# Additional value for industrial water at the Mellitah complex

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## ABSTRACT

In view of the limited availability of fresh water resources and the need for their conservation, the implementation of water recycling concepts within the framework of sustainable water management strategies thus of crucial importance. Wastewater treatment and reuse are technically feasible.

There is a wide range of proven technologies (conventional and advanced) available and water recycling systems can be tailored to meet specific demands. The treatment and reuse industrial wastewater provide a sustainable option within an industrial development. In many cases, Water recycling constitutes an economically attractive. The water reuse is very often obtained after association of several techniques. Many industrial users of fresh water are under increasing pressure to reuse water within their facilities. The goal is to minimize the amount of water that is discharged; there are a variety of reasons for this pressure, such as:

1. The cost of fresh water.
2. The cost of additional treatment to reach discharge limits.
3. Water availability
4. Environmental awareness.

This paper covers the preliminary design of the some of the reusable water in the Mellitah complex and the appropriate techniques for it as well as the fields of activity used. And estimate the quantity of water used by cooling water system and boilers in the complex, the discharged quantity to the sea as blow down and the amount that can be saved according to plant end user specification, as well as the international conventions on wastewater discharge. Nevertheless, the work will evaluate the quality of discharged and treatment water using different techniques, and finally to propose where reclaimed water can be utilized.

**Keywords:** water reuse, micro filtration, Reverse Osmosis (RO), water desalination.

## 1. Introduction.

In the last decade of the 21st century, the demand for food, energy and water has tenfold increased. The world has focused heavily on alleviating problems facing the food and energy sector, but the water sector has been placed on the sidelines because we mistakenly believe that we have sufficient water supplies to meet our future requirements. Unfortunately, we have failed to recognize the shift towards water resources management. With the depletion of natural sources of drinking water and over exploitation, research has been directed towards finding an alternative. Water reuse and reclamation are becoming an attractive option to keep expanding the limited supply of water.

### 1.1. Waste Water Sources and Estimation

At Mellitah complex plant the waste non-oily, water has many sources, at design time they were separated to two streams ending at the sea .During the last 12 years, many modifications have been made such as separating boiler blow down from cooling system make up and using sea water for boiler blow down cooling, this makes different water streams with different chemical constituents to be present in both sea water drainage streams.

Sources of water are mainly from the cooling system, boilers blow down, sour water stripper and sea water used for cooling. Since different sources are mixed, the experimental work will deal with separate water sources such as boiler water, cooling system blowdown and some mixed streams.

- **Cooling system:**

The quantity sent to the sea every day is 840 $m^3$ /day.

- **Boilers and waste heat boilers:**

Continuous blowdown of boilers and waste heat boilers are estimated between 1.5 and 3 percent of steam production rate. The total steam production needed is ranging from 550 to 650 $m^3$/hr. If 2 percent blow down is adapted for average 600 $m^3$/hr water circulation and 100 $m^3$/hr de-mineralized water makeup, the estimated water blowdown for all boilers is 14 $m^3$/hr

- **Sour water stripper:**

Water from sour water stripper containing hydrogen sulphide at 10 ppm is well known rejected at 28 $m^3$/hr for one unit, this water is mixed with other streams and directed to the sea.

In this paper the discharged quantity to the sea as blowdown is estimated, the quality and quantity of that can be saved according to the plant end user specification and/or international conventions on wastewater discharge is evaluated.

Once again, the major aim of this study is to focus on reusing blowdown of boilers, cooling system and non-oily, water at Mellitah Complex in order to save water in the plant and/or to add value to the water discharged to sea as well as to prevent any negative impact on the marine environment as part of commitment to the national and international conventions for the protection of the marine environment. [4]

The work will evaluate the quality of discharged and reclaimed water using micro- filtration and reverse osmosis techniques, moreover, to propose where reclaimed water can be utilized.

## 2. Experimental work:

### 2.1. Waste water purification:

In order to make the cooling water blowdown usable, two purification techniques were adopted, the micro- filtration and reverse osmosis, both were used for cooling water blowdown and boilers blowdown purification.

### 2.2. Microfiltration (MF):

Microfiltration used in this work is a commercial household type, used often for soft water purification, containing two cartridges in series as shown in figure (1).

Figure (1) Micro-Filtration setup connected to cooling system blowdown.

### 2.3. Reverse Osmosis (RO):

The RO used in this work is a common household type, used often for desalination of brackish water; it contains three cartridges in series as shown in figure (2).
RO in series with micro filtration was used for purification of cooling system blowdown and high pressure boilers. The cooling system or boiler blowdown is first introduced to microfiltration to remove suspended solids then to RO for desalination, the treatment arrangement is shown in figure (2).

Figure (2) Microfiltration and Single Pass R.O setup used for water desalination.

## 3. Results and Discussion:

### 3.1. The Quantity of Blowdown.

As indicated in the experimental work only three blowdown sources were taken into account, since they are continuously bleeded water to the sea; cooling water blowdown, boiler blowdown and sour water stripper.
The minimum quantity of water available for treatment is 80 $m^3$/hr., this quantity increases largely when increasing cooling system blowdown, discharging water from boilers or rainfall in winter.

### 3.2. Waste water, chemical analysis:

Chemical analysis of wasted water starts from each unit blowdown such as cooling system blowdown, power boilers and SRU (sulphur recover unit) boiler blowdown, then that mixed together streams and it ends with analysis of water discharged to the sea.

### 3.3. Mixed Stream water, chemical analysis:

Blowdown from boilers and cooling system are mixed with each other or with sea water and sour water at different stages ending with total mixing up at the sea drainage.
Cooling system blow down first mixed with Wafa boiler blow down. Finally different water streams delivered by two drainages underground pipelines ending in the sea and gives a notation of D1 and D2 as shown in figure(3).

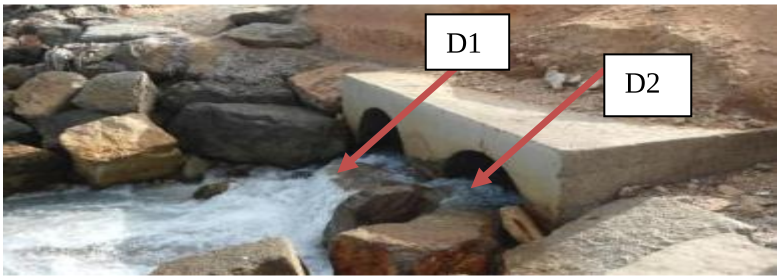


Figure (3) samples are overflow is discharged to the sea

### 3.4. Drains to the Sea Chemical Analysis:

The samples collected from both drains D1, D2, they have been taken to the lab and analysed.

Chemical analyses of both drains (D1 and D2) are presented in tables (1).

Table (1)

| Date: | Date: 10/02/2017 | | Date: 30/01/2017 | | Date: 3/03/2017 | |
|---|---|---|---|---|---|---|
| Compound/Location | D1 | D2 | D1 | D2 | D1 | D2 |
| Conductivity(µs) | 56.7 s/cm | 29.5 s/cm | 57.5 ms/cm | 27.3 ms/cm | 55.6 ms/cm | 14.60 s/cm |
| pH | 8.23 | 7.34 | 8.1 | 7.53 | 8.11 | 7.06 |
| Iron (ppm) | 0.0 | 0.13 | 0.0 | 0.03 | 0.04 | 0.17 |
| Zinc (ppm) | 0.14 | 0.07 | 0.07 | 0.07 | 2500 | 200 |
| Molybdate ( ppm) | 0.3 | 0.4 | 1.0 | 0.9 | 0.14 | 0.08 |
| Chlorides (ppm) | 0.0 | 0.0 | | | 1.5 | 0.5 |
| Chlorine (ppm) | 0.0 | 0.04 | 0.03 | 0.06 | 0 | 0 |
| Phosphate (ppm) | 0.16 | 0.02 | 0.8 | 0.5 | 0.01 | 0.04 |
| Volatile (ppm) | 0.0 | 01 | 0.0 | 2.0 | 0.15 | 0.04 |
| Color | | | 57.5ms/cm | 27.3ms/cm | 1 | 3 |
| Turbidity | | | 8.1 | 7.53 | / | / |

Further analysis was made by the Libyan Petroleum Institute, supplied with full glass bottled samples.

The analysis results are presented in table (2,3).

Table (2) Total Petroleum Hydrocarbon (TPH)

| | Sample | Sampling Date | TPH(mg/l) |
|---|---|---|---|
| **01** | D1 | 10/05/2017 | 0.00 |
| **02** | D2 | 10/05/2017 | 0.00 |

Table (3) *Heavy metals in drain one and two samples*

| Element (ppm) | D1 | D2 |
|---|---|---|
| **As** | < 0.02 | < 0.02 |
| **Cd** | < 0.002 | < 0.002 |
| **Cr** | < 0.002 | < 0.002 |
| **Fe** | < 0.005 | 1.30 |
| **Mo** | < 0.005 | < 0.005 |
| **Ni** | < 0.01 | < 0.01 |
| **Pb** | < 0.03 | < 0.03 |
| **Zn** | < 0.001 | < 0.03 |

In this study the treatment will concentrate on cooling system blowdown and boilers (high pressure, Wafa costal and waste heat boilers) water.

### 3.5. Micro Filtration Treatment Results:

The chemical analysis results of cooling water blowdown before and after filtration are shown in table (4), samples were taken on the 20th of August 2017.

Table (4) *Cooling system blowdown results Using Microfiltration*

| Element (ppm) | Before treatment | After Treatment |
|---|---|---|
| pH | 8.2 | 8.2 |
| conductivity(μs) | 341 | 327 |
| Turbidity | 10 | 8 |
| Zinc (ppm) | 2.18 | 2.10 |
| TSS | 5 | 3 |
| Iron (ppm) | 0.39 | 0.28 |
| Molybdate (ppm) | 6.1 | 6 |
| Color | 36 | 23 |

The Effect of microfiltration cooling system blowdown is typical of the filtration process, it reduces suspended solids, but not reduces on dissolved salts, hence concentration pollutants such as molybdate and zinc are the same. Reduction of suspended solids is of low value due to that only very fine solids are present in the system < 10 μm, the bigger size, most of it, was removed by a sand filter.
Obviously MF only is not suitable for water treatment that intended for boilers, but it can be used as cooling water makeup or for agricultural purposes.

### 3.6. Reverse Osmosis Treatment Results:

Microfiltration and RO purification results of cooling system blowdown water taken on the 10th of November 2017 is presented in the table (5), it shows the chemical analysis before and after water desalination process using MF and RO.

Table (5) *Cooling system blowdown results before and after MF and RO treatment.*

| Property | Treatment | | Salt Removal % | Property | Treatment | | Salt Removal % |
|---|---|---|---|---|---|---|---|
| | Before | After | | | Before | After | |
| Chloride (ppm) | 49.0 | 7.0 | 85.7% | T. Hardness (ppm) | 15 | 3.0 | 80% |
| T.Alkalinity (ppm) | 107 | 5.0 | 95.3% | TSS (ppm) | 3 | 0.0 | 100% |
| TOC (ppm) | 12.0 | 3.9 | 67.5% | TDS (ppm) | 203.49 | 6.6 | 96.8% |
| Conductivity (µs/cm) | 323 | 12 | 96.28% | Turbidity (Fau) | 8.0 | 0.0 | 100% |
| Nitrate (ppm) | 1.4 | 1.2 | 14.3% | pH | 8.1 | 6.35 | 21.6% |
| Phosphate (ppm) | 6.5 | 0.04 | 99.4% | Color (pt) | 50 | 0.0 | 100% |
| Silica (ppm) | 0.85 | 0.1 | 88.2% | Molybdate (ppm) | 6.0 | 1.0 | 83.3% |
| Copper (ppm) | 0.63 | 0.0 | 100% | F. Chlorine (ppm) | 0.37 | 0.0 | 100% |
| Iron (ppm) | 0.31 | 0.05 | 83.9% | Zinc (ppm) | 2.0 | 0.1 | 95% |

The results of the cooling system water blowdown treated by MF then RO are presented in a table (04). It is clear that all suspended and dissolved salts are reduced to some extent; some of them were higher than 90% such as alkalinity, copper, zinc, others at lower concentrations of > 80% such as Molybdate, silica and chloride.

For high pressure boilers at F2 area of NC41 plant, water was purified using MF and Single Pass R.O on 10/11/2017, the results of chemical analysis before and after treatment are shown in table (6).

Table (6) *MF and R.O treatment results of high pressure boilers blowdown water.*

| Property | Treatment | | Salt Removal % | Property | Treatment | | Salt Removal % |
|---|---|---|---|---|---|---|---|
| | Before | After | | | Before | After | |
| Chloride (ppm) | 16 | 3 | 81.25 % | T.Hardness (ppm) | 9.0 | 5 | 44.4 % |
| Sulphate (ppm) | 2.6 | 0. | 100 % | TSS (ppm) | 10 | 0.0 | 100 % |
| TOC (ppm) | 8.5 | 2.3 | 72.9% | TDS (ppm) | 49.77 | 13 | 73.9 % |
| Conductivity (µs/cm) | 79.0 | 20 | 74.7 % | Turbidity (fau) | 8fau | 0.0 | 100 % |
| Nitrate (ppm) | 2.1 | 0.9 | 57.1 % | pH | 9.99 | 6.8 | 31.9 % |
| Phosphate (ppm) | 21.0 | 0,05 | 99.8 % | Color | 41pt | 0.0 pt | 100 % |
| Silica (ppm) | 2.6 | 0.1 | 96.2 % | Iron (ppm) | 0.03 | 0.01 | 66.7 % |
| Copper (ppm) | 0.08 | 0.0 | 100 % | F.Chlorine (ppm) | 0.01 | 0.0 | 100 % |
| T. Alkalinity (ppm) | 21 | 17 | 19.0 % | Zinc (ppm) | 0.06 | 0.05 | 16.7 % |

The same results were reached for power boilers blowdown using both MF and RO. It is clear that all suspended and dissolved salts are reduced. The results of the treatment using both MF and RO clearly indicated that the techniques were effective to meet the guidelines specified by the EPA, standard specification for water used in boilers and cooling system in Mellitah Company, and water quality for Irrigation & Industrial applications.

### 3.7. Effecent Reuse Of Blowdown:

From the MF and RO treatment results for cooling system and boiler blowdown, it is clear that the desalination is effective in water reusing economically and environmentally. Desalinated water can be used directly as makeup for the cooling system, or passed to mixed bed for producing de-mineralized water. The other option is to send it to the nearby area for agricultural use. However, using of RO will give a 25% reject waste water, if 80 m3/hr, RO feed used, 20 m3/hr will be rejected as high salt concentrate, composed of chloride, phosphate, zinc and Molybdate salts, this rejected water can be directed to the existing desalination units as feed water along with water coming from the sea. The quantity will be less than 15% of feed, water, and salts rejected will be beneficial for the desalination units, I:e zinc and Molybdate will work as corrosion inhibitors and phosphate will prevent scale deposition. Schematic diagram of blowdown treatment and rejects reuse is presented in figure (4).

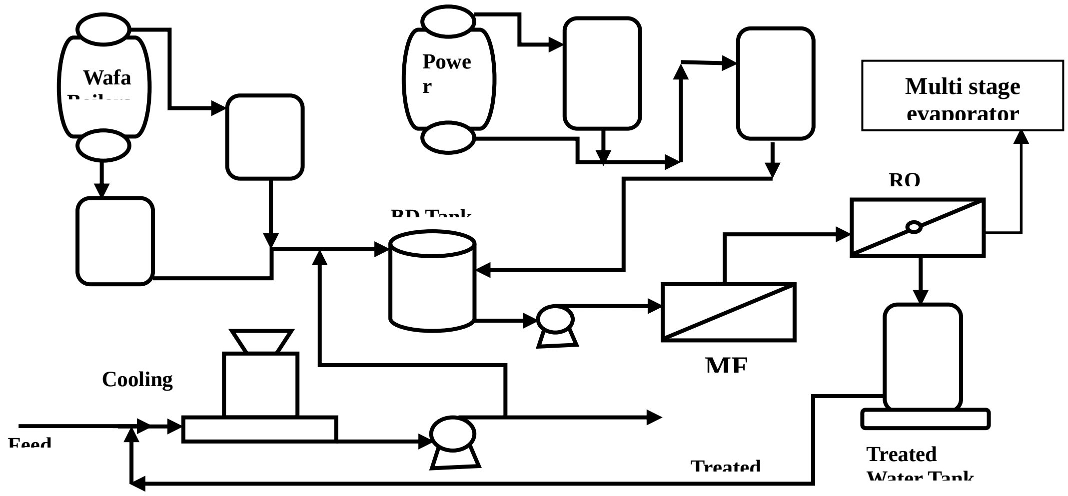


Figure (4) Cooling system and Boilers blowdown treatment and reuse layout

## 4. Conclusion:

In this paper it was possible to show both theoretical and practical concepts related to the quantity and quality of industrial wasted water at Mellitah complex, only boilers and cooling system blowdown was selected for treatment by both microfiltration and reverse osmosis methods. Further quantities can be added in case of more regulations and modification of the existing treatment is adapted. The results of the experiments clearly indicated that the techniques used for the treatment were effective enough to meet the guidelines specified by the EPA [i], standard specification for water used in boilers and cooling system in Mellitah Company, and water quality for Irrigation & Industrial applications.

**The following points can be concluded:**

1. For the first step only boilers and cooling water system blowdown can be reused, later steps sour water and other sources can be reused as well.
2. Micro-filtration can only remove suspended solids, its efficiency ranging between 40 and 60%, that's probably due to using sand filters (to remove big particles) before MF solids removal.

3. MF in series with RO is very effective in removing suspended and dissolved salts, its efficiency exceeding 80 %, the desalinated water is of good quality (conductivity, chloride , phosphate, zinc, Molybdate, nitrate, silica and sulphate all less than 1 ppm).
4. RO can reject up to 25% of waste water, this quantity can be directed to the existing multi-stage flash desalination unit, hence no discharge of wastewater into the sea, and desalination units will benefit of both zinc and Molybdate salts as corrosion inhibitors and from phosphate as scale inhibitor.
5. With this total reuse of cooling and boilers blowdown, the sea will be prevented from any pollutants, and it will meet all international and national convention on sea water protection.
6. Reclaimed water in excess of cooling system demand can be directed to mixed bed for the production of demineralised water to be used as boiler feed water.
7. Reclaimed water can be directly used for agricultural purposes in the nearby area.

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