Reusing of condensate water harvesting from spilt units for domestic and irrigation purposes: residential complex in Al-Mussiab Technical Institute and College, Iraq, as a case study

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Abstract. The research deals with the sustainable development of water resources. It considers with the possibility to benefit from condensate water harvesting from split units for domestic and irrigation purposes in residential complex of Al–Mussiab Technical Institute and College located in the Babylon Government of Iraq, which is selected as a case study. Ten samples of the water are collected in the scaled containers distributed in selected houses and apartments during six months of test in summer and winter seasons. The required physical and chemical parameters of water quality that is suitable for domestic and irrigation purposes requirements are tested. The results of the tests showed that the physical parameters are within Iraqi Standards while only Sulfates for heating condensate water are out of Iraqi Standards of chemical parameters. The results are also showed that the condensate water from cooling is soft in terms of suitability for washing clothes; while the condensate water from heating spilt units is very hard and the soap does not soak in the water; but they could be used to wash the floors and toilet as well as in the air coolers because there is no salt in them. On the other hand, the results demonstrate the validity of condensate water for drinking animals; especially the Poultry. The amount of condensate water harvesting from the split units that is collected from the residential complex forms 11% from the total consumption of water and this quantity of water could be added to the available water in the residential complex. It is concluded from the research, the condensate water from the cooling spilt units is within the limits, while the heating water exceeded the specified specifications for irrigation water and household water pumps. The research recommends to consider the placement of pipes and reservoirs for condensation water when designing residential complex, and to conduct studies about the effect of reusing the condensate water in agriculture on soil.

1. Introduction
Most of the central and southern regions of Iraq are generally characterized by a dry and semi–arid climate, so the regions suffer from a deficit in the water budget due to increased water requirements resulting from the increase in the population, growing demands for economic and social development, and limited access to water resources. This is done by finding safe ways to recycle some waste water sources to reuse for irrigation purposes, as well as for domestic uses, especially in the areas of residential complexes, benefitting from this water and reducing the water deficit. The harvesting of
condensate water from spilt units is a one way of solving the problem and represents a way for sustainable water resources.

Several researches talked about condensate water and its usage, [1] studied the estimation of the quantity and quality of water condensate that could be harvested from spilt units and its potential uses in the Faculty of Science Complex at the University of Port Harcourt. Although the water was not suitable for drinking, the limited volume harvested could be used for cleaning the laboratories, washing scientific equipment, watering of potted plants in greenhouses, conducting some scientific experiments and flushing toilets, etc. during periods of water scarcity, resulting from erratic power supply. [2] Determined the important properties of condensed water of a split unit and the uses of this unused valuable water. The study showed that the feasibility of using this condensed water in the battery, automobile radiator, boiler, toilet flushing and washing clothes.

The presented research aims at measuring the quantity of condensate water harvesting from the spilt units located in the residential complex of Al–Mussiab Technical Institute and College and the conducting of chemical and physical tests of the required parameters in these water necessary for the possibility of reusing this water for the purpose of domestic use and watering plants of the complex itself and compared with the specifications and determinants as a kind of sustainable water resources and reducing of both water shortages and the cost of living.

2. Description of the case study
The residential complex in Al–Mussiab Technical Institute and College is selected as a case study. It is located in the Babylon Government of Iraq within the location of both Technical Institute and College of Al–Mussiab neighbourhood in the Al–Mussiab Great River; as shown in figure 1.
On one hand, a statistical census work of the residential complex has been done with assistance of the Residential Unit at Al–Mussiab Technical Institute. The results of this work clarify that this residential complex contains a number of split units distributed in several houses and apartments, varying in size and construction, as well as a primary school and kindergarten and mini market. On the other hand, the production per 12hrs. of those split units are also implied in this work. The results of the statistical census work are given in table 1

| Type of buildings | Number | Number of split units per building | Operating time (hrs.) | Production per 12 hrs. (liter) |
|-------------------|--------|-----------------------------------|-----------------------|-------------------------------|
| Large houses      | 84     | 3                                 | 12                    | 6048                          |
| Small houses      | 21     | 2                                 | 12                    | 1008                          |
| French Houses     | 20     | 2                                 | 12                    | 960                           |
| Apartments        | 36     | 1                                 | 12                    | 864                           |
| Primary school    | 1      | 1                                 | 4                     | 8                             |
| Kindergarten      | 1      | 1                                 | 4                     | 8                             |
| Mini market       | 1      | 1                                 | 12                    | 24                            |
| Sum.              | 164    | 370                               |                       | 8920                          |

3. Condensate water parameters tests and standardizations
The condensate water harvesting from the split units are sampled and collected in the containers distributed in selected houses and apartments. The samples are subjected to physical and chemical tests according to the water requirements of domestic and irrigation purposes [3]. However, the physical parameters such as temperature, electric conductivity (EC), Odors, taste, and total dissolved (T.S.) have been tested; while the pH, Total Hardness (T.H.), Sodium (Na), Potassium (K), Calcium (Ca), and Sulfates (SO₄) have been tested as chemical parameters. On the other hand, the heavy metals such as Cadmium (Cd), Manganese (Mn), Lead (Pb), Zinc (Zn), Nickel (Ni), Aluminium (Al), Magnesium (Mg) and Mercury (Hg) have also been tested.

The condensate water samples harvested from cooling and heating split units are collected and then tested in the laboratory environment of the Directorate of Babylon Environment and the Ministry of Science and Technology. Ten samples are collected from different types of cooling spilt units and tested during summer session in August of 2018, while another set of ten samples are collected from different types of heating spilt units and tested during the winter session in January 2019. The results of the tests are compared with the Iraqi and International standards for irrigation, watering plants as well as the suitability of that water for various domestic uses such as household uses of washing floors, clothes, toilet and others; besides for consumption by domesticated animals in residential complex gardens.

3.1. Physical tests
The physical tests include:
1- The temperature is locally measured by a mercury thermometer (0 – 50) °C.
2- Electrical conductivity (EC) is measured in the laboratory using a conductivity meter.
3- Odors and taste using smell and taste properties. These qualities have been measured.
4- Total Dissolved Solid (TDS) are measured using a Gravimetric device.
3.2. Chemical tests
1. The pH was measured by a pH-meter device.
2. Total hardness (TH) is measured by a Titration device.
3. Sodium (Na) and Potassium (K) are measured by a Flame Photometer device.
4. Calcium (Ca) is measured by a Titration device.
5. Sulfates (SO\textsubscript{4}) are measured by the method of burning mineral deposits (Gravimetric).
6. Some heavy element ions have been measured such as Cadmium (Cd), Manganese (Mn), Lead (Pb), Zinc (Zn), Nickel (Ni), Aluminium (Al), Magnesium (Mg) and Mercury (Hg) using the Atomic–Audorption Spectrophotometer.

4. The productivity of condensate water quantity measurements
The productivity of condensate water harvesting from cooling and heating split units are collected in the scaled containers distributed in selected houses and apartments during period of operation in summer and winter seasons. The quantities of those collected water are then measured as volumes per day. However, the quantity of condensate water depends on the number of hours of operation of national electricity. The time period of operation is 12 hrs. per day for every Large houses, Small houses, French Houses, Apartments, and Mini Market, while this time is 4hrs per day for Primary School and Kindergarten as given in table 1; previously; where the total quantity of condensate water harvesting from cooling and heating split units is 8920 litres per 12 hrs.

5. Results analysis and discussion
5.1 Quantity of condensate water
The productivity of condensate water quantity harvesting from cooling and heating spilt units depends on numerous factors such as types of split units, operational age, and periodic maintenance procedures. Therefore, the average quantity of those harvesting water have been taken depending on the varieties of the types of split units and the operation conditions.

However, as given in table 1, the total number of buildings in the residential complex is 164 and if on an average, 6 people live in the large houses and 4 people live in the small houses, French houses, and Apartments then total number of people is 812 persons. The average per capita consumption of water per day is 100 litre/day [3]. Therefore, the total consumption of water per day is about 81200 litre/day (81.20m\textsuperscript{3}/day). Therefore, the quantity of condensate water harvesting from spilt units forms as 11% from the total consumption of water and this quantity of water could be added to the available water in the residential complex.

5.2 Quality of condensate water
5.2.1 Physical properties. The more important required tests are as follows:
1-Temperature: The condensate water is characterized by proximity to the temperature of the surrounding atmosphere. Any variation in temperature is weak as it is a temperature within the ambient temperature.
2-Odor and taste: Based on the senses of smell and taste, the samples are odourless as well as the taste as it is free from soluble salts.
3-Electrical Conductivity (E.C): the E.C rate is 261.70 μs / cm for cooling water and 956 μs /cm for heating water and is within Iraqi standards.
4-Total Dissolved Solid (TDS): the TDS for cooling and heating water are 143.50 mg/l and 592.50 mg/l, respectively, and are within the WHO standards.
5.2.2 Chemical properties. The chemical properties include the more important required tests as follows:

1- Acid function pH: the pH tests results of the condensate water of cooling and heating spilt units are 6.60 and 6.50, respectively and the water is acidic in nature. The results are within WHO standardizations.

2- Total hardness (T.H.) as CaCO₃: T.H. is 74.10 mg/l for cooling water and 475.81mg/l for heating water and it is within the WHO standardizations.

3- For sulfates (SO₄), the results for heating and cooling water are 191.90 mg/l and 449.50mg/l; respectively.

4- Positive Ionic:
   • Calcium (Ca): the concentration of calcium ionic of cooling and heating condensate water is 20.20 mg/l and 141.90 mg/l; respectively, which is within the WHO standardizations.
   • Sodium (Na) and Potassium (K): these components are little for cooling condensate water, which are equal to 7.10mg/l and 0.80 mg/l; respectively; while for heating condensate water are equal to 13.50 mg/l and 3.90 mg/l; respectively; and all are within the WHO standards.

5- Heavy metals elements: these elements for cooling and heating split units are within specific standardisations.

All physical and chemical properties tests of condensate water are given in table 2.

| Parameters          | Unit | Value Cooling | Value Heating | WHO standardisations [3] |
|---------------------|------|---------------|---------------|--------------------------|
| Physical properties |      |               |               |                          |
| Temp.               | °C   | 22            | 22            | ---                      |
| Odor and taste      |      | No Odor and taste | No feeling |                       |
| E.C                 | µs/cm| 261.50        | 956.00        | 2000                     |
| TDS                 | mg/l | 143.50        | 592.50        | 1500                     |
| Chemical properties |      |               |               |                          |
| PH value            |      | 6.60          | 6.50          | 6.5-8.5                  |
| Ca                  | mg/l | 20.20         | 141.90        | 800                      |
| Na                  | mg/l | 7.10          | 13.50         | 200                      |
| K                   | mg/l | 0.80          | 3.90          | 10                       |
| T.H as CaCO₃        | mg/l | 74.10         | 475.81        | 500                      |
| SO₄                 | mg/l | 191.90        | 494.50        | 250                      |
| Heavy metals elements |   |               |               |                          |
| Mn                  | mg/l | 0.126         | 0.109         | 0.20                     |
| Mg                  | mg/l | 18.00         | 22.00         | 80.00                    |
| Zn                  | mg/l | 0.150         | 0.163         | 2.000                    |
| Pb                  | mg/l | 0.019         | 0.028         | 0.100                    |
| Cd                  | mg/l | 0.006         | 0.008         | 0.010                    |
| Ni                  | mg/l | 0.011         | 0.016         | 0.200                    |
| Hg                  | mg/l | 0            | 0             | 0.001                    |
| Al                  | mg/l | 0.122         | 0.145         | 5                        |

5.2.3 Evaluation of condensate water quality from cooling and heating spilt units for different uses

1. Domestic uses: the classification of water based on total hardness (T.H.) is given in table 3.

| Table 3. Water calcification w.r.t. T.H. [4] |
The condensate water from cooling spilt units is classified as a soft water in terms of suitability for washing clothes, but the condensate water from heating spilt units is classified as a very hard water and the soap does not soak in the water, but both types of water could be used to wash the floors and toilet as well as could be used in the air coolers because there is no salt in them.

2. Watering Plants: the results showed that there is no danger of watering plants by using condensate water harvesting from the spilt units in terms of water matching with the Iraqi standardizations and as given in table 3.

3. Consumption by animals: In order to demonstrate the validity of condensate water for consumption by animals; especially the poultry, it is compared with standard specifications for public veterinary services within the United States of America as given in table 4.

| Animals     | TDS (ppm)   |
|-------------|-------------|
| Poultry     | < 2860      |
| Horses      | 6453        |
| Milk cows   | < 7150      |
| Cattle meat | < 10000     |
| Sheep       | < 12900     |

When comparing the results given in table 4 with the TDS value given in table 7, it is noted the validity for consumption by animals.

6. Conclusions

1- The condensation water from the cooling spilt units is within the limits, while the heating water exceeded the specified specifications for irrigation water and household water pumps.

2- The quantity of condensate water harvesting from spilt units forms as 11% from the total consumption of water and this quantity of water could be added to the available water in the residential complex and using in some domestic requirements such as washing of floors, garages and cars, flushing of toilets and baths, watering of plants and drinking water for animals.

7. Recommendations

1- When designing residential complex, the placement of pipes and reservoirs for condensation water should be considered

2- Conduct studies about the effect of reusing the condensate water in agriculture on soil.

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