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# A Novel Approach to Improve Octane Number and Reduce Sulfur Emissions in Regular Gasoline by Selective Naphtha Blending at Al-Diwaniyah Refinery

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ABSTRACT

This paper proposes a low CAPEX selective blending strategy to upgrade regular gasoline quality in Diwaniyah Refinery. It tests the hypothesis that segregating heavy naphtha from the gasoline pool and blending light naphtha only with imported high-octane gasoline can increase octane number (RON) and reduce sulfur content while decreasing import requirements. Four volumetric cases were evaluated: the refinery's current practice (72 vol% imported gasoline + 28 vol% mixed naphtha) and three alternatives replacing mixed naphtha with light naphtha at 72/28, 67/33, and 62/38 vol%. Blends were prepared at ambient conditions and characterized using ASTM D2699 (RON) and ASTM D5453 (sulfur content). Replacing mixed naphtha with light naphtha at the same import ratio increased RON from 82.5 to 84.5 and reduced sulfur content from 157 to 70 ppm. Further reductions in imported high octane gasoline to 67 and 62 vol% maintained sulfur content below 100 ppm (77 and 87 ppm), with RON values of 83.5 and 80.5, respectively. These results were confirmed by Aspen Hysys simulation and ANOVA, indicating that heavy naphtha exerts the strongest negative effect on quality of regular gasoline. The proposed segregation requires only modifications to pipeline routes, enabling improved fuel quality and compliance with sulfur standards while reducing the need for imported gasoline in smaller refineries.

## 1. Introduction

Improving the quality of regular gasoline that is supplied to consumers is of paramount importance particularly with regard to octane number (O.N) and sulfur content (S.C) [1-3]. Research octane number affects fuel combustion and engine performance, as lower octane levels lead to engine knocking, reduced power output, and a shorter vehicle lifespan [4-6]. At the same time, the high sulfur content negatively affects the quality of the environment by increasing emissions of sulfur oxides, causing serious health risks and contributing to the formation of acid rain, environmental degradation and corrosion of refining equipment [7-9].

Diwaniyah Refinery consists of two atmospheric distillation units, each processing 10,000 barrels per day of crude oil [10, 11]. Petroleum sourced from Basra oil fields, initially undergoes pretreatment processes, including sedimentation (settling) and desalting operations, to remove impurities, sediments, salts, and water [12, 13]. Crude oil heated through a series of heat exchangers followed by a furnace or fired heater, reaching temperatures ranging from 300 to 316 °C before entering distillation column. The heated crude oil fed into the atmospheric distillation column at flash zone region, operating at pressures about 1.2 bar-gage. The distillation column is equipped with 29 valve trays designed to fractionate crude oil into products arranged from the heaviest at bottom to the lightest at top: reduced crude residue (R.C.R,) gas oil, kerosene, heavy naphtha, and light naphtha, along with off gases. Light naphtha exits from the top of distillation column, subsequently cooled by air coolers. This cooled stream is then collected in knock out reflux drum, from which a portion is recirculated as cold reflux to maintain and control the column top temperature, while the remaining portion approximately 9 $m^3$/hr, is sent forward for blending and storage. Heavy naphtha produced at a rate of 3 to 4 $m^3$/hr from the lower trays of the column and is cooled in the battery limit area. Subsequently, both light and heavy naphtha streams are combined into a single stream directed toward the mixed naphtha tank. Notably, Al-Diwaniyah Refinery lacks essential downstream processing units, such as catalytic reforming and isomerization units. Hence, the production of regular gasoline for consumers are achieved by blending the mixed naphtha (containing both heavy and light streams) stored in the naphtha tank with imported high octane gasoline. Current operational blending ratios at the refinery involve approximately 72% by volume imported high octane gasoline and 28% by volume mixed naphtha, resulting in regular gasoline characterized by an octane number about 80 to 82. Though the required octane levels are achieved, a common mixture procedure at Al-Diwaniyah Refinery often results in regular gasoline with sulfur levels higher than the Iraqi standard of 100 ppm, and to achieve the required octane specifications, the proportion of imported high-octane gasoline is often increased. The traditional blending scheme, as shown in Figure 1, is where the heavy and light streams of naphtha are combined in one storage tank, which is a mixed-naphtha tank.

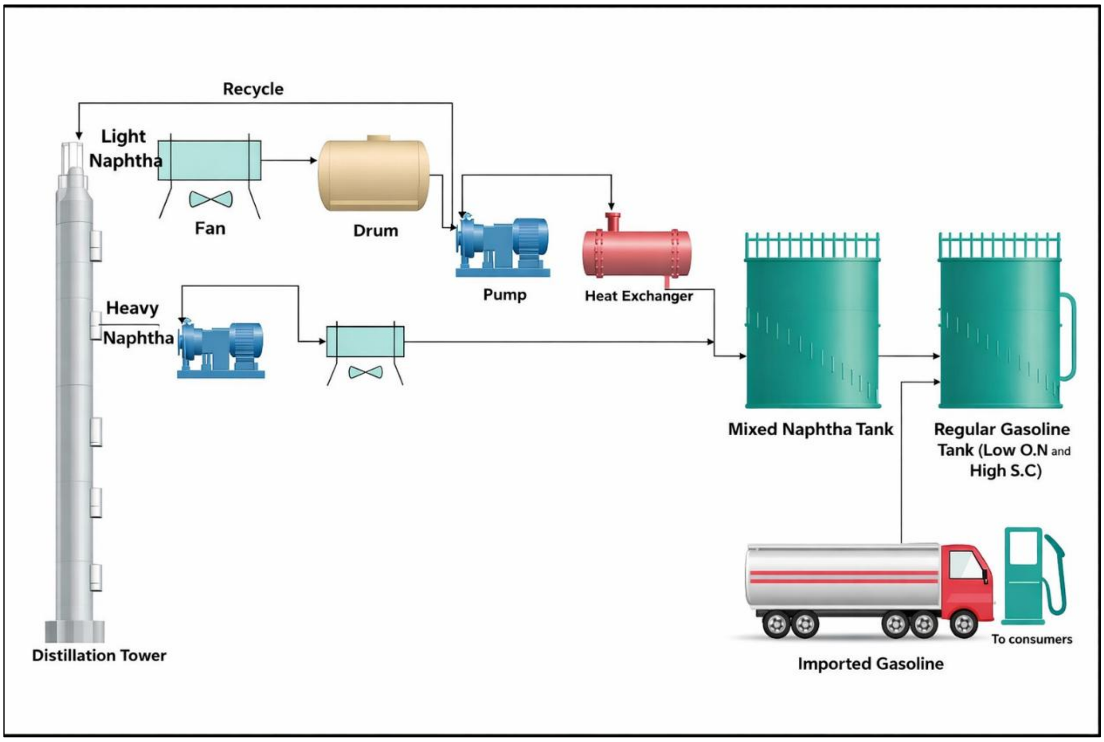


**Figure 1.** Blending process for production regular gasoline in Diwaniyah refinery.

Qasim et al. [14] identified that blending heavy naphtha with light naphtha into a single storage tank (mixed naphtha tank) significantly reduced the overall octane number and elevated sulfur content. This is due to the fact that light naphtha contains a higher octane number and lower sulfur content, whereas heavy naphtha has a lower octane number and higher sulfur content. Therefore, the previous study recommended reducing the production rate of heavy naphtha to improve the mixed naphtha's specifications in terms of octane number and sulfur content. However, it did not address the impact of separating heavy naphtha from light naphtha in the mixed tank on the specifications of regular gasoline. Therefore, this study tests the hypothesis that excluding heavy naphtha from the gasoline pool and blending only light naphtha with imported high-octane gasoline can increase RON, reduce sulfur content to meet the Iraqi specification, and reduce the imported high octane gasoline fraction required to achieve target quality. The studied variables are the volumetric blending ratios between imported gasoline and light naphtha (72/28, 67/33, and 62/38 vol%), benchmarked against the current practice using mixed naphtha. The novelty of this work lies in demonstrating a low-CAPEX, immediately deployable blending retrofit implemented through minor piping re-routing, validated by laboratory measurements and supported by simulation and ANOVA evidence, offering a replicable strategy for small refineries with limited upgrading infrastructure.

## 2. Materials and Methods

### 2.1 Background and Experimental Motivation

In a previous study conducted at Al-Diwaniyah Refinery, the effects of blending heavy and light naphtha in mixed naphtha tank on the final octane number and sulfur content were comprehensively investigated. Through employing Aspen HYSYS simulations as shown in Figure 2 and Analysis of Variance (ANOVA), the study concluded that increasing the proportion of heavy naphtha blended with light naphtha negatively influenced mixed naphtha. Specifically, ANOVA revealed the heavy naphtha flow rate as the most influential parameter (highest F-value) affecting octane number reduction and sulfur content elevation as shown in Table 1. [14]

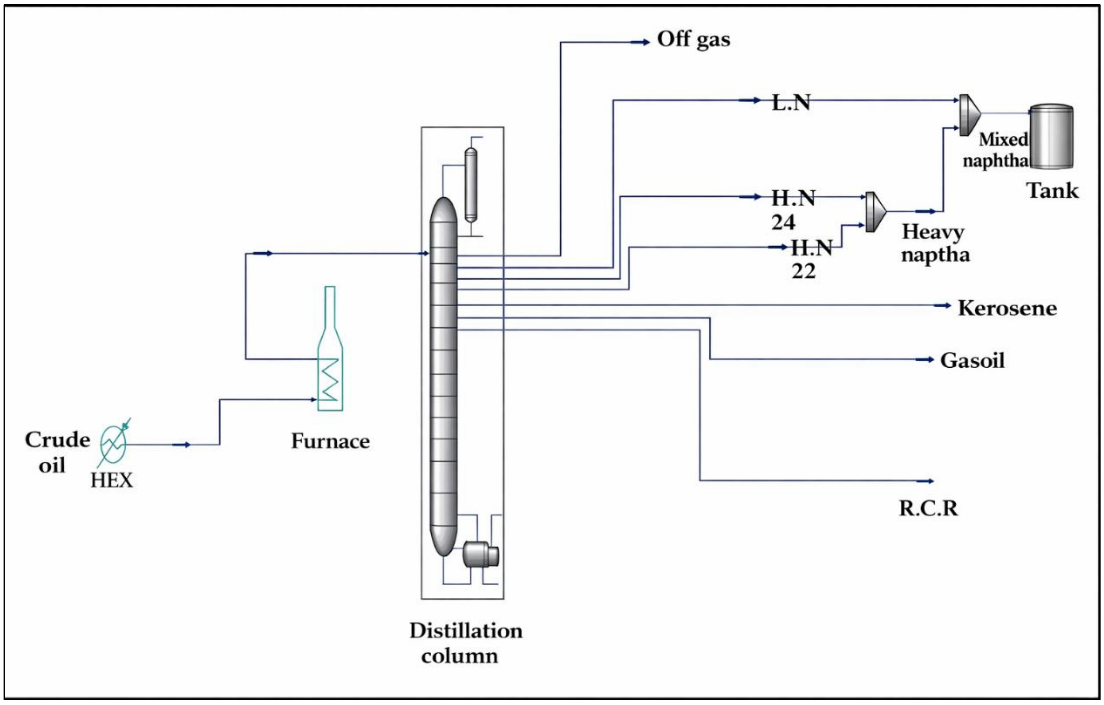


**Figure 2.** Simulation of blending process for mixed naphtha

**Table 1.** ANOVA of blending process

| Source | DF | F Value of Octane | F Value of Sulfur |
|---|---|---|---|
| Model | 9 | 429 | 31.69 |
| Linear | 3 | 1268 | 29.34 |
| Flow rate | 1 | 3422 | 241.26 |
| Top temp. | 1 | 360 | 32.65 |
| Pressure | 1 | 22.5 | 3.11 |

Based on these significant findings, the current experimental investigation was designed to practically validate the benefits of isolating flow rate of heavy naphtha from light naphtha and negligible other operation conditions such as temperature and pressure before blending with imported gasoline. The separated light naphtha stream was blended directly with imported high-octane gasoline to assess the impact on octane number improvement and sulfur content reduction, ultimately reducing the refinery's dependency on imported gasoline.

### 2.2 Feedstock and Sampling

Light naphtha (L.N) and heavy naphtha (H.N) were obtained from the overhead and side draw streams of the atmospheric distillation units at Al-Diwaniyah Refinery. Imported high octane gasoline (H.G, research octane number = 95 RON, near-zero sulfur content) was sourced from outside refinery.

### 2.3 Methods

Four volumetric blending scenarios were investigated to determine the effect of replacing conventional blended naphtha (light naphtha + high naphtha) with pure light naphtha, as shown in Table 2. Refinery's current practice volume ratio (72% imported gasoline + 28% mixed naphtha) are:

- Blend A: 72% imported gasoline + 28% pure light naphtha
- Blend B: 67% imported gasoline + 33% pure light naphtha
- Blend C: 62% imported gasoline + 38% pure light naphtha

**Table 2.** Ratios of experimental blending

| Blend ID | H.G (Vol%) | L.N (Vol%) | H.N (Vol%) |
|---|---|---|---|
| Current practice | 72 | 20.2 | 7.8 |
| A | 72 | 28 | 0 |
| B | 67 | 33 | 0 |
| C | 62 | 38 | 0 |

### 2.4 Analytical Methods

To evaluate the effect of the optimized blending ratios, lab tests were conducted at the AL-Dura refinery to identify the gasoline properties. Research octane number (RON) was also tested as per the ASTM D2699 using a cooperative fuel research (CFR) engine. The amount of sulfur was measured according to ASTM D5453. All the samples were homogenized and stabilized and analyzed under highly controlled laboratory conditions to guarantee reproducibility and accuracy.

## 3. Results and Discussions

Table 3 provides the octane numbers and the sulfur contents found through experimental tests that were carried out on a series of gasoline blending ratios, thus enabling the comparison of the current practice of the refinery and the optimal blending conditions as suggested in this paper.

**Table 3.** Octane number and Sulfur content of blending and feedstock samples

| Blend ID | Octane number | Sulfur content |
|---|---|---|
| Current practice | 82.5 | 157 |
| A | 84.5 | 70 |
| B | 83.5 | 77 |
| C | 80.5 | 87 |
| L.N | 55 | 250 |
| H.N | 40 | 1500 |
| H.G | 95 | 0 |

### 3.1 Octane Number Analysis

Table 3 shows that the current blending practice at the refinery (72% imported high-octane gasoline blended with 28% light and heavy naphtha combined) produces a regular gasoline with an octane number of about 82.5. By using light naphtha instead of the mixed naphtha stream (heavy and light), a significant increase in the octane number was achieved (from 82.5 to 84.5) even while maintaining the same blending ratios (72% imported high octane gasoline + 28% light naphtha). This clearly demonstrates the detrimental effect of heavy naphtha on the octane number as have low octane number is low (40) and confirming the validity of previous simulation and statistical results, while light naphtha with octane number 55.

The study explored the economic and practical viability of the reduction in imported high-octane gasoline quantity. A high octane rating of 83.5 was achieved by decreasing the percentage of imported gasoline to 67 percent and increasing the percentage of light naphtha to 33 percent, and the result is still higher than the refinery standard. A further reduction of the ratio of imported gasoline to 62 percent, resulting in a 38 percent light naphtha blend, gave an octane reading of 80.5, still meeting Iraq's gasoline requirements. These results highlight the high possibility of cost reduction that will be realized through less reliance on imported high-octane gasoline. Figure 3 shows the octane ratings of the samples.

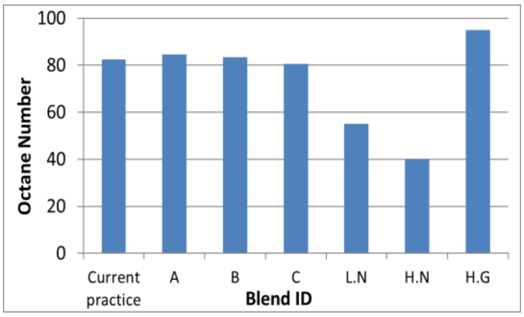


**Figure 3.** Octane number of feedstock and blending samples

### 3.2 Sulfur Content Analysis

One of the crucial findings of the optimization work was the decreased sulfur content of conventional gasoline. Under the current operating regime that utilizes mixed naphtha, the level of sulfur reached 157 parts per million, and this number is above the Iraqi fuel specification of 100 parts per million. The replacement of blended naphtha with pure light naphtha produced a significant reduction in sulfur emission with an elemental sulfur reading of 70 parts per million blended at a 72 percent ratio in imported high-octane gasoline. The achievement is a major step forward that would ensure that it adheres to the set standards of the environment.

Despite a reduction in the imported high-octane gasoline volumes of 67 percent and 62 percent, sulfur levels remained at rates lower than the stipulated levels of 77 parts per million and 87 parts per million, respectively. These discoveries highlight a definitive environmental benefit and, in tandem, an economic boost in optimizing operations realized by reduced imports of fuel. Figure 4 shows the content of sulfur in the sampled materials.

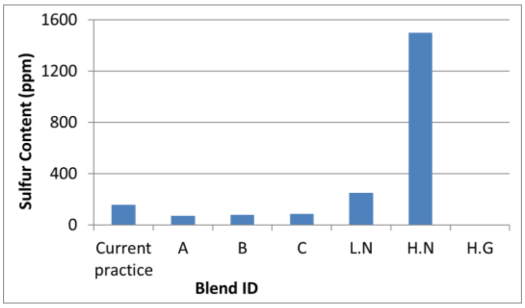


**Figure 4.** Sulfur content of feedstock and blending samples

### 3.3 Economic and Environmental Implications

One of the crucial findings of the optimization work was the decreased sulfur content of conventional gasoline. Under the current operating regime that utilizes mixed naphtha, the level of sulfur reached 157 parts per million, and this number is above the Iraqi fuel specification of 100 parts per million. The replacement of blended naphtha with pure light naphtha produced a significant reduction in sulfur emission with an elemental sulfur reading of 70 parts per million blended at a 72 percent ratio in imported high-octane gasoline. The achievement is a major step forward that would ensure that it adheres to the set standards of the environment.

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## 4. Technical and Economic Feasibility

### 4.1 Technical Feasibility

The proposed upgrade is limited to re-routing the heavy naphtha line away from the mixed naphtha tank and tying it directly into an existing export, while retaining the light naphtha line on the established blending route. No new storage tanks, pumps, reactors, or sophisticated control loops are required; all modifications are restricted to short pipe runs, block valves, and routine instrumentation tie-ins. As a result, the project constitutes a low-CAPEX, brown-field revamp that can be completed during a single turnaround window with negligible disruption to normal refinery operations. Figure 5 shows the proposed project for blending process.

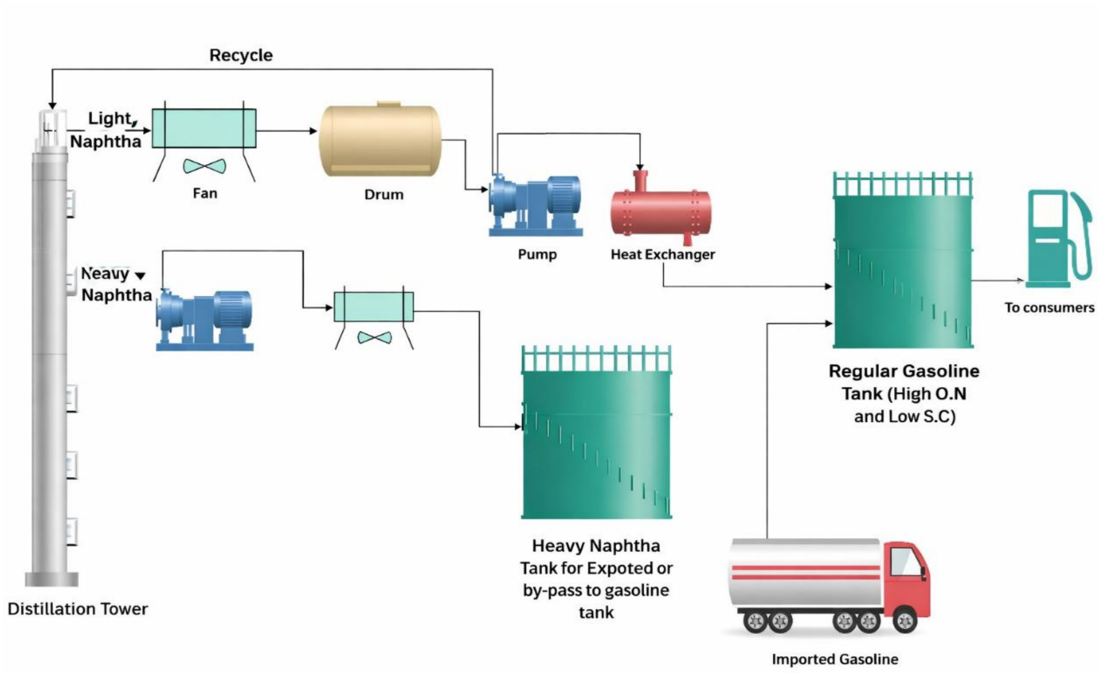


**Figure 5.** proposed project for production high specification of regular gasoline.

### 4.2 Economic Feasibility

By replacing mixed naphtha with pure light naphtha, the refinery can lower the imported-gasoline share from 72 vol. % to about 62 vol. % without sacrificing product quality, cutting annual fuel-procurement costs. The displaced heavy naphtha, now segregated, may be sold externally as cutter stock or petrochemical feed, creating an additional revenue stream. Because the retrofit is limited to minor piping and instrumentation tie-ins, capital outlay is minimal and can be recovered rapidly through the combined effect of lower imports and new heavy naphtha sales. Furthermore, achieving sulfur levels below 100 ppm eliminates prospective non-compliance penalties and defers costly desulfurization upgrades, reinforcing the project's strong economic merit.

## 5. Conclusions

This paper illustrates that the removal of heavy naphtha in the gasoline pool and the use of imported high-octane gasoline mixed with the light naphtha only significantly increases the quality of regular gasoline at Al-Diwaniyah Refinery. With the current operational regime (72 vol percent imported gasoline + 28 vol percent mixed naphtha), the product obtained had an octane number of 82.5 and a sulfur content of 157 ppm, surpassing the Iraqi sulfur regulation level (100 ppm). Replacement of mixed naphtha by pure light naphtha at the same import-gasoline ratio (72/28) increased the octane number to 84.5 and sulfur content to 70 ppm, therefore meeting the regulatory requirements and producing an approximate 55% sulfur reduction. Furthermore, the percentage of imported high-octane gasoline would be reduced to 72 vol., 67 vol., and 62 vol., respectively, and the sulfur content would be held down to 100 ppm (83.5 ppm and 80.5 ppm), which corresponds to octane numbers of 83.5 and 80.5, respectively. These results verify that heavy naphtha has the strongest negative effect on the normal gasoline quality, and selective blending is a possible approach to be used in order to enhance the fuel properties and reduce the reliance on imports. Technically, the proposed solution only requires small piping reconfigurations, and standard tie-ins are not required; thus, it is a low-CAPEX, easily practicable solution that can be installed in similar small refineries with small downstream processing capacity.

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## Conflict of interest

The author(s) must explicitly state that there are no conflicts of interest related to the publication of this article. A conflict-of-interest statement should be included in the manuscript, worded as follows: "The authors declare no conflicts of interest concerning this research."

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## Author Contribution

**A. Qasim, M. Mohan, and N. Qasim** proposed the research problem.

**N. Qasim, W. Raad, and A. Ibrahim** developed the theoretical framework.

**A.K. Salah, A. Qasim, M. Mohan, and N. Qasim** verified the analytical methods.

All authors participated in the discussion of the results and contributed to writing the manuscript.

## AI Declaration Statement

The authors confirm that the manuscript has been written without the assistance of generative AI or AI-based writing tools.

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