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RESEARCH ARTICLE

# Study of Some Physical and Chemical Properties of Water from the Al-Dur Water Treatment Plant, Salah Al-Din, Iraq

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**ABSTRACT**

Water is one of the most essential and precious elements on Earth due to its importance in sustaining the life of various living organisms. This study involves collecting five samples from different stages within the Al-Dur Water Treatment Plant (raw, sedimentation, alum, treated, and storage tank) and additional samples from household supplies serviced by the plant, from September 2023 to the end of February 2024. All samples were transported to the laboratory for immediate physical and chemical testing. The study measured the following parameters: air temperature, water temperature, turbidity, electrical conductivity, pH, total hardness, and total alkalinity. The results showed the lowest air temperature was 12.4°C, and the highest was 34.4°C. The lowest water temperature was 11.4°C, and the highest was 28.6°C. The highest turbidity value was 32.2 NTU, while the lowest was 1.58 NTU in 2024. The highest electrical conductivity value was 585 µS/cm, and the lowest was 412 µS/cm in 2024. The highest salinity value was 0.374 g/L, while the lowest was 0.261 g/L. The highest pH value was 9.6, and the lowest was 7.3, with pH values generally falling within the alkaline range, conforming to drinking water standards. The highest alkalinity value was 180 mg/L, and the lowest was 40 mg/L in the raw water stage in January 2024. The highest TDS value was 355 mg/L, and the lowest was 210 mg/L, with most TDS values conforming to the drinking water standard of less than 500 mg/L. The highest total hardness value was 338.3 mg/L, and the lowest was 138 mg/L, with the study results conforming to the recommended drinking water hardness values (250-500 mg/L). This study aims to investigate the physical and chemical properties of water from the Al-Dur Water Treatment Plant.

## INTRODUCTION

Water is one of the most essential and precious elements on Earth, crucial for the sustenance of various living organisms (Hassan et al., 2015). Water is vital for cell structure, composing 95% of the protein plasma mass of each cell, and is integral to the tissues of humans, animals, and plants. All digestive and metabolic processes Kadham *et al*. (2024) occur in an aqueous medium (Bresha & Sharif, 2018). Water sources can be classified into several main categories: rivers, seas, oceans, groundwater, and rainwater Ali et al. (2022). Among these, river water is the most significant as it is the primary source for meeting human needs (Chougule et al., 2009). Many countries worldwide have begun focusing on water conservation and addressing pollution and future water scarcity issues (Varol et al., 2011).

With advancements in various life aspects, developed countries have established different stations for water purification and filtration, ensuring water retains its physical and chemical properties while being free of contaminants, resulting in high-quality water (Al-Sultan, 2019). However, most urban areas have faced infrastructural damage, poor maintenance, inadequate services, and weak law enforcement, leading to the accumulation of various waste types, including commercial and industrial waste, in water bodies, causing pollution (Al-Safawi & Assaf, 2018). Contaminated water is a significant cause of disease and high mortality rates, with approximately 25 million people dying annually due to waterborne diseases, according to the World Health Organization (WHO) (Al-Safawi et al., 2018). This study aims to investigate the physical and chemical properties of water from the Al-Dur Water Treatment Plant Shakir et al. (2019).

## METHODOLOGY:

### Sample Collection:

Samples were collected starting in the morning, covering stages from raw water to household distribution, once monthly on the 15th of each month from September 2023 to the end of February 2024. Samples were collected after allowing the water to run for ten minutes to flush out stagnant, contaminated water. The bottles were filled with minimal air space to preserve the physical and chemical properties during transport, using 2.25-liter polyethylene bottles washed with sample water three times before collection. For measuring biochemical oxygen demand and chemical oxygen demand, 250 ml Winkler bottles were used. Microbiological tests employed narrow-mouthed, sterile glass bottles with a capacity of 200-250 ml.

All samples were transported to the laboratory for immediate physical, chemical, and microbiological testing. All glassware used was initially washed with distilled water and dried in an electric oven. Analyses were conducted in laboratories at Tikrit University and the Salah al-Din Water Directorate's Quality Control and Chemical Engineering departments.

### Physical Analyses:

Air and water temperatures were measured in the field. Air temperature was recorded using a mercury thermometer (0-100°C) placed in the shade at a one-meter height above ground level. Water temperature was measured by immersing a thermometer directly at the sampling site until the reading stabilized, repeating the process for accuracy.

Electrical conductivity (EC) was measured using a HANNA device, with samples immersed in glass containers for one minute until readings stabilized, recorded in µS/cm (APHA, 2003). Turbidity was measured upon sample arrival at the laboratory using a HACH TL2300 HANNA Turbidity Meter, expressed in NTU. COD was determined by adding dichromate to samples in acidic conditions, measured with a spectrophotometer, and quantified in mg/L or ppm based on dichromate consumption (APHA, 2017). BOD5 was measured by incubating opaque bottles at 25°C for five days in a water bath, calculating the difference in dissolved oxygen (DO) to determine BOD5 (APHA, 2005).

Total dissolved solids (TDS) were measured by immersing the HANNA device in water samples, recording readings in mg/L after two minutes (APHA, 2003).

### Chemical Analyses:

A Germany Lovibond pH meter was used to measure pH, calibrated with buffer solutions (4, 7, and 9) before each use. Total alkalinity was determined following APHA (2005) methods and expressed in mg/L. A 50 ml water sample was taken, and 2 drops of methyl orange were added, turning the solution yellow. The solution was titrated with standardized 0.02 N sulfuric acid until it turned pink. The total alkalinity as CaCO3 was calculated using the formula:

Total Alkalinity (mg/L)=(VH2SO4×1000×MW of CaCO3)Vsample\text{Total Alkalinity (mg/L)} = \frac{(V_{\text{H2SO4}} \times 1000 \times \text{MW of CaCO3})}{V_{\text{sample}}}Total Alkalinity (mg/L)=Vsample(VH2SO4×1000×MW of CaCO3)

The total hardness was determined using the Na2EDTA titration method (ASTM, 1984). A 25 ml water sample was taken, 1 ml of buffer solution and a small amount of Eriochrome Black T indicator were added, and titrated with 0.02 N Na2EDTA solution until the color changed to blue. The total hardness as CaCO3 was calculated in mg/L.

The study concluded that the physical and chemical properties of water from the Al-Dur Water Treatment Plant generally meet the recommended standards for drinking water, ensuring its safety and suitability for human consumption Abdulqader et al. (2022).

## RESULTS:

The study results indicated that the lowest recorded air temperature was 12.4°C at the raw water station in December, while the highest recorded value was 34.4°C at the same station in September, as shown in Table 1. The lowest recorded water temperature was 11.4°C at the alum station in February 2024, and the highest was 28.6°C at the second distribution station in September 2023, as illustrated in Table 2.

**Table 1: Monthly and Site-Specific Air Temperature Variations for the Studied Station (°C)**

| Sample/Month | Sept 2023 | Oct 2023 | Nov 2023 | Dec 2024 | Jan 2024 | Feb 2024 | Average |
|---|---|---|---|---|---|---|---|
| Raw | 34.4 | 32.0 | 25.4 | 12.4 | 14.4 | 17.6 | 22.7 A |
| Sedimentation | 34.2 | 31.2 | 24.2 | 19.1 | 13.6 | 16.7 | 23.2 A |
| Alum | 31.1 | 30.9 | 24.1 | 18.1 | 13.4 | 15.3 | 22.2 A |
| Treated | 31.1 | 31.0 | 23.1 | 18.2 | 13.7 | 13.3 | 21.7 A |
| Storage Tank | 30.1 | 30.2 | 23.2 | 18.1 | 13.3 | 14.4 | 21.6 A |
| Distribution 1 | 30.1 | 30.1 | 22.2 | 18.4 | 14.3 | 15.3 | 21.7 A |
| Distribution 2 | 30.4 | 30.2 | 22.6 | 17.9 | 14.2 | 17.3 | 22.1 A |
| Distribution 3 | 30.2 | 30.1 | 24.1 | 18.3 | 13.3 | 16.3 | 22.1 A |
| Distribution 4 | 30.1 | 30.3 | 23.4 | 17.7 | 13.2 | 17.4 | 22.0 A |
| Distribution 5 | 30.1 | 30.4 | 23.1 | 17.5 | 13.5 | 17.7 | 22.1 A |
| Monthly Average | 31.2 a | 30.6 a | 23.5 b | 17.6 c | 13.7 d | 16.1 c | |

**Table 2: Monthly and Site-Specific Water Temperature Variations for the Studied Station (°C)**

| Sample/Month | Sept 2023 | Oct 2023 | Nov 2023 | Dec 2024 | Jan 2024 | Feb 2024 | Average |
|---|---|---|---|---|---|---|---|
| Raw | 28.4 | 24.5 | 23.3 | 18.6 | 15.2 | 12.5 | 20.4 A |
| Sedimentation | 26.7 | 24.3 | 23.1 | 19.0 | 15.0 | 12.1 | 20.0 A |
| Alum | 27.2 | 24.1 | 22.1 | 18.9 | 15.3 | 11.4 | 19.8 A |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Treated | 26.3 | 23.6 | 22.3 | 17.5 | 15.3 | 12.7 | 19.6 A |
| Storage Tank | 26.1 | 22.3 | 22.8 | 17.9 | 15.1 | 12.5 | 19.5 A |
| Distribution 1 | 28.2 | 22.4 | 21.9 | 18.7 | 14.3 | 12.5 | 19.7 A |
| Distribution 2 | 28.6 | 22.1 | 22.2 | 17.4 | 14.5 | 13.6 | 19.7 A |
| Distribution 3 | 28.3 | 21.8 | 23.5 | 17.2 | 14.1 | 14.4 | 19.8 A |
| Distribution 4 | 28.2 | 21.8 | 23.6 | 18.5 | 13.0 | 14.6 | 19.9 A |
| Distribution 5 | 28.1 | 21.1 | 24.1 | 19.0 | 13.5 | 14.7 | 20.1 A |
| Monthly Average | 27.6 a | 22.8 b | 22.9 b | 18.3 c | 14.5 d | 13.1 d | |

The highest recorded value for electrical conductivity in water was 585 µS/cm at the alum station in February 2024, and the lowest was 412 µS/cm at the third distribution station in January 2024, as shown in Table 3.

**Table 3: Monthly and Site-Specific Electrical Conductivity Variations during the Study Period (µS/cm)**

| Sample/Month | Sept 2023 | Oct 2023 | Nov 2023 | Dec 2024 | Jan 2024 | Feb 2024 | Average |
|---|---|---|---|---|---|---|---|
| Raw | 480 | 447 | 417 | 471 | 485 | 517 | 469.5 A |
| Sedimentation | 426 | 439 | 419 | 469 | 457 | 477 | 447.8 CD |
| Alum | 430 | 463 | 451 | 454 | 428 | 585 | 468.5 A |
| Treated | 442 | 435 | 420 | 437 | 431 | 555 | 453.3 B |
| Storage Tank | 422 | 434 | 415 | 496 | 446 | 465 | 446.3 CD |
| Distribution 1 | 477 | 427 | 413 | 489 | 443 | 469 | 453.0 B |
| Distribution 2 | 438 | 440 | 402 | 483 | 466 | 470 | 449.8 BC |
| Distribution 3 | 434 | 433 | 413 | 468 | 412 | 477 | 439.5 E |
| Distribution 4 | 431 | 431 | 409 | 493 | 401 | 459 | 437.3 E |
| Distribution 5 | 418 | 440 | 429 | 476 | 440 | 457 | 443.3 D |
| Monthly Average | 439.8 c | 438.9 c | 418.8 d | 473.6 b | 440.9 c | 493.1 a | |

The study results, as shown in Table 4, recorded the highest turbidity value in water at 32.2 NTU at the second distribution station in January 2024, while the lowest was 1.58 NTU at the first distribution station in February of the same year.

**Table 4: Monthly and Site-Specific Turbidity Variations (NTU) in the Studied Station**

| Sample/Month | Sept 2023 | Oct 2023 | Nov 2023 | Dec 2024 | Jan 2024 | Feb 2024 | Average |
|---|---|---|---|---|---|---|---|
| Raw | 11.4 | 4.25 | 9.9 | 19.3 | 17.4 | 3.41 | 10.94 C |
| Sedimentation | 8.12 | 5.85 | 4.65 | 13.2 | 10.1 | 5.44 | 7.89 D |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Alum | 5.26 | 10.5 | 9.51 | 5.73 | 3.58 | 4.22 | 6.46 D |
| Treated | 7.43 | 6.14 | 4.2 | 19.7 | 7.82 | 5.5 | 8.46 D |
| Storage Tank | 6.37 | 5.79 | 4.15 | 14.8 | 31.9 | 31.2 | 15.70 A |
| Distribution 1 | 9.79 | 7.46 | 4.13 | 25.7 | 15.4 | 1.58 | 10.68 C |
| Distribution 2 | 18.5 | 4.66 | 4.02 | 22.1 | 32.2 | 3.04 | 14.09 AB |
| Distribution 3 | 23.9 | 3.46 | 4.13 | 25.7 | 11.9 | 2.1 | 11.87 C |
| Distribution 4 | 12.4 | 9.98 | 4.09 | 15.4 | 31.5 | 20.8 | 15.70 A |
| Distribution 5 | 13.8 | 14.5 | 4.29 | 15.9 | 13.0 | 20.4 | 13.65 B |
| Monthly Average | 11.70 b | 7.259 c | 5.307 c | 17.75 a | 17.48 a | 9.769 b | |

The study results in Table 5 showed that the highest pH value in water was 9.6 at the fourth and fifth distribution stations in December and January of 2024, respectively, while the lowest pH value was 7.3 at the third distribution station in December 2024.

**Table 5: Monthly and Site-Specific pH Variations during the Study Period**

| Sample/Month | Sept 2023 | Oct 2023 | Nov 2023 | Dec 2024 | Jan 2024 | Feb 2024 | Average |
|---|---|---|---|---|---|---|---|
| Raw | 8.2 | 7.5 | 7.6 | 8.2 | 9.5 | 8.7 | 8.28 B |
| Sedimentation | 8.9 | 8.8 | 8.2 | 8.3 | 9.2 | 8.5 | 8.65 A |
| Alum | 8.5 | 8.7 | 4.5 | 4.5 | 4.9 | 8.2 | 6.55 C |
| Treated | 8.4 | 8.7 | 8.2 | 8.3 | 9.3 | 7.6 | 8.42 AB |
| Storage Tank | 8.6 | 9.1 | 8.8 | 9.6 | 8.9 | 7.4 | 8.23 B |
| Distribution 1 | 7.6 | 8.8 | 8.01 | 9.1 | 9.17 | 8.8 | 8.58 A |
| Distribution 2 | 8.8 | 8.9 | 8.0 | 8.9 | 9.5 | 8.4 | 8.75 A |
| Distribution 3 | 8.1 | 9.1 | 7.4 | 7.3 | 8.7 | 8.1 | 8.12 B |
| Distribution 4 | 8.8 | 9.2 | 8.3 | 8.5 | 9.6 | 8.3 | 8.78 A |
| Distribution 5 | 8.2 | 8.9 | 8.7 | 8.8 | 9.6 | 8.9 | 8.85 A |
| Monthly Average | 8.41 ab | 8.77 a | 7.67 c | 8.05 bc | 8.737 a | 7.99 bc | |

The study results in Table 6 show that the highest alkalinity value in water was 180 mg/L at the first and second distribution stations from September to November 2023, while the lowest alkalinity value was 40 mg/L at the raw water station in January 2024.

**Table 6: Monthly and Site-Specific Total Alkalinity Variations (mg/L) During the Study Period**

| Sample/Month | Sept 2023 | Oct 2023 | Nov 2023 | Dec 2024 | Jan 2024 | Feb 2024 | Average |
|---|---|---|---|---|---|---|---|
| Raw | 120 | 140 | 130 | 60 | 40 | 100 | 98.3 D |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Sedimentation | 160 | 120 | 140 | 80 | 45 | 60 | 100.8 D |
| Alum | - | - | - | - | - | - | - |
| Treated | 140 | 120 | 160 | 60 | 60 | 80 | 103.3 CD |
| Storage Tank | 100 | 140 | 100 | 80 | 60 | 60 | 90.0 E |
| Distribution 1 | 140 | 160 | 180 | 80 | 50 | 166 | 129.3 A |
| Distribution 2 | 180 | 180 | 140 | 60 | 40 | 80 | 113.3 B |
| Distribution 3 | 160 | 160 | 120 | 80 | 60 | 60 | 106.7 C |
| Distribution 4 | 120 | 160 | 140 | 90 | 50 | 60 | 103.3 CD |
| Distribution 5 | 100 | 120 | 120 | 60 | 50 | 60 | 85.0 E |
| Monthly Average | 135.6 b | 144.4 a | 136.7 b | 72.2 d | 50.6 e | 80.7 c | |

The study results in Table 7 show that the highest recorded total hardness value in water was 338.3 mg/L at the sedimentation station in September, while the lowest recorded value was 138 mg/L in December and January.

**Table 7: Monthly and Site-Specific Total Hardness Variations (mg/L) During the Study Period**

| **Sample/Month** | **Sept 2023** | **Oct 2023** | **Nov 2023** | **Dec 2024** | **Jan 2024** | **Feb 2024** | **Average** |
|---|---|---|---|---|---|---|---|
| Raw | 236.8 | 299 | 276 | 161 | 138 | 207 | 219.6 DE |
| Sedimentation | 338.4 | 184 | 322 | 207 | 161 | 276 | 248.1 A |
| Alum | - | - | - | - | - | - | - |
| Treated | 188 | 276 | 276 | 184 | 184 | 253 | 226.8 C |
| Storage Tank | 263.2 | 230 | 230 | 161 | 184 | 230 | 216.4 E |
| Distribution 1 | 299 | 148 | 230 | 161 | 161 | 207 | 201.0 F |
| Distribution 2 | 207 | 276 | 276 | 207 | 207 | 238 | 235.2 B |
| Distribution 3 | 276 | 184 | 322 | 138 | 207 | 207 | 222.3 CD |
| Distribution 4 | 322 | 322 | 230 | 161 | 161 | 253 | 241.5 B |
| Distribution 5 | 253 | 322 | 322 | 184 | 138 | 276 | 249.2 A |
| Monthly Average | 264.8 a | 249.0 b | 276.0 a | 173.8 c | 171.2 c | 238.6 b | |

## DISCUSSION

The study results indicated that the lowest recorded air temperature was 12.4°C at the raw water station in December Kadham *et al.* (2023), while the highest recorded value was 34.4°C at the same station in September, as shown in Table 1. The lowest recorded water temperature was 11.4°C at the alum station in February 2024, and the highest was 28.6°C at the second distribution station in September 2023 Meri *et al.* (2023), as illustrated in Table 2. This variation in temperatures between study stations is attributed to seasonal changes and differences between day and night temperatures (Hussein, 1996; Mustafa, Raja, et al. (2023).

This study agrees with the findings of Alawi and Khamis (2022), which recorded the lowest air temperature as 12.6°C during winter and the highest as 24.7°C, while the lowest water temperature was 11.3°C and the highest was 22.6°C. Similar results were obtained by researchers such as Al-Dulaimi (2021) and Al-Douri (2019), who recorded temperature ranges of 11.5-27.3°C and 10.7-29°C, respectively, while Hakman (2018) recorded a range of 11.0-28.0°C in water Valluru *et al.* (2023).

The variation in temperature values during the study months is due to Iraq's hot continental climate in summer and cold in winter, with monthly temperature fluctuations (Al-Mundhiri, 2005; Mustafa, Kadham, *et al*. (2024).

Electrical conductivity is directly proportional to the amount of dissolved substances and their ionic strength, serving as a measure of the quantity and quality of dissolved ions in water (Bhat et al., 2018). It also depends on water temperature, as ions in water conduct electric charges. Hence Hsu *et al*. (2024), there is a direct relationship between the amount of dissolved salts in water and electrical conductivity (Al-Mundhiri, 2005). In this study, the increase in electrical conductivity values during winter is attributed to soil erosion from riverbanks into the main stream during the rainy season, increasing dissolved salt content in water Yaseen *et al*. (2023). Thirumulini & Joseph (2009) noted that substances added to water to remove turbidity could increase conductivity values (Ayale, 2018).

This study's results align with Alawi and Khamis (2022), which recorded the highest electrical conductivity in water as 567 µS/cm in February and the lowest as 62 µS/cm in March. The study also aligns with findings from Al-Douri (2019), Ismail (2018), and Al-Nasseri (2019), who recorded the highest conductivity values as 460, 565, and 579 µS/cm, respectively, during winter Lu *et al*. (2024).

The high turbidity levels in river water during winter are due to rainfall increasing turbidity through surface runoff of soils into the river (Wolde et al., 2020). Turbidity is directly proportional to the amount of rainfall and resulting runoff, and it also depends on river discharge and current speed (Al-Mashhdani et al., 2018).

The reduction in turbidity in water treatment stages depends on sedimentation tanks, filtration quality, and chlorination efficiency Saadh, Avecilla, *et al*. (2024). It also depends on the amount of alum added, operational efficiency, maintenance quality, and the project's age (Al-Araji, 2003; Nada et al., 2002; Abdul-Aziz, 2015). Our study's results align with Alawi and Khamis (2022), which recorded the highest water turbidity value as 37.1 NTU in February and the lowest as 3.1 NTU in April. These results also align with Yasin (2018), who studied monthly changes in the Tigris River water in Salah Al-Din province Mahmoud *et al*. (2024). The pH values were generally alkaline, a characteristic of Iraqi waters (Al-Saad et al., 2008). Natural water pH values range from 5 to 8.5, and many Iraqi water bodies have pH values slightly above 7 due to the presence of carbonate and bicarbonate ions (Mouloud et al., 1990). Our study's pH values align with Alawi and Khamis (2022), which recorded the highest pH value as 7.9 in March and the lowest as 7.1 in February and January. These results also align with the studies of Al-Naemi (2017) and Al-Sarraj et al. (2014) on the Tigris River within Mosul city, recording pH ranges of 7.7-8.4 and 6.8-8.0, respectively. The Tigris River's water is suitable as raw water for treatment plants as it falls within the permissible range of 6.5-8.5 for drinking water Saadh, Mustafa, *et al.* (2024).

The study results in Table 6 show that the highest alkalinity value in water was 180 mg/L at the first and second distribution stations from September to November 2023, while the lowest alkalinity value was 40 mg/L at the raw water station in January 2024. This result is lower than those obtained by Fratam (2018), Al-Sultan (2019), Mahmoud (2021), and Alawi and Khamis (2022), which recorded ranges of 230-146, 221-120, 240-145, and 140-300 mg/L, respectively.

The current study's values increased in autumn, reaching their highest in winter with rainfall and lower temperatures, which enhance the dissolution of carbon dioxide in water. Maintaining moderate alkalinity levels is essential to avoid adverse effects on soil, as high alkalinity values can increase soil acidity and limit nutrient availability (Almuktar et al., 2020).

The study results in Table 7 show that the highest recorded total hardness value in water was 338.3 mg/L at the sedimentation station in September, while the lowest recorded value was 138 mg/L in December and January. These results align with the findings of Al-Sultan (2019), Al-Hamdani (2015), and Al-Sarraj (2013), who recorded total hardness values in the Tigris River within Mosul city ranging from 235-310, 222-382, and 192-294 mg/L, respectively. However, they were lower than those obtained by Alawi and Khamis (2022), which recorded values ranging from 692-292 mg/L. The current study's results did not align with those of Al-Mujamai (2022), who recorded values ranging from 290-90 mg/L.

This discrepancy may be due to the distance the river travels from Mosul to Salah Al-Din, dissolving materials along its course. Al-Sahen (2019) found that total hardness values ranged from 153-177 mg/L in the Tigris River within Salah Al-Din province. The current study's results were lower than those obtained by Al-Saadoun (2021) in his study of the Diyala River, which recorded values ranging from 273.3-1323.3 mg/L. Seasonal variations in total hardness indicate a significant increase during rainy months, raising water levels and dissolved salts from fertilizers added to adjacent agricultural lands, which are washed into the river by runoff. The current study's results align with many studies indicating high total hardness values in Iraqi waters (Al-Samarrai, 2009).

## CONCLUSION:

The turbidity levels in drinking water stations did not meet the Iraqi standard No. 417 for drinking water (2001). However, the temperature, electrical conductivity, salinity, pH, and total hardness values were within the permissible limits according to local and international standards.

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