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Water Metering Pilot Project: A Case Study of Water Demand Management in the Sultanate of Oman

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تقييم تجربة تركيب عدّادات على الآبار الزراعية في سلطنة عمان

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الخلاصة: تعاني الموارد المائية في السلطنة من تزايد الضغط عليها بفعل النمو المطرد في أعداد السكان والتوسع الهائل في قطاع الزراعة الذي يستهلك حوالي 92% من مجمل الموارد المائية في السلطنة، كما أن حرص الحكومة على سياسة التنوع الاقتصادي الرامية إلى ازدهار السلطنة و الحفاظ على التنمية المستدامة في البلاد قد أسهمت إلى حد بعيد في استنزاف الموارد المائية الوطنية. فتدهور جودة المياه وخاصة في سهل الباطنة لا يشي فقط بدرجة التدهور في مخزون المياه الجوفية بل أيضا تشير إلى الحاجة الماسة لوضع خطط فعالة لإدارة الطلب على المياه مبنية على أسس علمية راسخة، من هنا حرصت وزارة البلديات الإقليمية و البيئة وموارد المياه على تنفيذ العديد من الدراسات المتعلقة بإدارة الطلب على المياه في مختلف القطاعات: الزراعية، الصناعية،التجارية والمنزلية. ومن هذه الدراسات، مشروع تركيب العدادات في منطقة جنوب الباطنة التي بدأت في عام 1994 بهدف تقييم أنماط استخدام المياه في عدد من المزارع التي تم اختيارها بشكل عشوائي في منطقة جنوب الباطنة، ولقد تم تقسيم المشروع إلى مرحلتين على مدى سبع سنوات، وفر فيها المشروع كمية هائلة من البيانات المتعلقة بجودة المياه ومعدلات الضخ بالإضافة إلى أنماط الفلاحة وأنظمة الري. يتم من خلال هذه الورقة استعراض نتائج مشروع تركيب العدادات مبينا دور هذه النتائج في وضع أسس لدراسات أخرى على إدارة الطلب على المياه في القطاعات الصناعية و التجارية والمنزلية،بالإضافة إلى دراسة توسيع تركيب العدادات لتشمل مناطق أخرى في السلطنة.

ABSTRACT**:** The Sultanate of Oman is experiencing increased pressure on its groundwater resources. This is mainly due to agricultural enterprises, which consume about 92 % of national water resources, as well as an upsurge in industrial, commercial and domestic water use. The ever-growing population, diversification of economic activities and the ensuing rise in national prosperity have meant an increasing demand for water. This has resulted in a marked depletion of groundwater supplies, intrusion of seawater, and deterioration of ground water quality in the case of the Al Batinah region. A scientific and effective water demand management strategy for the Sultanate is therefore needed. Accordingly, the Ministry of Regional Municipalities, Environment and Water Resources (MRMEWR) have conducted several studies related to water demand management in the agricultural, industrial and domestic sectors. One of these studies was the Water Metering Pilot Project (WMPP), initiated in 1994 with the objective of evaluating patterns of water use on a number of randomly selected farms in the southern Al-Batinah. The results obtained over a period of seven years confirm that water metering alone does not help reduce the quantity pumped. These findings have encouraged other advanced studies on water demand management in industrial, commercial, domestic and agriculture sectors in different areas of the Sultanate.

Keywords: Water meters, water abstraction, water quality.

Introduction

The Sultanate of Oman is one of the countries that have scarce renewable water resources due to its location within the arid zone characterized by low rainfall and high summer temperatures. Annual rainfall varies from 50 mm/yr, in central Oman to 300

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mm/yr in the mountain ranges, with an average of 100 mm, of which 80% is lost by evaporation. A further 5% drains off into the seas, leaving only about 15% for aquifer recharge.

Omani traditional agriculture has maintained an unstable balance between water resources and the various uses. Furthermore, the rapid increase in population, expansions in economic activities since the renaissance, beginning from the 1970s, and the introduction of modern technology in well drilling, have added even more pressure on the situation. At present, renewable water resources in Oman are overexploited and in some areas, particularly the Al Batinah Coast, water abstraction far exceeds recharge rates. Consequently, groundwater levels have declined and the resulting intrusion of seawater has led to the abandonment of several farms.

This paper presents the highlights of a water metering pilot study that was conducted during the period 1994 - 2000 by the Ministry of Regional Municipalities, Environment and Water Resources for selected farms in the southern Al Batinah (MRMEWR, 2000). The objectives were to evaluate water use patterns and relate them to previous studies on water demand management in agriculture, as well as to compare different types of water meters and their adaptability to Omani conditions.

Research Methodology

Selection of Farms

The farms were selected using well inventory maps and considering farm size, cropped area, types of crops, water quality and the number of wells in each farm. The farms selected were located in the lower catchments of Wadi Taww, Al Manumah and Ma'awil, in Wilayat Barka in the southern Al Batinah. These areas were associated with deterioration in water and soil quality caused by over abstraction of water due to increasing agricultural activities.

Farmers were approached through letters to explain the objectives of the Pilot Project, after which they were administered with questionnaires to collect relevant information. The project was undertaken in two phases. The first phase started in March 1994, when one hundred and eleven water meters were installed on wells in 27 farms, covering a total area of 475.5 ha. The second phase started in 1996 and involved the installation of 315 meters on wells in 115 farms covering a total area of 1425.5 ha (Table 1). A crop survey was conducted on each farm after the installation of the water meters. The total area was recorded as well as the area allocated to each crop in each farm.

Metering and Monitoring Activities

Helical vane type meters with nominal diameters (ND) of 50, 80 and 100 mm were supplied by four different manufacturers and installed on the selected farms. In 1997 a water meter-testing workshop was held in Barka for the purposes of acquainting participants with procedures for the calibration and evaluation of the efficiency of the water meters installed in the farms. In order to examine its suitability for the climate of the area, each meter was calibrated, maintained and examined periodically. Meters with 10% or more variation were subjected to thorough servicing, whereas defective ones were replaced. The cost of meter installation depends on the type of the meter, the diameter and the other equipment required for installation. For this project, most of the meters were of 3 inches diameter, and the cost of installation ranged between 250 and 280 Omani Rials (US$ 650-750) per meter.

Different monitoring activities were conducted to collect data for evaluating the feasibility of this project. Monthly water meter readings were taken and water quality was checked regularly by measuring the electrical conductivity, wherever possible. Monitoring

Table 1. Farms and meters in each phase.

Phase	Year	No. Farms	No. Wells	No. Meters	Remarks
First	1994	27	110	111	One well with two meters
Second	1996	115	314	315	One well with two meters
Total		142	424	426	

Table 2. Crop survey.

Year	1994		1996		1998		2000	
No. of Farms	27		115		142		33	
Area/Percentage	ha	%	ha	%	ha	%	ha	%
Alfalfa	10.50	3	76.06	8	54.18	4	24.36	14
Dates	85.68	21	143.64	16	236.80	20	36.12	21
Grass	99.54	25	356.58	39	418.32	35	52.50	30
Citrus & Mango	42.84	11	133.56	15	161.28	13	17.64	10
Winter vegetables	81.06	20	68.46	8	136.90	11	13.86	8
Mixed tree	79.38	20	126.42	14	199.90	17	28.14	16
Total (ha)	400		905		1207.5		173.04	

activities also included periodic surveys of cropping patterns and irrigation methods in each farm plot. In particular, data on uniformity of sprinkler and bubbler systems were collected from 41 farms in 1999.

Results and Discussion

Crop Survey

Results of the crop survey showed that the total area in the first phase (1994) was 475.44 ha for 27 farms, and the cropped area amounted to 400 ha, of which 25% was covered by grass, while palm trees represented 21% (Table 2). Winter vegetables covered 20% of the entire area, mixed trees accounted for 20%, while citrus and mango accounted for 11%. In the second phase (1996), 115 farms covering an area of 1,425 ha were studied. Of the entire area, 905 ha were cultivated with the following proportion of crops and trees: grass (39%), palm trees (16%), vegetables (8%), mixed trees (14%) and citrus and mango (15%). In 1998, 142 farms with a total area of 1979.5 ha were studied in phases one and two. Of the entire area, 1,207 ha or 61% of the total area was covered with vegetation. A breakdown of the cropping pattern shows that grass covered 35% of the area while palm trees covered 20%, vegetables accounted for 11%, mixed trees covered 17% and citrus and mango occupied 13%. In 2000 the final crop survey was conducted over 33 farms, of which 6 were from the first phase and 27 from the second phase. The total cropped area was 173.04 ha, with grass covering 30%, palm trees, 21%, vegetables 8%, mixed trees 16% of the area and citrus and mango covered 10%.

Water Abstraction

Annual water abstraction in the 142 farms covered in the project varied from one year to another due to the changes in the size of the cropped area (Table 3). It was observed that the lowest average abstraction rate per hectare occurred in 1994, during the first phase, with an average of 17,850 m^3/ha/year. Conversely, the maximum average abstraction rate took place in 2000 with an average of 24,220 m^3/ha/year, and this increase was attributed to the expansion of the area cultivated with grass and alfalfa, covering 44 % of the total cropped area, as shown in the last column of Table 2.

Irrigation Systems

Modern irrigation was applied in 60% of the total cropped area (Table 4). The irrigation methods

Table 3. Cropped area and average water abstraction per hectare.

	1994	1996	1998	2000
Water abstracted (m^3)	712,811	18,804,561	24,733,562	4,191,066
Cropped area (ha)	400	905.1	1207.5	173.04
Average abstraction rate (m^3/ha/year)	17,580	20,778	20,483	24,220

Table 4. Area covered by different irrigation systems.

Irrigation System	Area (ha)	%
Drip	238	8
Bubbler	194	7
Sprinkler	477	17
Spray Gun	852	30
Flood	1114	38
Total	2875	100

included flooding, which was used in 39% of the cropped areas, and spray guns, used in 30% of the area. Other methods were sprinklers, used in 17% of the area, bubblers applied in 7% of the area, and drip irrigation, which served 8% of the area.

Water Requirements

The average abstraction rate per cropped area is considered a good indicator of the efficiency of water use in agriculture, and water consumption per unit area is the index for measuring water loss. Data obtained from the 1998 survey was used to calculate water losses, as it covered the largest number of farms.

The water requirement for the farms was based on the studies conducted by the Ministry of Agriculture and Fisheries (MAF, 1995), and converted to the requirement per unit area by the assumption that every ha contains 250 palm trees or 386 trees (citrus and mango). The water abstraction was 24.7 Mm^3, with an abstraction rate of 20,481 m^3/ha. Comparisons indicated that 75 farms over-abstracted water, whereas 67 farms abstracted less than the crop water requirement and accounted for 37% of the total water abstraction. The total water over-abstraction was estimated to 17%. In 2000 the water requirements were estimated to 32.1 Mm^3, while the total water pumped, according to meter readings was 41.9 Mm^3 resulting in 30% water over-abstraction. The results obtained over a period of seven years (Table 5) confirm that water metering alone does not help reduce the quantity pumped as over-abstraction ranged from 17 to 30 %.

Water Quality

Over-abstraction caused a decrease in the water table and an increase of water salinity due to direct intrusion of sea water. The quality of water in 375 wells was monitored. By comparing the 2000 data with 1996 data, it was observed that 228, or 61% of the wells, suffered an increase in salinity by more than 20% compared with 1996. Furthermore, it was observed that 86 wells (23%) suffered an increase in salinity ranging from 1 to 20 %. On the other hand, there were 61 wells (16%) which had a decrease in salinity, with 20 of them reducing salinity by as much as 20%. Most of these wells are located in the recharge areas of the Wadi Alfulaij and Wadi Taw recharge dams.

Water Meter Performance

The results of water meters performance tests indicated that Irmaj meters recorded the highest accuracy level at 93%, while Kent scored 89% (Table 6). Meinecke brand had an efficiency of 88%, and Wolltex was 84% accurate. Though they were not the most accurate, Kent meters showed a better capability to adapt to climatic conditions and water quality with only 4% replacement compared to Woltex, which recorded 15%, and Meinecke with 26%. By far the most vulnerable was Irmaj, with 60% replacement. The performance of water meters was affected by a variety of technical and environmental problems, such as, the inability of the meters to read more than 999999, the rusting of the screws due to their vulnerability to saline water, the damage of the impeller as a result of the accumulation of sand, and dirt due to the absence of filters.

Further Studies in Water Demand Management

Based on the findings of this pilot project, especially the observation of over-abstraction of water and the salinization phenomenon, the MRMEWR launched four different demand management oriented studies. The aims of these studies was to assess the possible alternatives to control water demand rather than supply in the agricultural, industrial, commercial and domestic sectors. The following are brief descriptions of some of such studies.

Study on water demand management in the industrial and commercial sectors

This study aimed primarily at industrial and commercial establishments like hotels, restaurants, private schools and private hospitals and other organizations that rely on groundwater. This study is meant to serve as a benchmark and reference for policy and decision-making as well as an evaluation tool for future water allocation and tariff options in the commercial and industrial sector. The study, which is

Table 5. Estimation of water over-abstraction above the requirement.

Year	1994		1996		1998		2000	
No. of Farms	27		115		142		33	
	Abstraction	Requirement	Abstraction	Requirement	Abstraction	Requirement	Abstraction	Requirement
Mm^3	7.128211	5.597942	18.804561	15.501492	24.733562	21.172679	4.191066	3.214762
Cropped area (ha)	400		905		1,207.5		173	
Average. (m^3/ha)	1782	13995	20778.52	17129	20483.28	17533	24220.2	18579
% over abstraction	27		21		17		30	

Table 6. Performance of different water meters.

Meter type	Reading accuracy (%)	Damaged (%)	Replaced (%)
Irmaj	93	57	60
Kent	89	2	4
Meinecke	88	5	26
Wolltex	84	36	15

expected to last for a period of 16 months, commenced in August 2005 and should be completed by November 2006.

Technical and financial study on installing water meters on tube wells

The aim of this study is to assess the technical and financial feasibility of installing water meters on tube wells throughout Oman to control water abstraction, and assess the policy implications of such a mechanism. The project is expected to help policy makers have a better view in water resources management with detailed data for the allocation of groundwater resources, especially operational agricultural tube wells. The study commenced in August 2005 and is due in April 2006.

On farm water demand management practices using water saving technologies and modern irrigation systems

The focus of this study is to evaluate the efficiency of modern irrigation systems along with new control and management instruments, such as scheduling, applied for the prevention of water loss. The study commenced in August 2005 and should be completed by February 2007.

Pilot study for improving domestic water demand efficiency using water saving technologies

This study aims at assessing the adaptability of water saving technologies in the Omani setting. The study commenced in June 2005 and should be completed by May 2006.

Conclusions

Over the period 1994 - 2000 total water abstraction from a representative sample of metered wells exceeded the water requirements by 17 to 30 %.

Fifty-three percent of the total number of farms were responsible for 63% of total abstraction, and were causing the problem of over-abstraction. This implies that not all farmers are overpumping. However, the 63% of those who are overpumping are causing damage to water resources of the whole community. Salinity increased in 84% of the wells, with 61% recording more than 20% increase and another 23% experiencing an increase in salinity by 1 to 20%. These results clearly indicate that installing water meters does not solve the problem of over-abstraction, unless it is accompanied by other control measures. On the other hand, 16% of the monitored wells located on the recharge areas of Wadi al Fulaij dam recorded a decrease in salinity by as much as 20%. This shows the importance of dams in recharging aquifers. In regard to meter suitability, Kent water meters proved to be the best among the four brands tested, in terms of accuracy of measurement of water, resistance to salinity and accumulation of sand and dirt due to the absence of filters and to harsh weather conditions. The water metering pilot project allowed estimation of overpumping in the agricultural sector and showed the need to undertake more advanced studies on water demand control and management.

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