An alternative for fresh water supplies in the remote rural areas of the Marrakech-Tensift-Alhaouz region.

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1. Introduction

Morocco is classified as a water-poor country since the annual water availability is less than 1000 m^3/inhab. and it is projected to be as low as 585 m^3/ inhab. per year in 2050.

So planning of water resources limited to identification, mobilization and management of conventional water resources is not sufficient at all. That's why, national water authorities are now thinking about master plans reconsidering planning of conventional water resources within a more global vision which includes the use of non conventional water resources, especially desalinated water and waste water.

Furthermore, one of the main pillars of the new national strategy in the field of water, is the generalization of the water access, especially in rural areas; for this, the national program of water supply in rural areas, called PAGER, was launched some years ago to reach a rural population of 11 millions inhabitants in 31000 villages in the year 2007. It is now in progress, lead by the National Office of drinking water (ONEP), but despite the important efforts done by ONEP and sometimes with help of communes, NGOs and other organisms, ONEP is facing important field difficulties such:

-1. the dispersed nature of the villages, which calls for decentralized water production;

-2. the availability of brackish or sea water as the only water resource for rural communities in many regions;

-3. the broken geomorphologic nature of the areas (mountains,..);

-4. these villages are often not connected to the electrical grid.

For these rural populations, getting drinking water is a daily worry; they usually commute for more than 3 to 5 km (sometimes more) daily to get their daily needs of water. Furthermore, this task is usually performed by children and women at the expense of education or income generation activities. In addition, the chemical and the bacteriological quality of the water often do not comply with the common standards, thus leading to digestive systems diseases especially among children and infants.

Taking into account all these considerations, and since these regions are also well known for their abundant solar and/or wind energies which makes them attractive for decentralized renewable energy generation and use, Foundation Marrakech 21 which is an NGO working for local development, is involved in a project called ADIRA, Autonomous Desalination Systems (ADS) supplied by renewable energies In Remote Areas. This project is carried out in the framework of the MEDA program and sponsored by the European Community.

By mean of this project, Foundation Marrakech 21 wants to contribute to alleviate the scarcity of fresh water supplies in rural and remote areas using autonomous desalination units operating with renewable energies in some villages of the region.
ADIRA project aims at developing optimum concepts for fresh water supplies which are adapted to the features of rural areas of the south Mediterranean, particularly Morocco.
As the project is still going on, we will present in this paper just the work done since the beginning of the project and the first results obtained.

2. The ADIRA approach

The original feature of ADIRA project is its multidisciplinary approach, since it will take into account the technical, economical, environmental, organizational, socio-economic and socio-technical aspects. Furthermore stakeholders and decision makers are involved in the implementation of the project since the beginning with training and awareness raising sessions planned. We think that this way of doing can lead to adapted solution and ensure sustainability.

The main activities undertaken for this purpose are:

- Identification and quantification of potential regions and sites for ADS.
- Survey of market available technologies and development of technical concepts for the installation of the units.
- Planning, implementation and monitoring of pilot installations.
- Actor and stakeholder analysis in the water and energy sector and identification of barriers to boost ADS units.
- Preparation of tools, data bases, training and awareness raising materials.
- Dissemination of the results and experiences among stakeholders at the national and international levels.

3. Activities carried out

3.1. Sites survey and selection criteria

The investigations carried out by FM21 to identify suitable sites for ADS pilot units in Morocco were based on the following criteria:

- The availability of the water point and the absence of drinking water source within reasonable distance of the site.
- The remoteness of the site and the absence of electricity grid connection
- The availability of suitable solar and/or wind energy resources.
- The existence of potential uses of the desalted water in the site,
- The readiness of the targeted population to participate and to assist the project team in the operation, the maintenance and the monitoring of the system.
- The technical and financial feasibility of the installation
- The distance of the site from Marrakech (headquarters of FM21)

The proximity criterion, lead us to limit our research to the Marrakech-Tensift-Alhaouz administrative region which is known for both its solar and wind energy potentials. The Alhaouz province (inland region) which is one of the provinces of this region, has an average daily solar irradiation greater than 5 kWh/m^2 , and is consequently very attractive for PV-powered autonomous desalination units.
The province of Essaouira located along the Atlantic coast is well known for its wind energy potential; so it is the most favorable region to conduct investigations on wind energy powered reverse osmosis (RO) units.
Investigations carried out by FM21 to identify suitable sites for ADS units in Morocco were based on the following sources of information:

- Salinity maps of the ground waters of the region
- The available data on the drinking water needs in rural areas (PAGER program, National Office of Drinking Water ONEP)
- Solar and Wind energy resources data (Renewable energy development center, CDER Marrakech Morocco)
- Various data pertinent to the project (demography, accessibility, …)
- On-site investigations which also enabled us :
    - to establish contact with populations and to know their real needs and problems
    - to see the existing water infrastructure if any;
    - to take some preliminary measurements of the quality of water (salinity), depths of the water point…
    - to sample the water for detailed analysis (chemical and biological).

3.2. First results and analysis

Throughout its multiple field visits and data collected from different offices, FM21 has identified several potential sites. Their characteristics were compiled (demography, water infrastructure, needs,..); they are summarized in table 1.
It appears that the population range from 400 to 500 inhabitants per village; the local economy of the villages is based on basic and traditional agricultural activities, breeding, seasonal work (field work, harvesting, construction work,..). The TDS in the majority of the open wells and boreholes that were screened varied form 2.5 to 5 g/liter for the brackish water (except for douar Tasekra who has an exceptional high value). To our surprise, some of these sources were used for drinking despite the fact that their salinity and their chemical and bacteriological qualities are beyond the accepted limits; it is the case for Tazitount site in the Essaouira region with a conductivity of 3800 μS/cm, and AZLA site with conductivity 4300 μS/cm, …). When the salt content is high, water from the well is usually used for hygiene and even in some cases for livestock; we noticed this for Benhssaine in the Haouz province. In most other cases, rainwater harvesting and storage in ground-built reservoirs as well as water transportation are used to secure the needs of the populations.

Because of the high level of salinity, corrosion is also frequent in the metallic piping systems that are used.

Some of the sites are equipped with water pumping, storage (reservoirs) and distribution (fountains) infrastructures. However, most of the pumping systems in the surveyed sites are shutdown most of the time because of the lack of funds to buy fuel or to ensure maintenance. This is usually done by collecting money from the inhabitants, which is not an easy task in the absence of a strong and well structured village association. It should be noticed that the unit price of desalinated water (investment & operation included) is considerably high compared to municipal water cost. However, this price is considerably lower than the water brought by truck or the daily price that is paid by women and children in transporting fresh water from remote places since more than two hours / family/ day are spent by women and /or children searching drinking water. Time saved will be reinvested in at least two added value activities: children could go to school more regularly, women could perform other income generating activities (breeding, handicraft,) or participate in alphabetisation, awareness raising, or other training activities. This price is not high also if we consider the health problems that originate from the use of rough brackish water or if we consider the cost of rural exodus consequences due to uncomfortable conditions of life in these areas.

3.3. First favourable site

According to the criteria given above, FM21 is now focusing on Douar Benhsaine as a favourable site.When a site is considered as favourable, a detailed study is necessary to the conception of the adapted system and his implementation; this focusing study consists of collecting data on the different aspects such as: water data, energy data, evolution of water quality and energy data during the year (solar radiation, wind speed,..), data on infrastructures, socioeconomic data, data on environment, and other data (administrative permissions, regulations, costs practiced,…).

Table 2 and 3 give examples of the detailed data about the favourable village Benhsaine. For this village which is situated at 40km from Marrakech in the rural commune of Tamaguert, near Ait Ourir center, in addition to the favourable physical and chemicalconditions there is also very favourable social conditions: a strong willingness of the population to participate to the project, some basic existing infrastructures and a well structured association who already does exist and is managing in a good way the existing water infrastructures.

While technical study is going on to calculate the adapted technical performances of the system, contacts has be done with commune representatives; they gave us their full agreement to get involved in the project; they agree to give the land beside the existing infrastructures to install the PV arrays and are ready to contribute by the civil work (fountain, protection wire fence,..).

To ensure sustainability of the project, an agreement to be signed with population representative and a training schedule are planned. The agreement is still studied with European Community to see what will be the kind of agreement to sign with stakeholders who will be in charge of management of the drinking water produced. The training plan is being set up; this plan includes adapted training sessions to each category: operators and keeper of the infrastructures (operating and maintenance training),

decision makers (management, cost, organization,..) and final users (awareness raising to women, children,..).

Table 1: Characteristics of some sites investigated.

Village	Province	Nature of the water point	Conductivity (microS/cm)	Pumping infrastructure	Storage	Distribution network	Drinking water demand
Amassine	Alhaouz	Borehole, 150 m depth, 12'' diameter	11330	None	none	none	15 m^3/day.
Benhsaine	Alhaouz	Borehole 150 m depth, 12''diameter.	6950	Electric Pump and diesel generator	25 m^3 reservoir	Water is distributed to the houses	6 m^3/day.
Amalou:	Alhaouz	Well	3200	Mechanical pump	Will be constructed by the community	Foreseen by the community	7.5 m^3/day
Tazitount	Essaouira	Well	3 800	Non functional wind mill directly coupled to water pump	50 m^3	One fountain	6 m^3/day
Ait Tamlalt	Essaouira	2 wells, depths 16.6 m and 43 m	4300/3960	Manual pump (nonfunctional)	no	none	15 m^3/day
Tafedna	Essaouira	Borehole, depth 100 m, diameter 12''	5000	Pump +diesel engine	25 m^3	Water fountains (standpipes) in various locations	10 m^3/day
Tasekra	Essaouira	Borehole, depth 100 m, diameter 12''	14400	Electrical Pump	25 m^3	Distribution network	10 m^3/day
Azla	Essaouira	Well	4300	Electric Pump and diesel generator	25 m^3	Fountains in various locations	15 m^3/day
Idberbeniz	Essaouira	Borehole, depth 122 m, diameter 12''	5300	Electric Pump and diesel generator	25 m^3	Fountains in various locations	12,5 m^3/day
Tabayat	Essaouira	well	4700	none	none	none	10 m^3/day

Table 2: Water Data in Benhsaine site

	Data definition	unit	Value
General data of feed water (seawater or brackish (well) water)	Source of water	L/S	3 (Brackish)
	Depth, (in case of well)	m	150
	Total dissolved solids	mg / l	0,002
	Conductivity	microS/cm	6700
	pH	-	8,1
	Temperature	ºC	24
Cations in feed water	Na(+)	mg / l	2796
	K(+)	mg / l	15
	Ca(+2)	mg / l	113,8
	Mg(+2)	mg / l	324
	NH_4(+)	mg / l	0,56
Anions in feed water	Cl(-)	mg / l	2001
	SO_4(-2)	mg / l	185
	NO_3(-)	mg / l	0,455
	PO_4(-3)	mg / l	0,01
Others (feed water)	Hardness ($CaCO_3$)	mg / l	608
	Total Coliform	UFC/100 ml	0
	Fecal Bacteria Coliform	UFC/100 ml	0
Water uses	Water demand for drinking	m^3/day	5
	Water demand for hygiene	m^3/day	25
	Water demand for industry	m^3/day	0
	Water demand for agriculture	m^3/day	0
	Water demand for irrigation	m^3/day	0
	Water demand for livestock	m^3/day	12
Irrigation	Cultivated fields	hectares	300
	Fields irrigated with sprinkler irrigation	%	0
	Fields irrigated with burrow or drip irrigation	%	0

Table 3: Socioeconomic data of Benhsaine site

Data definition	unit	Value
Current population	In habitants	240
Female population	%	50%
Non sedentary population	Y/N	N
Immigrant population flow	persons/yr	−−
Emigrant population flow	persons/yr	−−
Number of births in one year	persons/yr	2,4
Number of deaths in one year	persons/yr	1,7
Occupation	-	Agriculture
Percapita incomes	$/month/inh	33,34
Unemployment level	%	?
Female unemployment	%	?
Number of houses	units	39
Livestock number (heads)	units	400
Type of livestock	-	cows,sheeps, goats, hens, horses, mules camels
Basic diagram of the site	-	Y
Real expenses for current fresh water supply on site	$/m^3	0
Water prices (if appropriate differentiated by consume purpose and by consume quantity)	$/m^3	0,5
Real expenses for current electricity generation	$/kWh	0
Electricity prices	$/kWh	0

3.4. Proposed system.

In the framework of the ADIRA project, the capacity of the desalination pilot units that FM21 will install will range from 5 to 10 m^3/day, depending on the water demand of the selected site. For Benhsaine village we plan to a 5 m^3/day system with a fountain in a first step before integrating the fresh water in a distribution grid directly to the houses in the village. The schematic diagram of a typical PV-powered RO system considered in this project is shown in figure 1.

To take in account the environmental aspect of the project, we planned to set up beside the installation solar ponds for treatment of the brine. The salt recovered could be sold by the association in charge of the system management.

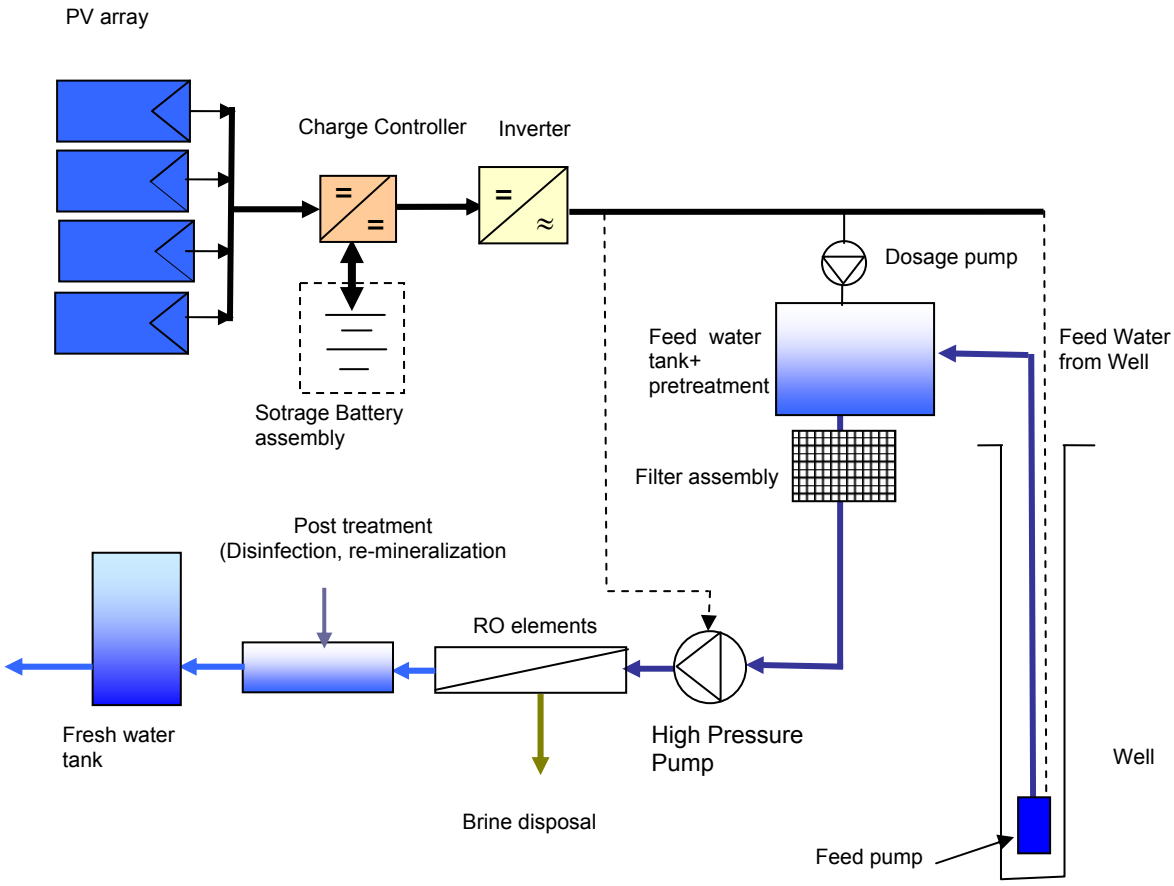

Figure 1: schematic diagram of an autonomous desalination system powered by photovoltaic energy

4. Conclusion

The work performed in the framework of the ADIRA project by FM21 enable the identification of several suitable sites for ADS units. The desalination unit may be installed either at the water point, the water reservoir site or near the fountains. The possible choice will be a function of other parameters such maintenance and monitoring, and security of the installation.

This pilot experience aims to show by a field experience implemented with pilot units that small autonomous desalination systems can constitute a very interesting alternative to solve drinking water shortage in remote areas and especially small rural villages such as in Moroccan rural areas..

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