Reduction of pollution caused by smoke from brick factories using a water system and reuse of water from brick production

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Abstract. Air pollution is an important contemporary issue and any attempt to mitigate pollution and the environmental impacts is considered significant. In Iraq, dark oil is used as the essential fuel for brick factories. Incomplete burning of this fuel discharges a black smoke, which contains substantial amounts of soot especially at the beginning of any operation. The main objective of this study is to investigate use of a system of spraying water to treat the black smoke that is emitted by brick factories, to reduce the pollution and reuse the industrially-generated black wastewater (IBW). In this study, five samples of water were used, comprising one sample of clean water (control sample) and four samples of IBW, which contained different quantities of soot according to the quantity black oil burned. The burning operation was reproduced by burning 0.5, 1, 1.5, 2 liters of black oil respectively for the four samples used. The IBW was tested in a laboratory of the environmental authority and it was found to be free from any increased concentration of heavy metals except copper(Cu) and zinc(Zn) elements with a ratio 0.02 to 0.20 mg/l and 2.25 to 2.61 mg/l respectively. The PH was neutral at around 7.3. Further laboratory tests of the IBW showed that it contained sulfates at about 426 to 646 mg/l, nitrates of 12.5 to 31 mg/l, and chlorides at 151 to 178 mg/l. The results showed that reuse of the IBW generated by the brick industry did not affect the compression strength for any samples compared with the control sample (zero soot), which means the adopted system gave a very good results, reducing pollution with the same compressive brick strength.

Key words: Black oil, Brick, Smock, Soot, Wastewater.

1. Introduction
The clay brick is the major material in building construction in Iraq, therefore brick factories are found in almost all towns, indeed the growth in population has led to increasing number of brick factories. The environmental Ministry of Iraq has determined that factories must be placed five kilometers away from towns to protect the population from air pollution [1]. Currently, stacks are used to mitigate the air pollution from brick factories. This method is not efficient, especially at the beginning of factory operations, so in this study a new method is tried, to reduce the emissions of black smoke that is produced during brick manufacture. This method uses a water spray tower which is a type of wet scrubber methods. It is widely known as a devices that may be used to mitigate or prevent air pollution and is efficient in removal of particulates, smocking and gases. The efficiency of this method is proportional with particle size and there are many configurations, such as the spray tower, cyclonic spray tower, dynamic scrubber, tray towers, Venturi scrubbers, Orifice scrubber and other designs [1].
This study adopts the idea of reusing industrial wastewater, because water is a major component of most industrial activities. The reuse of wastewater for industrial activity is easy, because it can be reused in many applications such as washing, rinsing and so forth [1]. However, the reuse of industrial wastewater (IBW) is dependent on many factors such as the quantity of wastewater, quality and concentration of pollutants, the technology used for treatment and level of contaminant removal, cost of treatment, raw water availability and the intended final use of the treated water [2,3].

There have been many attempts at, and studies of, the reuse of IBW. For example, the use of textile wastewater was studied using membrane and biological treatment [4], laundry wastewater treated using conventional treatment and ozonation processes [5], wastewater from washing bottles in the beverage industry after treatment with reverse osmosis and ion exchange [6]. Also, there have been attempts to reuse the sludge which is produced from water treatment by lime softening, in many applications such as cement production, dust control, neutralization of wastewater, and as filler in road construction [7].

The objective of this study is to investigate the use of a system of washing water to reduce the black smoke that is produced by brick factories. This system will reduce air pollution by transferring the pollution from air to water, and by reusing wastewater in the production of clay brick.

In this research, wastewater has been defined as generated water that is mixed with the black smoke that is produced from burning brick units. Although this wastewater contains a quantity of soot, it remains as neutral water (i.e. PH≈ 7.0) according to experimental results. This means that no chemical change happens to the brick paste during and/or after manufacture.

2. Experimental Works
For this study we designed a suggested pilot plate, to control the smoke flow and reduce the quantity of smoke that could be exposed to air by using water sprayers with a specific mechanism. The produced water was recycled and used in production of a new brick unit and we studied the mechanical properties.

2.1 Pilot plant
The designed pilot plant was constructed completely and comprised five units, the incinerator, duct, four water sprayers, water pump, and tank, as shown in Figure 1. The incinerator was made from an iron barrel and contained the black oil (used oil) to work the combustion operation. The duct was used to receive and control the smoke on outlet and in terms of its flow direction. The four water sprayers were used to spread the recycled water over the released smoke and drop the soot. The water pump was used to recycle the accumulated water from the sprayers. The tank was used to save the recycled water, with soot. The pilot plant was suggested and designed to simulate reality in the brick factory.

![Fig 1: Schematic diagram of the suggested pilot plant units.](image-url)
2.2 Preparation of the water samples

Table 1 shows details of the preparation of four samples of recycled water. These were prepared depending on the quantity of burned black oil (i.e. the burning period of the black oil).

| Case No. | Black oil quantity (Liter) | Period of burning (minutes) | The water quantity (Liter) |
|----------|---------------------------|----------------------------|---------------------------|
| 1        | 0.5                       | 45                         | 30                        |
| 2        | 1.0                       | 90                         | 30                        |
| 3        | 1.5                       | 135                        | 30                        |
| 4        | 2.0                       | 180                        | 30                        |

During the preparation of recycled water, it is noted that two types of soot were produced during experiment. The first was dissolved and the other floated and was easily removed from wastewater by scraping. The first type is used in production of brick unit and it is noted that there was no substantial difference between the samples in the quantity of dissolved soot or in chemical analysis.

2.3 Brick production

Five groups of bricks were produced, and grouped according to quality of water used in their production. Each group contained eight bricks units, as shown in Figure 2. Four groups (G1, G2, G3 and G4) were produced by using recycled water with different quantities of soot as mentioned in Table 1 and one group (G5) was produced using clean water, as a control sample. The experimental program and brick production comprised four main stages, which are given in Figure 3. These were:

1. Clay preparation: this stage included extraction of the clay from the soil, grinding the clay, addition the water with humidity ratio 5 – 10%.
2. Molding the brick: after configuration of the clay, the clay moved mechanically from the storage location to the segmentation and molding machine, where the final shape of brick was produced.
3. Brick burning: this was the final stage of brick production. Bricks were loaded into the furnace, which was 100 * 30 m and its temperature reached 400°C.
4. Sample testing: the bricks units were tested to find their compressive strength, as shown in Figure 4. This test was conducted in a structural laboratory in the engineering college at the University of Al-Qadisiyah.
3. Results and Discussion

3.1 Chemical properties of recycled water

The period of pilot plant operation was from 0.75 to 3 hours with 30 liters of recycled water, which was a proportional simulation of everyday furnace workings and the water used water to make bricks. All samples were analyzed in the chemical laboratory of Al-Qadisiyah Environment Directorate. Table 2 explains the properties of the water that was produced from smoke treatment.

Table 2: Chemical experimental results of adopted recycled water

| NO. of Trial | Parameters (mg/l) | Sulfates SO4 | Nitrates NO3 | Chloride CT | Cu | Pb | Zn | Fe | Hg |
|--------------|-------------------|--------------|--------------|-------------|----|----|----|----|----|
| Trial 1      |                   | 369.0        | 12.49        | 151.3       | 0.019 | Nil | 2.24 | 0.05 | Nil |
| Trial 2      |                   | 426.5        | 14.09        | 160.2       | 0.123 | Nil | 2.38 | 0.06 | Nil |
| Trial 3      |                   | 534.3        | 21.4         | 168.4       | 0.196 | Nil | 2.43 | 0.07 | Nil |
| Trial 4      |                   | 646.2        | 31.00        | 178.0       | 0.242 | Nil | 2.61 | 0.07 | Nil |
| Control sample |                | 329.5        | 6.5          | 142.0       | Nil | Nil | 0.15 | 0.03 | Nil |

3.1.1 PH

The PH values for all cases study were neutral, whereby the PH of clean water (control sample) was 8.11 while other values ranged from 7.74 to 7.54, because they contained some quantity of soot. Oil combustion produces
dioxide carbon gas and water, therefore the PH value decreased with increasing burning duration. Figure 5 explains the variation of PH with the quantity of combustion oil.

3.1.2 Nitrates

Experimental results explained that the amount of nitrate increased with burning duration of oil. The source of this nitrate was the essential oil components, which contained further chemical compounds. The largest nitrate value was shown by the sample that resulted from burning of two liters of black oil. All obtained values were accepted and adequate for use in such industries according to the Iraqi standard, which determines a nitrate value of 50 mg/l [9]. Figure 6 shows the variation of nitrates with combustion oil, and comparison with the Iraqi nitrate standard.

3.1.3 Sulfates

The increase in sulfate with burned oil was very obvious. The sulfate content for the control sample was 329.5 mg/l, while in the fourth trial it was 646.2 mg/l. This substantial difference is due to the nature of the oil used, which discharged a high concentration of sulfates, and by the spray of water which mixed with black smoke and
therefore the concentration was high in samples 2, 3, and 4. The Iraqi sulfate standard does not specify a numerical value but is expressed as a ratio, depending on the sulfate concentration in a water body. Figure 7 shows the variation of sulfates with combustion oil.

![Graph showing variation of sulfates](image)

Fig. 7 Variation of sulfates with quantity of combustion oil.

### 3.1.4 Chlorides

The variation in chloride concentration was low for all trials in comparison with the control sample, because the oil used has a very low concentration of chlorides. Therefore, all measures were below from the Iraqi standard for chlorides, which specifies a minimum of 200 mg/l [9]. Figure 8 shows the variation of chlorides with combustion oil and compares them with the Iraqi chlorides standard.

![Graph showing variation of chlorides](image)

Fig. 8 Variation of sulfates with quantity of combustion oil.

### 3.2 Brick Manufacture

Four samples of bricks were produced with reused water (black water) and the fifth brick sample was a control sample, which was produced with clean water. Each sample contained eight bricks, which were manufactured by mixing the same soil with different samples of water generated from the pilot plant. The water produced from the first trial was used for the first sample, and so on. Figure 9 shows there was no effect from reuse of the black water in brick manufacture on compressive strength; all brick samples had approximately the same compression strength, at about 300 kN. That means the use of recycled water in brick manufacture did not affect compressive strength.
4. Conclusions

In the present study, experimental work was conducted to investigate a proposed system of washing water for use in brick factories. This system was based on a new idea, of using water to transfer pollutants from air to water by reducing the smoke of brick factories, then using the recycled wastewater in the production of brick units. Experimental results revealed the following:

1. There are two types of soot in washing water, buoyant and dissolved. The buoyant soot can be removed by scraping, and the dissolved type may require special treatment. Therefore, such water must be reused in an appropriate field, to avoid water or soil pollution.
2. PH no more changed little due to soot in recycled water, this means that moreCO₂ gas could not be removed, so another technique (close system) is required for complete control all types of gas.
3. The experiment generated a sharp rise in sulfates that was proportional with operation period, but the level of chlorides changed little.
4. The used of recycled water (black water) in brick production has no effect on compressive strength. That means the use of recycled water in production of brick units does not have a side effect on compressive strength.

5. Recommendations
- We recommend development of the pilot plant work in a context the produced water is acidic and reused in brick and other manufacturing processes such as concrete mixing.

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