**Discover** Water

Case Study

# Study the optical properties of drinking water supply by KUKL and KVWSIP in Kathmandu Valley

**Bhishma Karki[1] · Saddam Husain Dhobi[2,4,5] · Indra Dhobi[3] · Digvijay Pandey[6] · Binay Kumar Pandey[7]**

Received: 20 August 2021 / Accepted: 27 September 2021
Published online: 11 October 2021


**Abstract**
The optical properties of two water supply samples Kathmandu Upatyaka Khanepani Limited (KUKL) and Kathmandu Valley Water Supply Improvement Project (KVWSIP) in the Kupondole Area, Lalitpur, Nepal show that the transmittance of light is higher for KVWSIP sample water than for KUKL. A large amount of work has been done to test the purities of KUKL and KVWSIP water supplies (chemically), but even their optical properties have not been studied. This method has no hazardous side effects or requires chemical method testing. In comparing the optical properties, the authors recommended that the public take KVWSIP water for good health and wealth rather than KUKL if they have an option. This is because KUKL is more contaminated and has more total dissolved solids (TDS) particles, while KVWSIP has fewer TDS particles. Therefore, if people take KVWSIP water in their daily life, they obtain relief from different types of water-related diseases.

**Keywords** Transmittance · Absorbance · Disease · Chemical method testing · Total dissolved solids

## 1 Introduction

Water is a special type of liquid used for different purposes and makes life possible on our planet. Pollution of water takes place when harmful substances (chemicals/microorganisms) are mixed with different sources of water like rivers, lakes, oceans, aquifers, or other bodies of water. The pollution of water harms aquatic life and ecosystems, as well as other living creatures who intake it [1]. Therefore, study is important. Water is utilized for a variety of functions, including drinking, food preparation, personal hygiene, etc. [2], and it must meet biochemical, microbiological, and physical quality criteria. Contamination of water and polluted water causes the transmission of communicable diseases, and according to WHO, about 2.5 billion people were affected by diarrheal disease in 2008. Similarly, a report from 58 countries shows about 589, 854 cholera (water related disease) cases in 2011, an increase of 85% from 2010 [3].

All around the world, about 663 million people are not able to access quality drinking water and about 1.8 billion people around the world take poor quality drinking water. The United Nations Sustainable Development Goals 6 state that by 2030, all people on the planet will have access to safe drinking water.A report also shows that the total water

✉ Bhishma Karki, magnum.photon@gmail.com; ✉ Digvijay Pandey, digit11011989@gmail.com | [1]Department of Physics, Tri-Chandra Multiple Campus, Tribhuvan University, Kathmandu 44600, Nepal. [2]Department of Physics, Patan Multiple Campus, Tribhuvan University, Lalitpur 44700, Nepal. [3]Department of Physics, Birendra Multiple Campus, Tribhuvan University, Chitwan 44200, Nepal. [4]Robotics Academy of Nepal, Lalitpur 44700, Nepal. [5]Innovative Ghar Nepal, Lalitpur 44700, Nepal. [6]Department of Technical Education, IET, Dr. A.P.J. Abdul Kalam Technical University, Lucknow, Uttar Pradesh, India. [7]Department of Information Technology, College of Technology, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, U.K, India.

supply needed in the Kathmandu valley is approximately 415.5 million liters per day (MLD), but the running project KVWSIP should provide up to 540.3 MLD by 2021, and this may fulfill the demand of the increasing valley population [4].

### 1.1 Contaminated and constituent in Kathmandu Valley supply water

Arsenic, chloride, fluoride, zinc, iron, manganese, hazardous substances like organic, inorganic and heavy metals are among the principal constituents of polluted water. Bacteria, fungus, algae, protozoa, plants, animals, and viruses are among the pathogenic species present in surface water. Microbiological agents are extremely essential in terms of public health, and they may also play a role in changing the physical and chemical properties of water.As previously stated, the various contaminated constituents and micro-bacterial present in the Kathmandu valley supply water are mentioned by Grönwall and Danert [5].

### 1.2 The problem of water supply in Kathmandu Valley

Most people hardly receive drinking water for 1 h every fourth day as currently supplied by KUKL. The supply water pipeline by KUKL is not considered under maintenance from the initial date to now; therefore, the contamination is high in KUKL, but KVWSIP is the latest that is initiated to supply the water in 2020 to 2021; therefore, the contamination is less than that of the past water supply system. Therefore, studying the total dissolved solids (TDS) in these supply waters is our major object. In this TDS study, we studied the basis of transmittance and absorbance (optical property) of water. To date, no one has studied the transmittance and absorbance properties of KUKL and KVWSIP water, which is supplied daily to public homes. However, other properties, such as chemical and contaminated properties, etc. are studied by a large number of researchers. This testing method is cheaper and does not pose physical or chemical hazards during testing, but chemical testing has different hazards.

### 1.3 Beneficial of the study

This testing technique is cheaper and poses no serious hazard during testing. The transmittance shows the TDS quantity present in water; a higher transmittance corresponds to a lower TDS, and a lower TDS corresponds to the water containing fewer chemical compounds or elements in the water. From an absorbance point of view, the lower the absorbance, the higher the transmittance, which implies the purity of water. If absorbance is high or transmittance is low, this means a higher TDS, which contains a large amount of contamination.

### 1.4 Research area and development

The water supply situation in KUKL facilitates drinking water to 2.8 million people in the Kathmandu Valley, with daily usage estimated to be at 415MLD. KUKL's water supply is fed by 35 surface water sources and 96 deep tube wells. KVWSIP, also known as Melamchi Subproject-II, was developed by the Nepalese government with financial support from the Asian Development Bank (ADB). Since 2001, the project has been working to meet the present and future demand for water in the Kathmandu Valley.

KVWSIP was approved by the Asian Development Bank on September 16, 2011, and the project began on February 7, 2012, with a budget of $130 million. The goal is to increase the availability of water about 80%. According to 2011 population growth rate, the valley's population will reach 4 million by 2025 [6]. Water scarcity has developed in Nepal's Kathmandu Valley as a result of rapid population increase, unplanned urbanization, and the drying up of traditional water resources. The growing problem of water scarcity has been worsened by the influence of climate change [7].

### 1.5 Statement of the problem

Water consumption has been noted as a serious concern for the fast rising urban population, which has expanded from 1 million (6.5%) in 1981 to 4.52 million (17%) in 2011. The Kathmandu Valley's population is expected to expand by 4.63% every year, as reported by the Kathmandu Valley development authority in 2015. According to KUKL, water demand increased from 320 to 360 MLD while enhanced work increased from 111 to 124 MLD.In its initial stage, the KVWSIP is a new drinking water project for the valley, with a capacity of 170 MLD. The entire capacity of 600 MLD, which includes existing in-valley sources, is expected to supply forecast demand for a population of around 3 million people up to 2030.

## 2 Review

### 2.1 TDS and transmittance of light

TDS concentrations of natural water sources were observed to range from 30 mg/l to 6000 mg/l as reported by WHO/UNEP/GEMS in 1989. In a report, it showsthat levels in the Great Lakes ranged from 65 to 227 mg/l, whereas in 36 of 41 rivers studied in Canada, levels were below 500 mg/l. The components of TDS are chlorides, sulphates, magnesium, calcium, and carbonates. This causes corrosion in water distribution systems. The level of TDS in different pies used to supply drinking water has a high level (> 500 mg/l) as reported by Tihansky in 1974. Early epidemiological research suggests that even modest levels of TDS in drinking water may have favorable impacts, despite the fact that two small studies have found negative consequences. Consumers generally tolerate water with TDS values below 1000 mg/l, though this varies depending on the conditions reported by WHO/SDE/WSH in 1996.Among the different sources of water supply in the Kathmandu valley, groundwater is one of the most important, accounting for around half of the city's total water consumption. Water demand is expected to be around 540.3 MLD by 2021, with a significant imbalance between supply and demand.The basic requirement for water for a human is about 50 L per capita per day, which may be fulfilled by KVWSIP [8].

A report shows 100 samples of water taken from different places in the Kathmandu valley from different sources, like wells, public water sources, surface water, ground water, and so on. The report shows total coliform and Escherichia coli bacteria were the most troublesome pathogens, found in 94% and 72% of all water samples, respectively. The Kathmandu Valley gets almost half of its water from groundwater sources [9]. The pH value of the taken sample ranges from acidic (> 6 pH), neutral, and alkaline (> 7 pH), and such pH rages in drinking water have a negative impact on public health. Among the enteric bacteria isolated from groundwater samples is [10]. According to the WHO, about 80% of all sickness and diseases are caused by poor sanitation, pollution, or a lack of water. About 884 million people around the world consume poor quality drinking water, and about 2 million children die per year from diarrhea. Every year, nearly 10,500 children in Nepal eventually die due to the poor quality of their drinking water.

### 2.2 Optical properties of water

Appropriate interpretation and measurement of the optical properties of drinking water is essential because this method is based on photon source and chemical free testing. According to the literature, absorbance is measured at various temperatures ranging from 2.5 °C to 40.5 °C, and the results show that absorbance is reduced by 300–550 nm but distinct by 700 nm [11]. In the near-infrared region, the photons are absorbed by the dissolved impurities present in the sample, which also determine the transmittance of light through the sample. The absorption of light by dissolved materials can have a 10–50% impact on light scattering measures [12]. A composite index assesses how far numerous water quality parameters depart from normal. Since no universal indicators/technology have been developed to study the water quality composite index, some countries are using aggregated water quality data to construct water quality indices (Table 1).

The aim of the government of Nepal is to provide universal, safely managed, water and sanitation access to all Nepalese people by 2030. In Nepal due to unsafe, poor sanitation and unhygienic behaviors shows that about 15.3% mortality is due to diarrheal disease and 24.8% mortality is due to acute respiratory illness in Nepali children between 1 and 59 months [13, 14]. The Kathmandu valley has a poor water management system for both surface and groundwater sources. Bhandari et al. tested 52 water samples from well and tap. They found chloride, total hardness (TH), copper, nitrate, sulfate, turbidity, and so on. Similarly, we also studied microorganisms like *Escherichia coli* about 21.5%, *Citrobacter* spp. about 20.9%, *Klebsiella* spp. about 19.8%, *Proteus* spp. about 13.9%, *Enterobacter* spp. about 8.72%, *Salmonella* spp. about 5.8%, *Shigella* spp. about 5.2%, and *Pseudomonas* about 4.1% and so on [10].

Koju et al. took about 969 samples from different water sources and analyzed them for physical, chemical, and microbiological reasons. They found that the concentration of nitrate is within the WHO standards but other physical, chemical, and microbiological parameters are exceeded by 0.1–86% [15]. Most South Asian cities, like New Delhi, Karachi, and Kathmandu, have poor drinking water management systems. But due to the demand and development, the improvement was reported in different literature [16].

**Table 1** Transmittance of pure water observed by Jerlov in 1968

| S. No. | Wavelength (nm) | Transmittance (%) |
|---|---|---|
| 1 | 400 | 95.8 |
| 2 | 450 | 98.1 |
| 3 | 500 | 96.5 |
| 4 | 550 | 93.3 |
| 5 | 600 | 83.3 |
| 6 | 650 | 75.0 |
| 7 | 700 | 60.7 |
| 8 | 750 | 9.0 |

## 3 Materials and methods

In this work, our major focus is to develop a technique to study the optical properties of the KUKL water supply and KVWSIP, which is new work related to water research in the Kathmandu Valley water supply system. This technique has a benefit over the chemical testing method because the testing chemical is not easily available and may be harmful during testing. To study the optical properties of theKUKL and KVWSIP drinking water supplies, we used TheneminoSpectrometers v2.7. The phenomena responsible for studying the OP of drinking water considered in our research are discussed below in Fig. 1. The pH value was tested using a digital pH meter and found to be 8 for theKUKL water supply and 8.5 for theKVWSIP water supply; the experiment was performed on a daily basis at $24 \pm 1$°C.

### 3.1 Sample collection

The sample was collected from the Kupondole area from two supply pipelines (KUKL and KVWSIP), which is located in Lalitpur District, Nepal, which is one of the cities in Kathmandu Valley among three.

### 3.2 Beer-Lambert law for transmittance and absorbance

Beer and Lamber studied that when light passes from dissolved materials, a certain amount of light is absorbed and some light is transmitted from the sample. The transmittance and absorbance also depend upon the solution concentration and path traveled through the solution or sample. A spectrophotometer is a device that measures the intensity, or the amount of energy carried by radiation per unit area per unit time, of light entering and leaving a sample solution. Let it represent the intensity of light as it passes through a transparent medium, and let it represent the intensity of light after it has passed through the substance. Then, the transmittance is defined as Transmittance = $\frac{I_t}{I_0}$, and in percentage, it is defined as $T(\%) = \frac{I_t}{I_0} \times 100\%$. Additionally, absorbance (A) is the quantity of light absorbed by a solution and calculated from the transmittance percentage as $A = 2 - \log_{10}(T(\%))$. It is also known as optical density. For example, 10% of the transmittance is equal to 1 Au (absorbance unit), and 1% of the transmittance is equal to 2 Au.

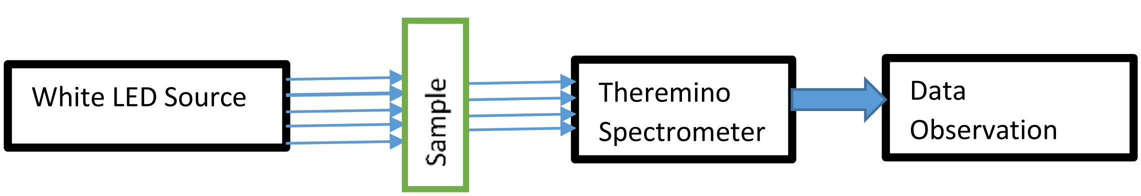



**Fig. 1** Block diagram of the experiment to study the transmittance and absorbance of samples

### 3.3 Phenomena of measuring transmittance

A sketch of the measured transmittance is shown in Fig. 1. below. When the photon of a visible photon passes through the prepared sample, the sample is absorbed and transmitted photons. In our cases, we use a visible photon because we select the sample that transmits the visible photon.For this experiment, 5 ml of KUKL and KVWSIP drinking water is put in a borosilicate tube. Then calibration of the Theremino spectrometer was made and the sample was put in the path between the source and the Theremino spectrometer. The data is observed for KUKL and KVWSIP, listed in the Appendix section.

### 3.4 Phenomena of photon

When visible photons pass through the sample, some photons are absorbed in the sample while others pass through the sample. For our study, the same material sample is used at a different temperature to study the transmittance of a photon through the sample. Moreover, visible photons are used to study the transmittance of the samples.To study the absorbance and transmittance, we used visible-wavelength photons from 420 to 720 nm. The results show that absorbance increases with wavelength, implying that the photon is absorbed by the impurities in the sample, and the opposite phenomenon was observed for transmittance. Therefore, high absorbance indicates the larger interaction of molecules (impurities) with photons, and low absorbance shows less interaction of molecules (impurities) with photons.

## 4 Results and discussion

### 4.1 Optical properties of the KUKL water supply in Kupondole Area, Lalitpur Nepal

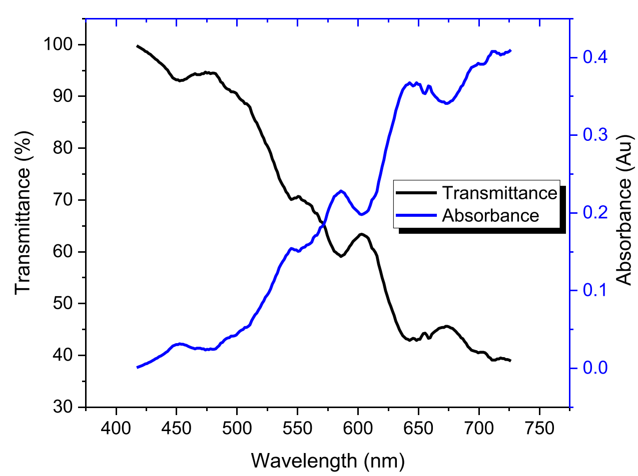
The transmittance for visible photons decreases with an increase in the wavelength of the photon, as shown in Fig. 2 of the KUKL water supply in the Kupondole area, Lalitpur Nepal. On the other hand, one can say that absorption increases with an increased wavelength of photons for the sample. Theredifferent deep points at wavelengths for both absorbance and transmittance. The deep points are due to the interaction of molecules (impurities [11]: constituent, chemical, elements) with photons.

Finally, the transmittance decreases with an increase in the wavelength of photons. This shows that the TDS particles present in water are increasingly smaller than the visible photon wavelength, which is the optical property of the KUKL water supply in the Kupondole area, Lalitpur Nepal.

### 4.2 Optical properties of the KVWSIP water supply in Kupondole Area, Lalitpur Nepal

The transmittance coefficient for visible photons decreases with an increase in the wavelength of a photon of the KVWSIP water supply in the Kupondole Area, Lalitpur, Nepalis shown in Fig. 3. A similar nature of the graph is observed for the

**Fig. 2** Optical properties ofthe KUKL water supply in Kupondole Area, Lalitpur, Nepal



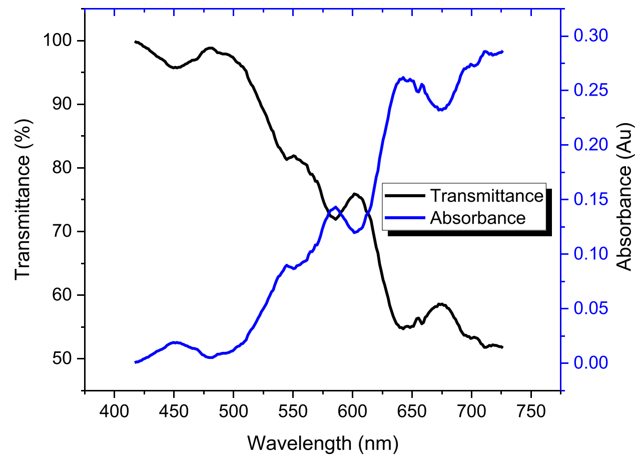



**Fig. 3** Optical properties of the KVWSIP water supply in Kupondole Area, Lalitpur, Nepal

KUKL water supply in the considered area. KVWSIP also has different deep points at wavelengths for both absorbance and transmittance. The deep points are due to the interaction of molecules (impurities [11]: constituent, chemical, elements) with photons as in KUKL drinking water. This interaction shows the size of the particles present in it.

The optical properties and transmittance of KVWSIP water are different than the transmittance of the KUKL drinking water supply, in general. Finally, the transmittance decreases with an increase in the wavelength of photons, as shown in Fig. 3 above the KVWISP water supply of the research area.

### 4.3 Comparison optical properties of KUKL and KVWSIP supply water

A comparative study of the optical properties of these two samples, KUKL and KVWSIP, is shown in Fig. 4 below. The study shows that the transmittance properties at 3 deep points for the same wavelengths of 452.5 nm, 585.8 nm, and 642.6 nm have different transmittances, as shown in Fig. 4 below. In general, we can say that the transmittance of a photon through the KVWSIP sample is high, while KUKL is low. This means that the TDS particle size present in the KUKL sample is higher than that in the KVWSIP sample because the KUKL water supply system is old and has different contamination in the sample. The transmittance of KVWSIP is higher because it is the latest and contains the least amount of TDS with its new supply.

The transmittance of KVWSIP is higher, which means that the TDS is less, which implies that the high transmittance sample has more purities than the low transmittance sample; more details are provided in the Appendix section.

Figure 5 below represents the optical absorbance properties of the KUKL and KVWSIP water supplies in the Kupondole Area, Lalitpur, Nepal. This shows that the absorbance of KUKL supply water is higher, which means that the contamination and TDS particles present in the particle are higher.

Additionally, for KVWSIP, there is less water supply, which means that there is less contamination and fewer TDS particles present in the particles. Therefore, based on optical properties or density, one can also represent or identify the purities of

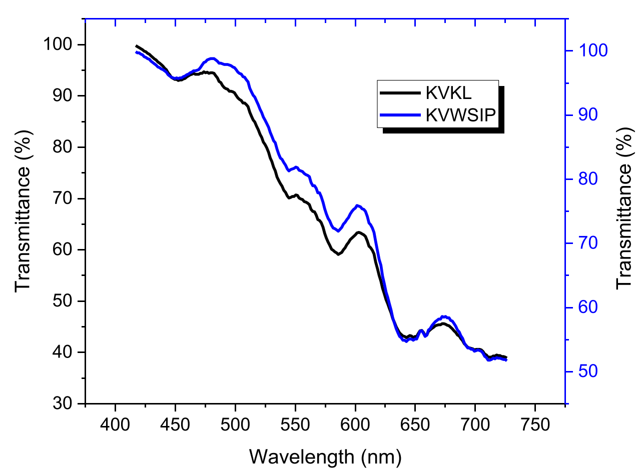



**Fig. 4** Comparison of transmittance properties of KUKL and KVWSIP water supply in Kupondole Area, Lalitpur, Nepal

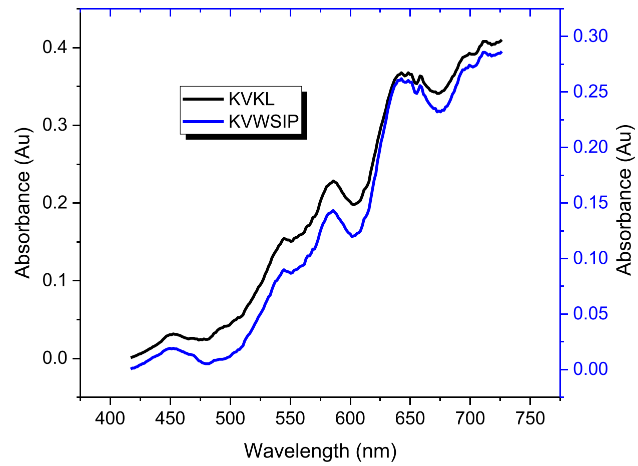



**Fig. 5** Comparison of the absorbance properties of the KUKL and KVWSIP water supplies in Kupondole Area, Lalitpur, Nepal

drinking water. Based on optical density, this article is the first article to study the optical properties of the KUKL and KVWSIP supply water systems in Kathmandu Valley. This method is simple and harmless and more beneficial than the chemical method.

## 5 Conclusion

From the experiment, the optical density of the KUKL and KVWSIP water supplies were studied, and it was found that the transmittance of the KVWSIP water supply is higher than the KUKL water supply, and the absorbance of the KUKL water supply is higher than the KVWSIP water supply. This is because of the presence of contaminated and TDS particles in the water supply system (pipe). A higher transmittance means a lower presence of contaminated and TDS particles, while a lower transmittance means a higher presence of contaminated and TDS particles in the sample. Therefore, this optical property comparative study recommended that the public take KVWSIP water for different purposes rather than KUKL, if they have an option between these two water supply systems. Since TDS and contamination are the best parameters to check the quality of water, it depends upon the maintenance and/or replacement of pipes, sources of water, leakage in pipes, and many more. But here the authors consider the maintenance of pipe lines (old pipes) as a major problem because it is an old water supply system in the valley and from its initial installment of pipe lines, it has not been replaced or maintained until now. If maintenance is not done at the proper time, the water becomes more contaminated and causes different diseases related to water.

**Acknowledgements** Special thanks to Tri-Chandra Multiple Campus, Tribhuvan University.

**Author's contributions** All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Bhishma Karki, Sadam Hussain Dhobi,Indra Dhobi,Binay Kumar Pandey and Digvijay Pandey. The first draft of the manuscript was written by Bhishma Karki and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

**Funding** No funding.

**Data availability** All data generated or analysed during this study are included in this published article.

**Declarations**

**Competing interests** The authors declare no competing interests

## Appendix

| KUKL | | | KUWISP | |
|---|---|---|---|---|
| Wavelength (nm) | Transmittance (%) | Absorbance (Au) | Transmittance (%) | Absorbance (Au) |
| 417 | 99.8 | 0.000869 | 99.9 | 0.000434512 |
| 418.4 | 99.6 | 0.001741 | 99.7 | 0.001304842 |
| 419.8 | 99.4 | 0.002614 | 99.7 | 0.001304842 |
| 421.3 | 99.2 | 0.003488 | 99.5 | 0.002176919 |
| 422.7 | 99 | 0.004365 | 99.4 | 0.002613616 |
| 424.1 | 98.7 | 0.005683 | 99.1 | 0.003926346 |
| 425.5 | 98.6 | 0.006123 | 99 | 0.004364805 |
| 426.9 | 98.3 | 0.007446 | 98.8 | 0.005243055 |
| 428.4 | 98.1 | 0.008331 | 98.7 | 0.005682847 |
| 429.8 | 97.8 | 0.009661 | 98.4 | 0.007004902 |
| 431.2 | 97.5 | 0.010995 | 98.2 | 0.007888512 |
| 432.6 | 97.2 | 0.012334 | 98 | 0.008773924 |
| 434 | 97 | 0.013228 | 97.8 | 0.009661145 |
| 435.5 | 96.6 | 0.015023 | 97.5 | 0.010995384 |
| 436.9 | 96.4 | 0.015923 | 97.4 | 0.011441043 |
| 438.3 | 96.1 | 0.017277 | 97.2 | 0.012333735 |
| 439.7 | 95.8 | 0.018634 | 97.1 | 0.01278077 |
| 441.1 | 95.4 | 0.020452 | 96.9 | 0.013676223 |
| 442.5 | 95.1 | 0.021819 | 96.7 | 0.014573526 |
| 444 | 94.5 | 0.024568 | 96.3 | 0.016373713 |
| 445.4 | 94.1 | 0.02641 | 96.1 | 0.017276612 |
| 446.8 | 93.6 | 0.028724 | 95.9 | 0.018181393 |
| 448.2 | 93.4 | 0.029653 | 95.8 | 0.018634491 |
| 449.6 | 93.2 | 0.030584 | 95.7 | 0.019088062 |
| 451.1 | 93.2 | 0.030584 | 95.8 | 0.018634491 |
| **452.5** | **93** | 0.031517 | **95.7** | 0.019088062 |
| 453.9 | 93.1 | 0.03105 | 95.8 | 0.018634491 |
| 455.3 | 93.1 | 0.03105 | 95.8 | 0.018634491 |
| 456.7 | 93.3 | 0.030118 | 96 | 0.017728767 |
| 458.1 | 93.4 | 0.029653 | 96.1 | 0.017276612 |
| 459.6 | 93.7 | 0.02826 | 96.3 | 0.016373713 |
| 461 | 93.9 | 0.027334 | 96.4 | 0.015922966 |
| 462.4 | 94.1 | 0.02641 | 96.6 | 0.015022874 |
| 463.8 | 94.2 | 0.025949 | 96.7 | 0.014573526 |
| 465.2 | 94.4 | 0.025028 | 96.9 | 0.013676223 |
| 466.7 | 94.2 | 0.025949 | 96.9 | 0.013676223 |
| 468.1 | 94.2 | 0.025949 | 97 | 0.013228266 |
| 469.5 | 94.2 | 0.025949 | 97.1 | 0.01278077 |
| 470.9 | 94.4 | 0.025028 | 97.4 | 0.011441043 |
| 472.3 | 94.4 | 0.025028 | 97.8 | 0.009661145 |
| 473.8 | 94.7 | 0.02365 | 98.2 | 0.007888512 |
| 475.2 | 94.5 | 0.024568 | 98.3 | 0.007446482 |
| 476.6 | 94.6 | 0.024109 | 98.6 | 0.006123085 |

| KUKL | | | KUWISP | |
|---|---|---|---|---|
| Wavelength (nm) | Transmittance (%) | Absorbance (Au) | Transmittance (%) | Absorbance (Au) |
| 478 | 94.4 | 0.025028 | 98.7 | 0.005682847 |
| 479.4 | 94.5 | 0.024568 | 98.8 | 0.005243055 |
| 480.8 | 94.5 | 0.024568 | 98.8 | 0.005243055 |
| 482.3 | 94.4 | 0.025028 | 98.8 | 0.005243055 |
| 483.7 | 93.9 | 0.027334 | 98.6 | 0.006123085 |
| 485.1 | 93.5 | 0.029188 | 98.4 | 0.007004902 |
| 486.5 | 92.8 | 0.032452 | 98.1 | 0.008330993 |
| 487.9 | 92.6 | 0.033389 | 98.1 | 0.008330993 |
| 489.4 | 92 | 0.036212 | 98 | 0.008773924 |
| 490.8 | 91.6 | 0.038105 | 97.9 | 0.009217308 |
| 492.2 | 91.4 | 0.039054 | 97.9 | 0.009217308 |
| 493.6 | 91.3 | 0.039529 | 97.9 | 0.009217308 |
| 495 | 90.9 | 0.041436 | 97.8 | 0.009661145 |
| 496.5 | 90.9 | 0.041436 | 97.7 | 0.010105436 |
| 497.9 | 90.8 | 0.041914 | 97.5 | 0.010995384 |
| 499.3 | 90.6 | 0.042872 | 97.4 | 0.011441043 |
| 500.7 | 90.1 | 0.045275 | 97.1 | 0.01278077 |
| 502.1 | 89.6 | 0.047692 | 96.7 | 0.014573526 |
| 503.5 | 89.3 | 0.049149 | 96.5 | 0.015472687 |
| 505 | 89.1 | 0.050122 | 96.4 | 0.015922966 |
| 506.4 | 88.6 | 0.052566 | 96 | 0.017728767 |
| 507.8 | 88.6 | 0.052566 | 95.9 | 0.018181393 |
| 509.2 | 88.3 | 0.054039 | 95.5 | 0.019996628 |
| 510.6 | 87.9 | 0.056011 | 95.2 | 0.021363052 |
| 512.1 | 86.8 | 0.06148 | 94.2 | 0.025949097 |
| 513.5 | 86 | 0.065502 | 93.6 | 0.028724151 |
| 514.9 | 85.3 | 0.069051 | 93.1 | 0.031050319 |
| 516.3 | 84.9 | 0.071092 | 92.8 | 0.032452024 |
| 517.7 | 84.1 | 0.075204 | 92.2 | 0.035269079 |
| 519.2 | 83.4 | 0.078834 | 91.6 | 0.038104526 |
| 520.6 | 82.5 | 0.083546 | 90.9 | 0.041436117 |
| 522 | 81.9 | 0.086716 | 90.4 | 0.04383157 |
| 523.4 | 81 | 0.091515 | 89.7 | 0.047207557 |
| 524.8 | 80.5 | 0.094204 | 89.2 | 0.049635146 |
| 526.2 | 79.9 | 0.097453 | 88.7 | 0.05207638 |
| 527.7 | 79 | 0.102373 | 88.1 | 0.055024092 |
| 529.1 | 77.9 | 0.108463 | 87.3 | 0.058985756 |
| 530.5 | 77.2 | 0.112383 | 86.7 | 0.061980903 |
| 531.9 | 76.1 | 0.118615 | 86 | 0.065501549 |
| 533.3 | 75.4 | 0.122629 | 85.7 | 0.067019178 |
| 534.8 | 74.2 | 0.129596 | 84.7 | 0.07211659 |
| 536.2 | 73.5 | 0.133713 | 83.9 | 0.076238039 |
| 537.6 | 72.9 | 0.137272 | 83.3 | 0.079354999 |
| 539 | 72.4 | 0.140261 | 83.1 | 0.080398976 |
| 540.4 | 71.6 | 0.145087 | 82.6 | 0.083019953 |
| 541.9 | 71.2 | 0.14752 | 82.2 | 0.085128182 |
| 543.3 | 70.5 | 0.151811 | 81.6 | 0.088309841 |
| 544.7 | 70.1 | 0.154282 | 81.3 | 0.089909454 |
| 546.1 | 70.2 | 0.153663 | 81.5 | 0.088842391 |
| 547.5 | 70.4 | 0.152427 | 81.6 | 0.088309841 |

| KUKL | | | KUWISP | |
|---|---|---|---|---|
| Wavelength (nm) | Transmittance (%) | Absorbance (Au) | Transmittance (%) | Absorbance (Au) |
| 548.9 | 70.4 | 0.152427 | 81.7 | 0.087777943 |
| 550.4 | 70.7 | 0.150581 | 81.9 | 0.086716098 |
| 551.8 | 70.6 | 0.151195 | 81.8 | 0.087246696 |
| 553.2 | 70.1 | 0.154282 | 81.4 | 0.089375595 |
| 554.6 | 69.9 | 0.155523 | 81.3 | 0.089909454 |
| 556 | 69.8 | 0.156145 | 81.2 | 0.090443971 |
| 557.5 | 69.4 | 0.158641 | 80.9 | 0.092051478 |
| 558.9 | 69.3 | 0.159267 | 80.7 | 0.093126465 |
| 560.3 | 69.1 | 0.160522 | 80.6 | 0.093664958 |
| 561.7 | 68.8 | 0.162412 | 80.4 | 0.094743951 |
| 563.1 | 67.9 | 0.16813 | 79.5 | 0.099632871 |
| 564.6 | 67.5 | 0.170696 | 79 | 0.102372909 |
| 566 | 67.4 | 0.17134 | 79 | 0.102372909 |
| 567.4 | 66.8 | 0.175224 | 78.6 | 0.104577454 |
| 568.8 | 65.9 | 0.181115 | 77.9 | 0.108462542 |
| 570.2 | 65.7 | 0.182435 | 77.9 | 0.108462542 |
| 571.6 | 65.3 | 0.185087 | 77.3 | 0.111820506 |
| 573.1 | 64.4 | 0.191114 | 76.4 | 0.116906641 |
| 574.5 | 63.2 | 0.199283 | 75.4 | 0.122628654 |
| 575.9 | 62.3 | 0.205512 | 74.6 | 0.127261173 |
| 577.3 | 61.5 | 0.211125 | 73.9 | 0.131355562 |
| 578.7 | 60.9 | 0.215383 | 73.5 | 0.133712661 |
| 580.2 | 60.1 | 0.221126 | 72.8 | 0.137868621 |
| 581.6 | 59.9 | 0.222573 | 72.4 | 0.140261434 |
| 583 | 59.6 | 0.224754 | 72.3 | 0.140861703 |
| 584.4 | 59.4 | 0.226214 | 72.1 | 0.142064735 |
| **585.8** | **59.1** | 0.228413 | **71.9** | 0.14327111 |
| 587.3 | 59.3 | 0.226945 | 72.2 | 0.141462802 |
| 588.7 | 59.5 | 0.225483 | 72.5 | 0.139661993 |
| 590.1 | 60 | 0.221849 | 73 | 0.13667714 |
| 591.5 | 60.4 | 0.218963 | 73.3 | 0.134896025 |
| 592.9 | 61 | 0.21467 | 73.7 | 0.132532512 |
| 594.3 | 61.4 | 0.211832 | 74 | 0.13076828 |
| 595.8 | 62 | 0.207608 | 74.6 | 0.127261173 |
| 597.2 | 62.3 | 0.205512 | 75 | 0.124938737 |
| 598.6 | 62.6 | 0.203426 | 75.3 | 0.123205024 |
| 600 | 62.9 | 0.201349 | 75.5 | 0.122053048 |
| 601.4 | 63.3 | 0.198596 | 75.9 | 0.119758224 |
| 602.9 | 63.4 | 0.197911 | 75.8 | 0.120330794 |
| 604.3 | 63.3 | 0.198596 | 75.7 | 0.12090412 |
| 605.7 | 63.1 | 0.199971 | 75.4 | 0.122628654 |
| 607.1 | 62.9 | 0.201349 | 75.3 | 0.123205024 |
| 608.5 | 62.6 | 0.203426 | 75 | 0.124938737 |
| 610 | 61.7 | 0.209715 | 74.2 | 0.129596095 |
| 611.4 | 60.7 | 0.216811 | 73.2 | 0.135488919 |
| 612.8 | 60.4 | 0.218963 | 72.9 | 0.137272472 |
| 614.2 | 59.9 | 0.222573 | 72.4 | 0.140261434 |
| 615.6 | 59.2 | 0.227678 | 71.7 | 0.144480844 |
| 617 | 57.6 | 0.239578 | 70.3 | 0.153044675 |
| 618.5 | 56.3 | 0.249492 | 68.8 | 0.162411562 |

| KUKL | | | KUWISP | |
|---|---|---|---|---|
| Wavelength (nm) | Transmittance (%) | Absorbance (Au) | Transmittance (%) | Absorbance (Au) |
| 619.9 | 55 | 0.259637 | 67.5 | 0.170696227 |
| 621.3 | 53.9 | 0.268411 | 66.6 | 0.176525771 |
| 622.7 | 52.5 | 0.279841 | 64.9 | 0.187755303 |
| 624.1 | 51.5 | 0.288193 | 63.8 | 0.195179321 |
| 625.6 | 50.3 | 0.298432 | 62.4 | 0.20481541 |
| 627 | 49.5 | 0.305395 | 61.6 | 0.210419288 |
| 628.4 | 48.6 | 0.313364 | 60.6 | 0.217527376 |
| 629.8 | 47.7 | 0.321482 | 59.6 | 0.22475374 |
| 631.2 | 46.6 | 0.331614 | 58.4 | 0.233587153 |
| 632.7 | 45.8 | 0.339135 | 57.5 | 0.240332155 |
| 634.1 | 45 | 0.346787 | 56.7 | 0.246416941 |
| 635.5 | 44.4 | 0.352617 | 56.1 | 0.251037139 |
| 636.9 | 43.8 | 0.358526 | 55.5 | 0.255707017 |
| 638.3 | 43.5 | 0.361511 | 55.3 | 0.257274869 |
| 639.7 | 43.2 | 0.364516 | 54.9 | 0.260427656 |
| 641.2 | 43.1 | 0.365523 | 54.9 | 0.260427656 |
| **642.6** | **42.9** | 0.367543 | **54.7** | 0.262012674 |
| 644 | 43.1 | 0.365523 | 55 | 0.259637311 |
| 645.4 | 43.3 | 0.363512 | 55.1 | 0.258848401 |
| 646.8 | 43.2 | 0.364516 | 55.1 | 0.258848401 |
| 648.3 | 42.9 | 0.367543 | 54.9 | 0.260427656 |
| 649.7 | 43.1 | 0.365523 | 55.1 | 0.258848401 |
| 651.1 | 43.1 | 0.365523 | 55.1 | 0.258848401 |
| 652.5 | 43.7 | 0.359519 | 55.7 | 0.254144805 |
| 653.9 | 44.2 | 0.354578 | 56.3 | 0.249491605 |
| 655.4 | 44.3 | 0.353596 | 56.4 | 0.248720896 |
| 656.8 | 43.9 | 0.357535 | 56 | 0.251811973 |
| 658.2 | 43.3 | 0.363512 | 55.5 | 0.255707017 |
| 659.6 | 43.4 | 0.36251 | 55.7 | 0.254144805 |
| 661 | 44.1 | 0.355561 | 56.5 | 0.247951552 |
| 662.4 | 44.4 | 0.352617 | 56.7 | 0.246416941 |
| 663.9 | 44.7 | 0.349692 | 57.2 | 0.242603971 |
| 665.3 | 44.9 | 0.347754 | 57.5 | 0.240332155 |
| 666.7 | 45.2 | 0.344862 | 57.8 | 0.238072162 |
| 668.1 | 45.3 | 0.343902 | 58 | 0.236572006 |
| 669.5 | 45.4 | 0.342944 | 58.2 | 0.235077015 |
| 671 | 45.4 | 0.342944 | 58.2 | 0.235077015 |
| 672.4 | 45.6 | 0.341035 | 58.6 | 0.232102384 |
| 673.8 | 45.6 | 0.341035 | 58.5 | 0.232844134 |
| 675.2 | 45.5 | 0.341989 | 58.6 | 0.232102384 |
| 676.6 | 45.3 | 0.343902 | 58.4 | 0.233587153 |
| 678.1 | 45.2 | 0.344862 | 58.4 | 0.233587153 |
| 679.5 | 44.9 | 0.347754 | 58 | 0.236572006 |
| 680.9 | 44.6 | 0.350665 | 57.9 | 0.237321436 |
| 682.3 | 44.2 | 0.354578 | 57.5 | 0.240332155 |
| 683.7 | 43.9 | 0.357535 | 57.1 | 0.243363892 |
| 685.1 | 43.4 | 0.36251 | 56.5 | 0.247951552 |
| 686.6 | 43.2 | 0.364516 | 56.2 | 0.250263684 |
| 688 | 42.7 | 0.369572 | 55.6 | 0.254925208 |
| 689.4 | 42.3 | 0.37366 | 55.2 | 0.258060922 |
| 690.8 | 41.7 | 0.379864 | 54.5 | 0.263603498 |

| KUKL | | | KUWISP | |
|---|---|---|---|---|
| Wavelength (nm) | Transmittance (%) | Absorbance (Au) | Transmittance (%) | Absorbance (Au) |
| 692.2 | 41.4 | 0.383 | 54.1 | 0.266802735 |
| 693.7 | 41 | 0.387216 | 53.7 | 0.270025714 |
| 695.1 | 40.9 | 0.388277 | 53.7 | 0.270025714 |
| 696.5 | 40.8 | 0.38934 | 53.5 | 0.271646218 |
| 697.9 | 40.7 | 0.390406 | 53.5 | 0.271646218 |
| 699.3 | 40.5 | 0.392545 | 53.2 | 0.274088368 |
| 700.8 | 40.6 | 0.391474 | 53.3 | 0.273272791 |
| 702.2 | 40.6 | 0.391474 | 53.4 | 0.272458743 |
| 703.6 | 40.6 | 0.391474 | 53.3 | 0.273272791 |
| 705 | 40.5 | 0.392545 | 53.2 | 0.274088368 |
| 706.4 | 40.2 | 0.395774 | 52.9 | 0.276544328 |
| 707.8 | 39.7 | 0.401209 | 52.4 | 0.280668713 |
| 709.3 | 39.5 | 0.403403 | 52.2 | 0.282329497 |
| 710.7 | 39.1 | 0.407823 | 51.8 | 0.28567024 |
| 712.1 | 39.1 | 0.407823 | 51.8 | 0.28567024 |
| 713.5 | 39.1 | 0.407823 | 51.9 | 0.284832642 |
| 714.9 | 39.3 | 0.405607 | 52.1 | 0.283162277 |
| 716.4 | 39.3 | 0.405607 | 52 | 0.283996656 |
| 717.8 | 39.5 | 0.403403 | 52.2 | 0.282329497 |
| 719.2 | 39.4 | 0.404504 | 52.1 | 0.283162277 |
| 720.6 | 39.4 | 0.404504 | 52.1 | 0.283162277 |
| 722 | 39.2 | 0.406714 | 52 | 0.283996656 |
| 723.5 | 39.2 | 0.406714 | 51.9 | 0.284832642 |
| 724.9 | 39.1 | 0.407823 | 51.9 | 0.284832642 |
| 726.3 | 38.9 | 0.41005 | 51.7 | 0.286509457 |

## References


1. Bhattarai R, Dahal KR. Review of water pollution with special focus on Nepal. J Emerg Technol Innovat Res. 2020;7(5):100–1.
2. Bos R, Alves D, Latorre C, Macleod N, Payen G, Roaf V, Rouse M. Manual on the human rights to safe drinking water and sanitation for practitioners. UK: IWA Publishing; 2016.
3. WHO. Water Quality and Health Strategy 2013–2020, 2020;1–17.
4. Udmale P, Ishidaira H, Thapa BR, Shakya NM. The status of domestic water demand: supply deficit in the Kathmandu Valley, Nepal. Water. 2016;8(196):1–9. https://doi.org/10.3390/w8050196.
5. Grönwall J, Danert J. Regarding groundwater and drinking water access through a human rights lens: self-supply as a norm. Water. 2020;12(419):1–21. https://doi.org/10.3390/w12020419.
6. KUKL. Land Acquisition and Involuntary Resettlement Due Diligence Report, 2019. https://www.adb.org/sites/default/files/project-documents/34304/34304-043-sddr-en_0.pdfAcessed 15th Sept 2021.
7. Shrestha RP, Mahajan KL. Traditional water resource use and adaptation efforts in Nepal. J Int Dev Cooperat. 2016;22(1&2):47–58. https://core.ac.uk/download/pdf/197304029.pdf.
8. Thapa BR, Ishidaira H, Pandey VP, Bhandari TM, Shakya NM. Evaluation of water security in Kathmandu Valley before and after water transfer from another basin. Water. 2018;10(224):1–5. https://doi.org/10.3390/w10020224.
9. Warner NR, Levy J, Harpp K, Farruggia F. Drinking water quality in Nepal's Kathmandu Valley: a surveyand assessment of selected controlling site characteristics. Hydrogeol J. 2008;16:321–34.
10. Bhandari P, Banjara MR, Singh A, Kandel S, Rawal DS, Pant BR. Water quality status of groundwater and municipal water supply (tap water) from Bagmati river basin in Kathmandu valley, Nepal. J Water Sanitat Hygiene Dev. 2021;11(1):102–11. https://doi.org/10.2166/washdev.2020.190.
11. Buiteveld H, Hakvoort JHM, Donze M. Optical properties of pure water. SPIE Proc. 2016;2258:1–10. https://doi.org/10.1117/12.190060.
12. Downing J. Effects of light absorbance and scattering in water samples on OBS measurements. Campbell Scientific, Inc.;2008.
13. USAID-Nepal. Water and development country plan, 2020:1–2.
14. WHO. Safer water, Better Health. Geneva; 2019.
15. Ravi M, Snigdha K. COVID-19 and its impact on air pollution. Int J Res Appl Sci Eng Technol (IJRASET). 2020;08(11):344–6. https://doi.org/10.22214/ijraset.2020.32139.

16. Shrestha KB, Kamei T, Shrestha S, Aihara Y, Bhattarai AP, Bista N, Thapa BR, Kazama F, Shindo J. Socioeconomic impacts of LCD-treated drinking water distribution in an urban community of the Kathmandu Valley, Nepal. Water. 2019;11(1323):1–12. https://doi.org/10.3390/w11071323.