEP, undated).

In some Pacific islands, for example, despite high precipitation rate (e.g. Pohnpei with 10,000 mm/yr), water is sometimes not available where and when it is needed, as small surface water catchment sizes preventing adequate natural storage to get through dry periods. Islands like Kiribati, Tuvalu, Niue and the Marshall have no surface water resources at all. In Tuvalu and the Marshall Islands, rainwater provides the main potable resource and groundwater is only used for drinking in times of drought. Small low-lying atolls also have no surface water and very limited groundwater resources. For these islands the limited supply is a major constraint. Recent droughts in the Pacific region (e.g. 1997-98) linked to changing climatic patterns, have highlighted this as a priority in the region (Pacific Islands Forum, 2005). Limited water availability due to physical features despite sufficient precipitation is common in other regions as well. In some of the Virgin Islands (USA), for example, the terrain is steep with limited flat, low-lying areas. Drainage consists of short, deeply incised streams that have steep gradients and are dry outside the wet periods. Groundwater sources are also limited. Thus, despite seasonal periods of intensive rainfall, the principal sources of water supply are seawater desalination plants (USGS, undated).

Deforestation processes can worsen the problem and cause excessive run-off. In Mauritius, for example, deforestation processes led to significant erosion of top soil by rainfall in most regions of the island (Mauritius: Water: Resources, Uses & Pollution).

Water resources availability on islands is very much influenced by tourism, which further exacerbates the water scarcity. The growth of tourism on some islands puts considerable pressure on the available water resources (Asian Development Bank, 2006). This is very much true in the case of developed tourism as peak season results in high demands and worsens the water scarcity problem. In most of the Mediterranean islands tourism is one

of the predominant consumers of water (Manfred, undated) and water supply is especially stressed during the tourist season as it coincides with the dry season. In Cyprus, for example, a rapid increase in the number of tourist arrivals placed additional seasonal demands for water (Anonymous, 2006). In Malta the tourist sector accounts for 8% of the water consumption, but 40% of tourists arrive at summer months when natural supplies are low. Since the tourist sector gets a high priority in terms of water supply – due to its relative importance to the economy, this affects water supply for domestic and agricultural uses (Birdi, 1997). This is the case in other islands as well (e.g. Kook Islands, Fiji Islands, and French Polynesia). In small Pacific islands water supply to tourist resorts represent a reasonably high proportion as the total water consumption and water usage rate of 500 l/d/p is not uncommon (in comparison to 50-150 l/d/p for local inhabitants) (Asian Development Bank, 2006). In Mauritius, while the domestic water consumption ranges between 180 to 220 l/d/p, in the tourist sector consumption can reach 1000 l/d/p in five star hotels as it is government policy to encourage high class tourism which entails high consumption patterns, water included (Mauritius: Water: Resources, Uses & Pollution). Furthermore, in Pacific islands economic activities, including tourism, severely reduce the spatial extent of the drainage basins that are vital to freshwater supplies (Khaka , 1998). The trend of development of Golf courses on islands (e.g. on Majorca and Barbados), as a tourist attraction, also increases the problem as Golf courses are large water consumers (Kliot, unpublished B).

The problem of water scarcity will only get worse with economic growth and development leading to increase in water demand. This, coupled with increasing water wastage (primarily due to aging and therefore leaking supply systems and illegal connections), and limited attempts to introduce conservation and demand management measures, mean that water availability will become a major issue (Pacific Islands Forum, 2005) Unfortunately many islands do not manage their water as a scarce resource and their practices lead to waste, depletion and pollution.

2.1.2 Decreased water resources quality related mainly to seawater intrusion to groundwater.

Due to lack of surface water, dependence on groundwater emerges, when groundwater is available. However, withdrawal rates that exceed the sustainable water yield can result in temporary or permanent sea water intrusion. Given that islands are surrounded on all sides by marine water, saltwater intrusion into groundwater resources is a common and major problem (Khaka , 1998). This affects both water quality and quantity, as the transition zone (gradually mixing fresh and salt water), moves upward (USGS, 2000).

In Mediterranean islands extensive overexploitation of groundwater is common, often resulting in the decline of the water table as well as to the deterioration of water quality, primarily through saltwater intrusion in coastal areas. In some cases this has resulted in the exploitation of deeper lying aquifers, thereby further reducing the remaining reserves of the island (Manfred, undated). In Malta, rising water demands have resulted in increasing levels of production and groundwater resources have been exploited beyond their sustainable yield, resulting in high salinity levels in groundwater (chloride concentration of over 1,000 ppm have been recorded), and ultimately tap water. In the South of the island where the main source of water is groundwater, many settlements receive tap water with high salinity levels, above the European recommended gridline (Birdi, 1997). In Cyprus, groundwater resources have been heavily over-pumped especially during periods of drought, leading to seawater intrusion of many coastal aquifers and deterioration of both quality and quantity of groundwater (Anonymous, 2006). In Lopez Island (USA) a statistically significant increase in concentration of chlorides over time was detected, indicating seawater intrusion to local aquifer (USGS, 2000).

Additional pollution of freshwater resources, surface and mainly groundwater, can be contributed mainly to untreated wastewater (as discussed in section 2.2) as well as the use of pesticides, fertilizers, and other pollution related to agricultural activities. Water resources pollution is a major problem that affects water quality and thus availability.

On islands with developed tourism, water quality problems are further stretched, as the high water demand in the peak season results in over-pumping from groundwater as well as in higher pollution loads from untreated wastewater.

2.1.3 Policy and institutional setting are very much related to the abovementioned constraints and are vital for any solution for sustainable management. Problems can relate to a fragmented system - a multitude of agencies that deal with water. There are often several organizations involved in, and responsible for, the various aspects of water resources. Data collection, health issues, service delivery, environmental management and other activities are generally delegated to different government agencies, many of whom rarely talk to or consult each other. In addition, their programmes are rarely integrated with those of other organizations whose activities may impact on water resources, such as tourism, land-use planning and human settlements. All these factors contribute to the absence of an integrated approach to water management (Khaka , 1998). Additional problem is insufficient knowledge of the freshwater resources (e.g. limited knowledge of type, extent and sustainable yield of water resources; insufficient regular monitoring system of water resources; limited analysis of water resources data for planning, etc) as well as the development of water related infrastructure. Other problems relate to: low priority within the central government (except in times of extreme conditions e.g. droughts and floods); outdated laws and inadequate legislation to protect and conserve water resources; insufficient enforcement; and poor administration (Asian Development Bank, 2006).

In Pacific islands for example, water governance is highly complex due to the specific socio-political and cultural structures relating to traditional community, tribal and inter-island practices, rights and interests, which are all interwoven with colonial and 'modern' practices and instruments. There remains poor data and knowledge of ground water systems in the region, which lead to an inability to properly manage the resource. There is a lack of understanding on how other land use activities affect water resources such as mining, forestry and agriculture and a lack of effective watershed planning and management mechanisms to address this. Further to this there are limited protection

methods/frameworks for water reserve areas in small atolls e.g. Bonriki water catchment area in Kiribati (Pacific Islands Forum, 2005).

2.2 At the local/city level

2.2.1 Uneven water distribution: In some cases, local availability of water resources may be insufficient and it is necessary to divert water from the source to a distant location for consumption (inter-basin transfer). Inadequate transportation of water from the water resource to all points of use results in some parts of the island suffering shortage of water. In Jamaica, for example, while there is sufficient water to meet all demands the resources are unevenly distributed as water resources are not necessarily located close to the major centers of water use, and transporting water to these areas is inadequate in some parts of the country. The present shortfall is estimated at 126 MCM/yr. In Malta, the Government has established a desalination plants but the nature of the distribution system is such that there is an inequity in the quantity and quality of water supplied. Certain settlements, mainly in the South in the end of the principle main, receive little or no water, usually of relatively poor quality, for long periods, while others in the North receive large amounts, usually of the relatively good quality water from the desalination plants (Birdi, 1997).

2.2.2 Insufficient municipal water supply and wastewater treatment systems. This is considered as the main problem at local level. Water supply systems as well as wastewater treatment and disposal are usually the responsibility of local authorities. This is often done via utility companies (public, non-profit, or privately owned). These are designed to protect public health; protect the environment; and meet customers' needs. To achieve that, they are required to install facilities, and properly mange, operate and maintain these facilities. However, in many islands these are not adequately addressed and water and wastewater utilities are undeveloped. As a result problems with quality of water supply and wastewater services occur (Asian Development Bank, 2006).

Water supply - very often there is insufficient drinking water system coverage and/or old systems with leakage resulting in water wastage. Leakage and other losses from piped

distribution systems increase the already stretched demand for freshwater. Increased abstractions to supply leakages may lead to over-exploitation of the available water sources, whereas reducing water leakage can assist with water shortages during droughts as well as delay infrastructure costs to develop additional sources to supply future demands (Asian Development Bank, 2006).

While most Pacific islands now have water supply schemes to their capital towns, very often systems are old and most existing urban service providers report high leakages (typically 30-50%, but up to 80%) resulting in water wastage. Rural regions are not often connected to central water systems (Pacific Islands Forum, 2005). In Mauritius, although 97% of the population is connected to central water supply systems ccurrent water losses in the system is estimated at 55% (Mauritius: Water: Resources, Uses & Pollution). In Malta 54% of water production is unaccounted for due to shortcomings of the major distribution system (leakages, metering, theft, etc) (Birdi, 1997). Sustainable provision of adequate supplies of non-polluted freshwater and efficient service providers is a major challenge for many developing islands.

Pollution by untreated wastewater: island population tends to be concentrated along the coastline, often with high density. Water pollution occurs if pollution sources are not properly managed (Khaka , 1998) such as in cases when untreated domestic and/or industrial wastewater is discharged directly into the environment (UNEP, undated). Indeed, in many islands wastewater collection and treatment usually lag behind the development of water supply systems.

In Pacific islands, only few have sewerage systems, and they rely almost entirely on on-site sanitation (Pacific Islands Forum, 2005). For example, in the Kook Islands septic tanks are widely used. These are poorly built, not well maintained and seldom emptied. When emptied, septage is dumped wherever a site can be found. As a result, the inner reef lagoon water quality is deteriorating (Asian Development Bank, 2006). In Mauritius 80% of the population uses pit latrines, potentially polluting the groundwater where water table is high (Mauritius: Water: Resources, Uses & Pollution). In Malta, illegal

settlements pollute both groundwater and the sea due to untreated wastewater, and some of the existing sewerages systems ex-filtrates in some places, polluting the groundwater (Birdi, 1997). In small Caribbean islands, wastewaters from beer factories, distilleries, agro-industries, and other industries, are dumped directly into the available streams and rivers, causing them to become polluted and biologically dead (UNEP, undated). Trinidad and Tobago already face a serious problem of wastewater pollution which will increase as water supplies are increased in the absence of programmes to improve wastewater management. Many streams that were used in the past to supply water to communities are now unusable because of pollution. Even when wastewater treatment facilities are available, problems with operation and maintenance can result in pollution. In the Island of Ebeye (Marshall Islands) wastewater treatment facilities exist but pumping station convey the wastewater to the lagoon when the facilities are not in operation (Asian Development Bank, 2006).

Pollution from insufficient wastewater facilities affects severely the water resources and thus has health implications. This is especially the case in highly dense populated areas such urban and peri-urban areas where the sanitation systems are principally pit latrines, and can thus affect and be affected by popular tourist destinations. Unless action is taken, the problem is likely to get worse with population growth. On islands with highly permeable soils and high water table, this is especially acute (Asian Development Bank, 2006). Indeed, in islands like Kiribati, Tuvalu, Niue and the Marshall Islands, due to rapid infiltration and little natural attenuation, groundwater is highly susceptible to contamination and water borne diseases (Pacific Islands Forum, 2005) and in Micronesia extensive bacterial contamination of wells was detected (Asian Development Bank, 2006).

Decreasing water resources quality, if not addressed, affects not only health issues, but also water quantities, if wells are shot down. This exacerbates the problem of water scarcity on islands.

2.2.3 Institutional, financial, and operational management

The abovementioned problems of inadequate water supply and sanitation services are often related to inadequate management and operation of utility companies. This includes issues of: planning (e.g. lack of up-to-date set objectives and action plans; insufficient data collection), financial management (correct tariff systems; functional budgets; accounting; adequate reserve funds, etc), and operation management (lack of metering, leak detection, wastage reduction, and appropriate technology). Very often there is lack of information needed to design measures and investments to improve the delivery of these services (Asian Development Bank, 2006).

In Pacific islands, for example, the sustainability of the water providers is questionable. Full cost recovery needs to be achieved by these service providers, but low tariffs and a socio-cultural perception that water is free, have not helped achieve this goal (Pacific Islands Forum, 2005). In a survey of utility companies in small Pacific islands several constraints were detected. Utility companies were financially unstable; collection rate of water bills were less than 50%; there was lack of data; insufficient equipment; poor maintenance of equipment; limited technical expertise; etc. It was concluded that the human resources and institutional capacities of theses utility companies are extremely weak, posing a major development constraint (Asian Development Bank, 2006). In the island of Fiji, for example, the existing tariff structure is not sustainable as it does not generate sufficient revenues to meet operation and maintenance costs let alone any contribution to capital expenditure; Sewerage tariffs do not cover proper operation and maintenance costs; and the billing system is declining with the collection efficiency steadily falling and now averaging 56% for the whole of Fiji. In the Island of Kiritabi the situation is similar with even lower billing system efficiency of 47% (Asian Development Bank, 2006).

The issue of wastewater pollution is especially relevant in relation to tourism due to the increased wastewater volumes in peak season. If not treated, wastewater pollution loads are much higher due to higher generated wastewater volumes. However, very often existing facilities are not suitable to cope with these big fluctuations, resulting in fresh

and marine water pollution (Khaka, 1998). On the other hand, tourism relies on good water quality, whereas inadequate or unreliable water supply systems, as well as polluted water and unsanitary conditions, can deter tourists from visiting certain tourist destinations. In the island of Penang, Malaysia, for example, beaches and seas are polluted to the extant that the island is loosing these tourist attractions. On the Caribbean island of Bonaire, which lives nearly completely from coral reef tourism, the coral reef is slowly destroyed by untreated wastewater which, if not addressed, will eventually affect the livelihood of the local population (UNEP/GPA, 2000).

2.3 At the individual unit level

The abovementioned problems of water scarcity and pollution by wastewater can also affect and be affected on the level of individual unit: a hotel/resort and/or the individual water user, be it a local or a tourist. These problems can thus be addressed on this level. In this case, actions to save water, develop alternative water resources, and reduce pollution, can be done locally by local water users. In relation to sustainable tourism, decentralized wastewater treatment and water recycling schemes in hotels, small tourist resorts and isolated vacation homes, as well as more efficient water use practices by locals and tourists alike can make a big difference.

2.3.1 High water demand in peak season – on islands with water scarcity, individual hotels and tourist resorts may face local water scarcity in peak season when water demand is high and in case that local water resources are exhausted. In other cases where water is available, via for example desalination, high water costs can become a real problem in peak season. High water demand in peak season is related to higher water consumption by tourists (e.g. in Mauritius) as well as to the need to water large areas of lawns and gardens and even Golf courses.

In Barbados, a hotel located in the southern coast faced severe local water scarcity. The hotel is located is one of the driest areas of the island. It is formerly supplied with freshwater from a groundwater well, but because of the high water demand, especially for

the irrigation of large expanses of lawns and garden plants, saltwater intrusion occurred to the point where the freshwater supply was virtually exhausted and an alternative local water source had to be developed (Anonymous, undated).

2.3.2 Local pollution by wastewater – in islands where part of the population is not connected to proper wastewater collection and treatment facilities, or in cases of isolated resorts, hotels, and any other tourist attraction/venue, wastewater pollution from individual units such as hotels and small tourist resorts can occur. In many costal areas hotels, resorts and vacation homes are a main source of pollution due to untreated wastewater. In Mauritius, for example, hotels with less than 75 rooms are not legally required to treat wastewater and commonly use cesspits, potentially polluting the lagoon (Mauritius: Water: Resources, Uses & Pollution). In Trinidad and Tobago the hotel sector produces large volumes of wastewater on a daily basis, currently without proper treatment. In Malta individual houses use cesspits which are assumed to be a significant source of pollution (Birdi, 1997). Any solution to wastewater pollution should address the problem of big fluctuation in wastewater streams in tourist resorts. On the other hand local wastewater treatment and reuse can increase local water potential and address the issue of higher water demand in peak season such as for watering lawns and gardens.

2.3.3 Inadequate water use and pollution control practices by individuals – water use and sanitation practices by users can have a big impact on water management. The potential for pollution may be high due to inadequate personal hygiene practices, and water wastage can be high. For example, reported cases from the Hawaiian Islands and Canary Islands indicated that water from public standpipes or communal tanks that is intended solely for drinking and cooking purposes was used for washing or bathing. These practices often arise due to a lack of understanding of the seriousness of water wastage and pollution (UNEP, undated).

2.4 Summary

Water challenges and constrains on islands are mostly connected to the limited water resources. These are further stretched by inadequate practices and polices such as over-

pumping and over-using existing resources as well as degradation of water quality, leading to decreasing water availability. All these are further stretched by developed tourism. Some solutions are described in section 3.

3. Relevant solutions to water related problems on islands

As mentioned in section 2, water problems on islands relate to two main issues: water availability and quality. To improve these, both technological and managerial/policy solutions are needed. These can be addressed on the three above-mentioned levels and can thus involve different stakeholders/decision makers.

3.1 At the island level

At this level water-related problems and challenges relate mainly to policy development and/or involve large investments in infrastructure/technology by the state/islands authorities. Solutions at this level are presented according the main problems and challenges most commonly faced: water scarcity, decreased water quality and policy and institutional settings.

3.1.1 Water Scarcity

Solutions include measure to increase water potential (supply side) and reduce water demand/consumption (demand side). The latter is introduced under “policy and institutional setting”.

The Supply side - measures to increase water potential

Existing water resources

Rainwater harvesting

Rainwater harvesting is a technology used for collecting and storing rainwater from rooftops, the land surface or rock catchments using simple techniques such as jars and pots as well as more complex techniques such as underground check dams (GDRC, 2006).

Rainwater harvesting is applied in many Mediterranean islands. While this measure can be implemented on the community/individual household level, it is often related to national policy. In Malta, for example, the construction of cisterns is demanded by law when a new house is built. Other methods of water harvesting also exist. In Cyprus, water from greenhouses rooftops is collected and is used for irrigating the crops within the greenhouse (Kliot, unpublished A). Rainwater harvesting is practiced on many small Pacific islands as well. In islands such as Tarawa and Kiribati recent building regulation require that new buildings include minimum rainwater storage of 5,000 L; in the northern atolls of the Cook Islands, the main current water supply source is rainwater; and in Tuvalu rainwater collection is the primary source of water and regulations regarding rainwater harvesting have been in place since 1990 (Asian Development Bank, (2006).

Rainwater harvesting is one of the most appropriate solutions to increase water supply. The technologies are simple to install and operate, local people can be easily trained to implement them, and construction materials are also readily available. It is convenient in the sense that it provides water at the point of consumption, and family members have full control of their own systems, which greatly reduces operation and maintenance problems. Running costs, also, are almost negligible. Water collected from roof catchments usually is of acceptable quality for domestic purposes and has few negative environmental impacts. Depending upon household capacity and needs, both the water collection and storage capacity may be increased as needed within the available catchment area. Nevertheless, rainwater harvesting could not be viewed as a main or sole source of water, mainly due to limited supply and uncertainty of rainfall. This may make rainwater harvesting less attractive to some governmental agencies tasked with providing water supplies (GDRC, 2006) and should be viewed, in most cases, as a supplementary measure/source.

Increasing water storage

Increasing water storage by means of large infrastructure projects (e.g. dams and reservoirs) can be useful way to increase water availability. This is applied in most Mediterranean islands, where possible. Rainwater collection reservoirs were built in

Crete, in Malta a large number of dams was built across drainage lines to retain storm water, etc. (Kliot, unpublished A). In Cyprus, dams' capacity was increased from 6 MCM in 1960 to 307.5 MCM today (Anonymous, 2006). In some small islands, however, there might not be available space for such measures.

Non-potable water sources

Non-potable water sources include seawater, brackish water and treated wastewater. The use of seawater and brackish water is common in many small Pacific Islands in order to conserve valuable freshwater resources. On the Islands of Tarawa, Majuro, and Ebeye (Marshall Islands) for example, these are used for toilet flushing and for fire fighting. Dual pipe systems are used to distribute water to households, one for freshwater and the other for seawater. On some islands seawater is used for cooling of electric power generation plans as well as for swimming pools (Asian Development Bank, 2006). Reuse of treated wastewater (water recycling) can be used for agricultural and landscape irrigation, industrial processes, toilet flushing, and groundwater recharge – depending on the level of treatment and effluent quality. This is further mentioned in sections 3.2.1 and 3.3.1.

Additional water resources

Water importation

Water importation refers to water transfer from another island or from the mainland. Some small islands with limited or no fresh surface and groundwater, and limited rainwater capacity rely on freshwater importation. In other cases, this is used in case of droughts. Water is usually imported by sea transport, e.g. large boats/tankers, and in some cases people on islands will travel by boat or canoe to nearby islands with more available water sources (Asian Development Bank, 2006).

Singapore, for example, without natural freshwater rivers and lakes, relies heavily for decades on water importation from Malaysia to supply half of the water consumption on the island. However, due to a dispute on the price of water, the government of Singapore decided to increase self-sufficiency in its water supply. Pacific islands such as Tonga and

Fiji also rely on water importation (Asian Development Bank, 2006). Water importation is common also in Mediterranean islands. Rhodes exports water to the near-by islands of Symi and Halki which suffer from sever water shortage. In Majorca, water was transferred by tankers from the mainland to provide water in the tourist season to the 2 million visitors. Snatorini and other Greek islands also supplement their water resources by importing from near-by islands (Kliot, unpublished A).

Desalination

Desalination refers to any of several processes (e.g. RO - reverse osmosis) that remove the excess salt and other minerals from water in order to obtain freshwater. Desalinated water is a more expensive resource than freshwater for many countries, with total costs of 0.5- 1.0 $/CM (Lenntech, 2004), although costs will decline in the future as technology progresses. A number of factors determine the capital and operating costs for desalination, including capacity and type of facility, location, feed water, labor, energy, financing and concentrate disposal. Generally the cost of removing salt from seawater is higher than that of removing salt from brackish water. In some cases, disalination processes can be used to produce also electricity (e.g. in the Middle East and North Africa). Desalinated water can be mixed with water that contains higher levels of total dissolved solids as it is more pure than the usual standards (California Coastal Commission, undated).

Most of the Mediterranean islands are wealthy enough to supplement their water resources with desalinated water for domestic use (e.g. Malta, Cyprus, Majorca) (Kliot, unpublished A). This, however, does not provide a full solution to water scarcity. In Malta, for example, the introduction of 5 desalination plants has not been sufficient to meet rising water demands as the more that water was produced – the more it was consumed and a new plant is built in the South of Malta (Birdi, 1997). Desalination systems can also be found in some small Pacific islands (e.g. Marshall Islands, Tuvalu, Kiribati) but these have been provided as a response to sever droughts and are stored for emergency purposes only. The only operational desalination units for regular water

supply in the pacific are in limited urban areas, tourist resorts and military facilities (Asian Development Bank, 2006).

While desalination provides a reliable source of water that is not subjected to the seasonal changes, with minimal environmental impact, the sophistication of these systems (e.g. RO) require high maintenance and expertise, as well as materials and equipment of very high standard, not usually available locally, resulting in high importation costs. There is usually a need for foreign expertise and resulting loss of foreign exchange (UNEP, (undated). Thus, although desalination can provide a good solution to supply domestic water demands, the high cost of desalinated water requires the introduction of other measures in parallel, and many consider this as a last resort solution that should only be developed when more conventional water resources are exhausted and in any case cannot be a substitute to more economical long-term and less expensive water supply strategy, but rather a supplement (Asian Development Bank, 2006).

While measures such as desalination and water importation are suitable for increasing water supply, generally speaking islands should utilize naturally occurring freshwater resources before such options (Asian Development Bank, 2006).

The demand side – measures to reduce water demand/consumption – is discussed in section 3.1.3 under Policy and Institutional Setting and in section 3.2.1.

3.1.2 Decreased Water Quality

The issue of seawater intrusion: Seawater intrusion (or salt water intrusion) is the underground flow of salt water into wells and aquifers. It occurs when water is withdrawn faster than it can be recharged in a coastal aquifer. Solutions include technological and policy measures.

One technological measure to improve the situation is the use of infiltration Galleries. Infiltration Galleries (also called “horizontal wells” or "skimming wells") generally consist of buried horizontal conduit systems which are permeable to water (e.g. PVC

slotted pipes), laid in trenches dug at or close to mean sea level thus allowing water to be drawn towards a central pump. Once the gallery pipes are laid, the area is backfilled and the only structure seen above ground level is a pump well and pumping system. These seem to be a much more appropriate method of pumping from small coral islands. They avoid the problem of saline intrusion because they spread the impact of pumping over a wider area of the freshwater lens than wells or boreholes. Infiltration galleries are successfully operating in a number of islands such as Tarawa in Kiribati, Kwajalein in the Marshall Islands and Lifuka, Tonga. On the island of Bonriki, Tarawa, a yield of about 1 million l/d is obtained from 17 galleries, each 300 m long (Asian Development Bank, 2006).

Other very important measures are policy measures to reduce seawater intrusion. These are related to reducing pumping rates from groundwater as a result of increasing water potential from other resources and reducing water wastage.

3.1.3 Policy and Institutional Settings

Policy and Institutional Settings related problems often pose barriers to sustainable water management on islands, even in cases that water resources are abundant. To improve the situation, the following fields need to be addressed: integrated water resources management – cooperation between all relevant national agencies instead of the common situation of fragmented system. There is a need for greater integration efforts within the water sector as well as a holistic view to ensure that all relevant factors are taken into account; complete monitoring of water extraction; good data base to ensure/improve adequate factual basis for political decision making; relevant rules and regulations and their enforcement; enhanced efficiency of water administration; enhanced conjunctive use of water from different sources for different purposes (in the domestic use, for example, using “first class” water for cooking and drinking and “second class” water for bathing and washing) (Asian Development Bank, 2006); proper measures to protect water resources; etc.

Other related issues are policy measures to reduce water demand/consumption. These can include: **Relevant water pricing** i.e. an increase in consumer prices, possibly differentiated between different user groups; alternatively/additionally, quotas on water extraction may be imposed, again possibly differentiated between different user groups; **Eliminate/reduce subsidies for water prices –** to promote a healthy and just economic development, as well as the objective of achieving full-cost recovery; **Provide economic incentives for rational water use in all sectors -** incentives may be provided through, e.g., specific water tariffs (Lange, undated). In Cyprus, during drought periods, subsidies were established for saving good quality domestic water, e.g. for the installation of grey water recycling systems in houses (Anonymous, 2006); **Support sectors with high economic potential and small water needs –** this should be done in parallel to introducing incentives to save water for water-intensive sectors (Lange, undated); **Improved agricultural practices** (addressing quantity, quality of water) such as improved irrigation systems (e.g. drip irrigation), shift to crops with low water requirement, etc.

* These issues – both introduction of large scale technologies and infrastructure to increase water supply, as well as policy issues related to water management are usually the responsibility of national/state/island agencies and thus should be addressed on this level.

3.2 At the local/city level

3.2.1 Insufficient municipal water supply and wastewater treatment systems

Water systems

Improved drinking water supply systems, mainly for the purpose of reducing unaccounted for water and water wastage, is a main task. This should be related to both technology and management of the utility companies. Measures can include, for example, leakage control, metering and charging on water usage basis, and water saving devices.

Big leakages from systems are a major cause for water wastage. Reducing water losses, on the other hand, is one of the most important methods of saving water and should be addressed to conserve the existing freshwater resources, before investing in alternative and expensive solutions such as desalination. Active leakage control assists in reducing water losses. In some small Pacific Islands (e.g. Fiji, Tomga, and Samoa) a number of utility companied have introduced leakage control programmes, and even addressing leakages in households connections can have a great effect. In Niue Island a 55% reduction of water usage was achieved this way, nearly halving the operational costs of groundwater pumping. In Cyprus, leakage detection methods are applied on water distribution systems for reducing water losses and real time tele-monitoring and tele-control are now used to optimise the operation and maintenance of the systems (Anonymous, 2006). Metering and charging on water usage basis is an effective tool. In Islands such as Solomon Islands, Marshall Islands, Samoa etc, these were implemented and water usage reduction have been recorded as a result. In Samoa consumption fell from 825 l/p/d to 325 l/p/d following the introduction of metering. In Nicosia, Cyprus, the total unaccounted for water in 1984 was 29% of the demand. The municipality took steps such as replacement of water meters and leaking pipes and as a result water saving reached 7 MCM (Kliot, unpublished A). Water saving devices can also be useful (Asian Development Bank, 2006).

W*astewater treatment*

It is recommended that steps be taken towards a “zero water pollution” policy especially in the smaller islands where water resources are limited and highly susceptible to contamination. Improved methods for sanitation and wastewater treatment are required to prevent water resources pollution from wastewater. This requires both the appropriate technology as well as skilled staff within the wastewater services sector to improve wastewater management (Asian Development Bank, 2006). Solutions can include both low-tech low-cost as well as relatively high-tech and high-cost systems, depending on local situation.

As above mentioned, wastewater treatment can also provide opportunities for water recycling. Wastewater reuse can be addressed on a national/island level but at the same time can be promoted on the local/city level, using the municipal WWTP. Thus, a common type of recycled water is water that is reclaimed from municipal wastewater. In Cyprus, for example, to increase water supply, recycling of treated municipal effluents for irrigation and groundwater recharge purposes is promoted. Reuse schemes using treated domestic effluents are now in operation and many more are under study or construction (Anonymous, 2006). In Malta, three wastewater recycling plants are expected to provide enough water to satisfy all agricultural demands (Birdi, 1997). On Angel Island State Park in San Fransisco Bay (California, USA), where the city sewer has been used to its maximum capacity, it was chosen to apply a groundwater recharge system. This system emits treated wastewater under the ground. This is then used for irrigating adjacent municipal parks or preserves (Onsite Water Treatment, undated).

3.2.2 Institutional, financial, and operational management

Very often, the problems related with delivering satisfactory water supply and appropriate sanitation services in urban areas are primarily institutional and financial. They reflect inappropriate policies, inadequate cost recovery mechanisms, and the lack of appropriate incentives for consumers to reduce demand to sustainable levels, all of which undermine the ability to operate and maintain water supply and wastewater systems properly. This is the case, for example, in many Pacific islands.

Cost-recovery mechanism (e.g. tariffs), are extremely important and are the structure through which costs of water supply and wastewater costs, as well as the associated financial, environmental and social costs are recovered from users. Appropriate tariff system, should thus be in place. This should be supplemented by appropriate metering, billing (above 90%), penalty for non-payment, and revenue collection, for successful implementation.

In the Maldives, for example, a proper tariff system and management structure satisfies economic and financial objectives and at the same time is affordable as evidenced by

consumers' willingness to pay. The tariff structure provides households with the correct economic signals and thus has a demand management effect (includes higher charges for higher consumption whereas other classes of customers pay a flat rate charge). The tariff includes a fixed monthly charge that is in line with the costs of maintaining a connection, plus monthly meter reading and billing functions. All this results in a sustainable system (Asian Development Bank, 2006).

Additional problems related to organizational issues as there is a wide variety of organizational structures that could be set-up within the local government to manage the utility. Structure of the organization, as well as its ownership affects the effectiveness of the utility (Asian Development Bank, 2006).

* These issues of providing proper water supply and sanitation services are usually the responsibility of municipalities and local authorities and thus should be addressed on this level. This includes improving infrastructure and technology as well as improving management of utility companies.

3.3 At the individual unit level

3.3.1 High water demand in peak season

Wastewater recycling (on a unit level)

When water resources are exhausted during high water demand, technologies such as wastewater recycling can be a suitable option, as water can be recycled and reused onsite. For example, when an industrial facility recycles water used for cooling processes. More relevant examples are recycling schemes in tourist resorts or hotels.

The Sam Lord's Hotel in Barbados, for example, faced severe local water scarcity (due to saltwater intrusion to local well) which affected its water availability to meat demands during peak season. It developed an alternative water source to cope with the high demands for water for irrigation of gardens and lawns in the tourist season. The hotel now treats its wastewater and reuses it for these irrigation purposes. The use of the treated

effluent resulted in substantial savings in irrigation water costs and reduces the likelihood of water pollution. This also eliminates the need to use potable water supplied by the BWA public domestic supply system for irrigation and makes it available for other uses. However, inadequate operation and maintenance may pose some health risks (Anonymous, undated).

Other methods

Putting careful attention to water use management may also help individual units to save scarce water during peak season. In Jamaica, Sandals Negril Beach Resort & Spa uses low-flush toilets and urinals which use only 5.7 liters (1.5 gallons) of water per flush, aerators and low-flow devices on faucets, water-saving showerheads with a maximum flow of 9.5 liters (2.5 gallons) per minute, and ground care water-saving techniques to reduce water loss from evaporation. In the three years from 1998-2000, total water consumption per night was reduced 28.6% (The Center for Environmental Leadership in Business, undated).

3.3.2 Pollution by wastewater

Hotels can produce significant quantities of wastewater, both gray-water, which mainly comes from washing machines, sinks, showers, baths and roof runoff, and black-water, which comes from toilets (The Center for Environmental Leadership in Business, undated). On site solutions are well developed nowadays and can be applied in case of isolated hotels, resorts and other tourist attractions to provide high effluent quality. This is important to reduce pollution loads to the environment but also for recycling. Solutions for individual units related to tourism can be initiated and implemented by these local units themselves.

In addition to the above mentioned example of the Sam Lord's Hotel in Barbados, other examples can be presented. The Le Sport resort in St. Lucia, for example, treats wastewater in three interconnecting lagoons that filter wastewater with aquatic plants and mesh. The filtered water is then disinfected further with ultra-violet rays and used for irrigation on the resort's grounds. In its first year of operations, the new treatment method

saved about 3.8 million liters of water and thousands of dollars (The Center for Environmental Leadership in Business, undated). Grecotel in Greece worked with local authorities in the state of Rethymnon, Crete, to build a water treatment plant for the community and to install a wastewater treatment plant that treats water from both the hotel and the local community, thereby helping to preserve local water quality. Wastewater is treated through the hotels' own biological plants (Faulk, 2000).

3.3.3 Inadequate water use and pollution control practices by individuals

Public information and education (both for locals and tourists) is a critical water conservation priority. Raising awareness of water issues at all levels is critical in the successful implementation of water conservation programmes and activities. It is anticipated that water conservation activities, such as water loss reduction programmes and public awareness campaigns for rational water use could result in significant water savings. This entails changed water use practices by individual users. In islands such as Marshall Islands, Kiribati, Tonga and Samoa, radio programs, for example, have been used as a means of raising public awareness to reduce water consumption (Asian Development Bank, 2006).

* These issues of water scarcity and increasing water availability, especially in peak tourist season, as well as prevention of pollution by wastewater, and appropriate solutions for these issues, can be addressed also at the individual unit level. Promoting these solutions in many hotels, small resorts, tourist attractions, and vacation homes, can make a big difference and promote sustainable tourism. Wastewater treatment and recycling scheme in tourist venues and resorts can reduce the pressure of tourist related water problems. The more water is used, the more can be recycled, to reduce the use of potable water, and so on. A closed water cycle. This should be addressed with stakeholders at this level.

4. Conclusions

Water problems on islands are mainly related to the limited water resources. This results in water scarcity or shortage (including uneven distribution over time and space), leading

to over-using available freshwater resources. Due to the limited water resources, water related problems that are common elsewhere as well, such as pollution by wastewater and inadequate water supply systems (mainly huge leakages) become more acute on islands and thus require special attention and appropriate management. These: water pollution and water wastage further degrades the limited water resources and thus further worsens the water scarcity. All these are even more acute in islands with developed tourism. Water consumption/demand is much higher, resulting in over pumping from existing resources, affecting their long-term quality and thus their sustainability; wastewater volumes are much higher, and if untreated increase pollution loads; water wastage can be increased due to tourist' water use practices, etc. On the other hand, tourism is very often the most important or the second important economic sector on islands, and may be endangered if tourists will be deterred from coming due to degraded environment and health hazards. All these call for sustainable water resources management.

Several solutions to improve water management on islands are outlined. However, there is no single action that will improve sustainable water management on islands. Instead, an integrated approach that includes a range of measures is requires at all levels. These include both introduction of appropriate technology as well as improve management, policy and institutional setting issues.

Solutions include mainly development of alternative/additional water resources as well as preservation of the existing ones. On many islands alternative water resources are introduced, some common and easier to implement such as rain harvesting, others are more complicated and costly, such as desalination and importation. These can provide good solutions but have their limitations. Rain harvesting is limited in dry seasons, water importation means relying on external sources of water, and in desalination the high cost is a limitation. These, therefore, cannot be seen as the sole solution. It is also shown, as in the Malta case, for example, that increasing water supply cannot be expected to solve water shortage problems. The more water is produces, the more is used. It seems that it is more advisable to improve the utilization of the existing freshwater resources (e.g. reducing water wastage and pollution) before other options such as desalination and

importation are introduced, or at least in parallel to them. This requires introduction of measures such as: appropriate management of the existing resources (integrated approach; increased data and monitoring, etc); reduce water consumption/demand - by improving water supply systems management and infrastructure/technology on one hand (e.g. reduce leakages from systems) and encourage water saving by different means on the other; reduce water pollution (e.g. by wastewater treatment); and increase water potential from existing resources by e.g. water recycling, rain harvesting, increased storage, etc. This should be addressed by decision makers at state/island level but can also be initiated and implemented at city and individual level.

It seems that there is a limited capacity on most islands, especially in small and/or developing islands, to deal with these issues. The ability to adequately manage water resources is hindered by the lack of technical know-how and equipment, trained staff, knowledge of freshwater sources, and inadequate monitoring of the quality and supply of fresh water resources. These can be addressed by capacity building in the field of technological as well as managerial solutions. Focus should be put on both the professionals in the water sector as well as the members of the communities with emphasis on the tourist sector (hotel owners, small resorts managers, managers of other tourist attractions and venues).

Capacity building programme can include *At the island level* i) institutional setting: including IWRM, policies, planning, legislation, regulation, etc; ii) Water resource management: water supply management – water quality assessment and monitoring; water resources planning; development and management of conventional (e.g. rainwater harvesting) and non-conventional sources (e.g. desalination); surface water catchments management; groundwater systems management; etc; and iii) Costal zone management; *At the local/city level* i) Water services management (institutional/financial/operational): including system efficiency and conservation through leakage assessment, detection and repair; system improvement; water treatment; water quality monitoring; operation and maintenance issues; cost recovery mechanisms; tariffs; metering; billing; cost and asset accounting; etc.; ii) Sanitation facilities: including appropriate sanitation technologies;

urban sewerage collection systems; treatment process; etc.; and *at the individual unit level* i) Introduction of appropriate water use practices and technologies. *Community awareness programmes* including water source protection; water storage and purification practices; washing and cleaning practices; use and maintenance of sanitation systems; reduce wastage; etc. are needed to support efforts and decisions made by authorities as well as encourage sustainable water use practises.

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