

## Investigation of Cyanide, Arsenate, Phosphine and Nitrate Molecules in Samples of Water from Different Areas Using Raman Spectroscopy

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### Abstract

*Water pollution is one of the biggest problems. This problem has become more and more dangerous as a result of harmful human activities. Increasing numbers of factories, use of fertilizers and pesticides to improve the quality and ripening of crops and also the random mining of minerals are responsible for rising water pollution. Cyanide, Arsenate Phosphine and Nitrates are very dangerous water pollutants and harmful chemical substances having adverse effect on humans, soil and animals. They are responsible for causing many dangerous diseases in humans. This study aims to investigate and determine the presence of these pollutants in water samples collected from northern Sudan. To examine water samples, a Horiba Lab RAM 3D Raman spectrometer was deployed. The findings showed that the samples include various amounts of harmful compounds such cyanide, nitrate, arsenate, and phosphine, which can cause fatal disorders in humans.*

**Keywords:** Raman Spectroscopy, Water pollution, Cyanide, Arsenate, Phosphine and Nitrate.

### Declaration of Interest Statement:

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## 1. Introduction

Water is an inorganic chemical substance with formula H<sub>2</sub>O consists main of Earth's surface. It is so important for all form of life, nothing can live without water as God mentioned that in the Holy Qur'an in Surat Al-Anbiya, verse (We made from water every living thing. Then will they not believe?). 96% of the water on Earth is found in the oceans and seas, which cover 71% of the planet. The seas play a crucial part in maintaining the Earth's climate and the amount of water draining from its surface. They also act as a marine ecosystem that is home to numerous living things. In the pores and fissures between rocks, groundwater is kept underground. After glaciers, groundwater has the second-highest concentration of fresh water [1].

Water is regarded as one of the most important factors that govern the nation's economy. Agriculture uses more than 70% of the freshwater [2].

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The hydrogen and oxygen atoms in the water molecule framed at a point of  $104.5^\circ$ . In two of the four corners of a tetrahedron with oxygen in the centre, hydrogen atoms are located. Solitary sets of valence electrons that are not a part of the bonding are at the other two corners. In comparison to hydrogen atoms, lone pairs repel one another more strongly. The O-H bond spans approximately 0.096 nm [3].

The availability of this natural resource, which is becoming scarcer in some locations, is a serious social and economic problem. Almost a billion people currently regularly drink polluted water. The Millennium Development Goals for water were set by the UN in 2000 with the aim of halving the global number of people lacking access to clean water and sanitation by 2015. The Sustainable Development Goals, which incorporate guaranteeing widespread admittance to clean water and sterilization by 2030, were vowed to by the UN in 2015 notwithstanding lopsided advancement that way. Poor water quality and lack of sterilization causes around 5,000,000 deaths. Every year, 1.4 million baby fatalities are connected with diarrhea [1]. Water is scarce and is instead recycled as drinking water during precipitation [4].

Still, 90% of wastewater enters local rivers and streams untreated in underdeveloped countries. Many nations experience moderate to severe water stress; in some of these nations more water is removed each year than is replenished by their own natural water cycles. Stress deteriorates groundwater resources in addition to surface freshwater bodies [5].

At the beginning of the year, 1985 the applications of laser were expanded. These particular applications permit laser qualities that are unfeasible with white light, such as coherency, great monochromaticity, and the capacity to reach very high energies [6].

Several laser varieties produce light that is nearly monochromatic and has a set range of wavelengths, making them naturally pure sources of light. The laser components should be clearly developed in order to focus more on the virtue of laser light (measured as the "linewidth") than the immaculateness of some other light source. Hence, a crucial tool for spectroscopy is the laser. Raman spectroscopy is made possible by the high light force that can be generated in a small, highly collimated shaft when utilised to cause a nonlinear optical effect in a substance. Other spectroscopic procedures in view of lasers can be utilized to assemble very delicate identifiers of different synthetic substances that can screen particle fixations at the parts-per-1012 (ppt) level. High power laser concentrations may result in beam-induced atomic emission; this technique is referred to as laser-induced breakdown spectroscopy [7].

Since 1960, there have been more powerful, monochromatic laser sources available, which has greatly accelerated a variety of spectroscopic experiments. Prior to 1960, a mercury arc which has a significantly wider line width and less strong Laser radiation—was widely used as a Raman source. Higher resolution is now feasible and weaker Raman scattering can be noticed.

Most laser sources may seem to have a significant drawback for disciplines of spectroscopy other than Raman spectroscopy, namely their lack of tenability. There are methods for adjusting, or shifting, the nuclear or sub-atomic energy levels necessary until the change under focus advances into a lucky event with the laser light in regions of the spectrum, particularly the infrared, where tunable lasers are not typically available. This can be done using a method known as laser Stark spectroscopy, which involves introducing an electric field to the material. The equivalent magnetic field-based method is called laser magnetic resonance (also known as laser Zeeman) spectroscopy [8].

## 2. Absorption and Emission of Radiation

Only a few energy levels allow for the existence of atoms and molecules. As all other states have more energy than the ground state, which has the least energy, they are collectively referred to as electrified states. There are numerous excited states, and each one has energy that is specifically added to and beyond the energy of the ground state. The "atomic ground state," which practically all atoms and particles are in under ordinary conditions, is the state wherein an atom has minimal measure of energy accessible to it. It is assumed that a molecule is in a "energized nuclear state" if it possesses more energy than it does in its ground state [9].

A two-level atomic framework is capable of three distinct processes. Ingestion, animated outflow, unconstrained emanation, and their cooperation together decide the parameters for laser action.

### 2.1 Absorption

Absorption happens when light hits an atom with enough energy to set off an electronic transition between two energy levels. These outcomes in less low-level individuals and more upper-level individuals [11]. The atomic system is excited into a higher energy state if an electron shifts to a higher energy level in reaction to the incoming photon, as depicted in figure 1. A photon will really at that time be absorbed on the grounds that the energy gap between the underlying and last states impeccably matches the photon's quantum energy [1].

This suggests that specific frequencies of incident energy are absorbed by the atoms. When radiation interacts with the problem, the situation will be simple if there aren't any sets of energy states where the photon energy might elevate the structure from the lower to the upper expression [10].

$$dN_1 = -B_{12}\rho(\nu_0)N_1 dt \quad (1)$$

Where  $\rho(\nu_0)$  is the range energy thickness of radiation at frequencies close ( $\nu_0$ ),  $N_1$  is the number of inhabitants in iotas in the ground state,  $N_2$  is the number of inhabitants in molecules in the energized state, and  $B_{12}$  is the Einstein coefficient of retention. Just within the sight of a field is retention possible; the course of ingestion is upgraded.

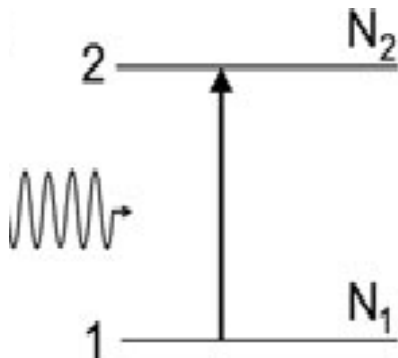


Figure (1) Stimulated Absorption

### 2.2 Spontaneous Emission

To understand the peculiarity of spontaneous emission, we should anticipate that an atoms or particle's two energy levels, 1 and 2, will have energies  $E_1$  and  $E_2$ , respectively (figure 2). The discussion that follows can use any two levels from the infinite range of levels that an atom can have. It is realistic to consider level 1 to be the bottom level, though. Let's imagine for a moment that level 2 is the atom's initial condition. The atom normally decays to level 1 when  $E_2 > E_1$ . The  $E_2 - E_1$  equivalent energy differential must be released by the atom. The process is referred to as spontaneous (or radiative) emission when this energy is transmitted as an electromagnetic (em) wave. The well-known expression then yields the frequency of the emitted wave, ( $\nu_0$ ) :

$$\nu_0 = \frac{E_2 - E_1}{h} \quad (2)$$

where  $h$  is Planck's constant. [12]

$$dN_2 = -A_{21}N_2 dt \quad (3)$$

Where  $A_{21}$  is the spontaneous emission Einstein coefficient. The upper level's population declines exponentially

$$N_2 = N_2(0)e^{-A_{21}t} = N_2(0)e^{-t/\tau_{sp}} \quad (4)$$

$N_2(0)$  is the thickness of excited two-level nuclear frameworks at time zero, and is the usual lifespan of an energetic two-level atomic framework regarding unrestrained discharge (=spontaneous lifetime  $\tau_{sp}$ ). We have the straightforward relation

$$A_{21} = 1/\tau_{sp} \quad (5)$$

The reciprocal of the spontaneous lifespan is the Einstein coefficient  $A_{21}$ .

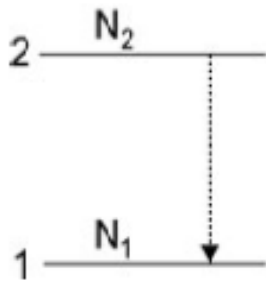


Figure (2): Spontaneous emission

### 2.3 Stimulated Emission

Consider for a minute that atom is initially identified at level 2 and that a wave incident on the substance has a frequency of  $\nu = \nu_0$ , or the same as the spontaneously produced wave (Figure 3). Since this wave has a similar recurrence as the atomic recurrence, there is a little likelihood that it will make the atom go through the process 2-1. For this situation, the episode wave is joined by an extra (em) wave that contains the energy contrast  $E_2 - E_1$ . The animated outflow peculiarity is this.

Both spontaneous emission and induced emission are fundamentally different processes. During spontaneous emission, atoms release a (em) wave that is not clearly related to the wave released by another atom. Moreover, the wave can be directed in any direction. Any atom that is released contributes in phase and in the same direction as the arriving wave since the incidence (em) wave forces the process in the case of stimulated emission [11].

The stimulated emission mechanism of the laser allows for the release of increasingly more similar photons in the manners described below. Imagine that a metastable excited electron emits a photon when it transitions to the ground state. If a photon goes through a material and collides with another electron that is metastable excited, the metastable excited electron will drop to a lower energy level and emit another photon. Two photons with the same energy are there right now. These photons will each release an additional photon if they go through the material and come into contact with an electron that is in a metastable state, so from 2 photons we get 4, and so on. In this manner, laser light is generated [10].

The rate of  $N_2$  is:

$$dN_2 = -B_{21}\rho(\nu_0)N_2 dt \quad (6)$$

Where  $B_{21}$  is the stimulated emission Einstein coefficient. As per figure, the radiation delivered by invigorated outflow has a similar recurrence, polarization, course, and stage as the invigorating radiation (1.3).

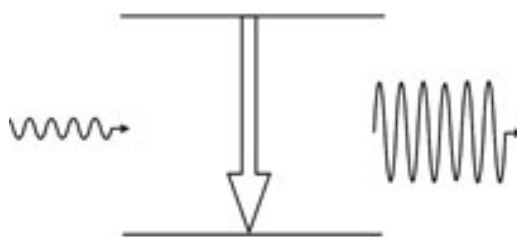


Figure (3) Stimulated Emission

### 3. Spectroscopy

The study of how electromagnetic radiation interacts with matter is known as spectroscopy. A large portion of the principal hypotheses of physical science, including quantum physical science, quantum electrodynamics, and the general and extraordinary speculations of relativity, were inferred through spectroscopic examination. Spectroscopy has been a crucial tool in advancing science's understanding of the electromagnetic and atomic forces as applied to high-energy collisions.

All specialized areas of science and innovation utilize spectroscopic methods. By involving radio recurrence spectroscopy of the core in an attractive field, magnetic resonance imaging (MRI) is used to picture within delicate tissues of the body with unmatched exactness. The alleged black body radiation of three magnitudes was also discovered using microwave spectroscopy.

By using spectroscopy techniques with high-energy molecular gas pedals, it is possible to determine the internal structure of the proton and neutron as well as the circumstances of the early cosmos during the first millisecond of its existence. Using optical, radio, and X-beam spectroscopy, it is possible to find the synthesis of distant stars, intergalactic particles, and, interestingly, the early overflow of components prior to the development of the primary stars. To determine the substance organisation and real design of materials, optical spectroscopy is typically used.

Spectroscopic techniques are quite precise. There can be many isotopes or a single atom in a species with 1020 or more atoms. The use of spectroscopic techniques is typically the most efficient way to detect low concentrations of pollutants. Particular kinds of microwave, optical, and gamma-beam spectroscopy can measure limitless recurrence varieties in slender spectroscopic lines. Using ultrahigh goal laser techniques, frequency shifts as small as one section in 1015 of the recurrence being checked can be observed. Frequency estimations have proven to be the most accurate actual estimations because of their responsiveness [12].

### 4. Raman Spectroscopy

Smekal postulated the phenomena of inelastic scattering of light in 1923, and Raman and Krishnan made the first experimental observation of it in 1928. Raman spectroscopy is the term that has since been used to describe the phenomena. In the initial experiment, a sample that was either a purified liquid or a dust-free vapour was exposed to sunlight through a telescope. By the sample, a second lens was positioned to gather the radiation that was reflected. The existence of scattered radiation from the incident light with an altered

frequency, which is the fundamental aspect of Raman spectroscopy, was demonstrated using a series of optical filters [13].

The partnership between the incident light and the illuminated molecule's electrons results in the Raman dissipating peculiarity. The energy of the incident light is insufficient in non-reverberation Raman scattering to excite the particle to a higher electronic state. When everything is taken into account, Raman dispersion causes the particle to move from its initial vibrational state to a different vibrational state (Figure 4).

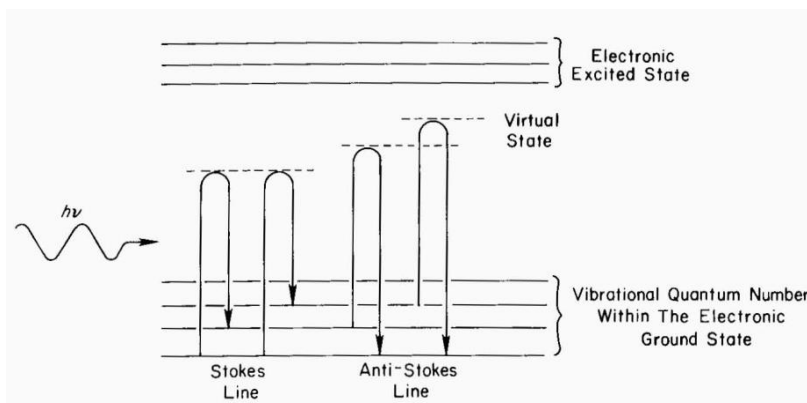


Figure (4) The origin of Raman scattering

#### 4.1. Stokes and Anti-Stokes Lines

The incident light must cause a change in the chemical polarizability or the dipole moment for a molecule to display the Raman Effect. Take carbon dioxide as an illustration. A change in the form of the electron cloud qualitatively represents the change in polarizability. As seen in Figure 5, when the electron cloud surrounding the CO<sub>2</sub> molecule interacts with the oscillating wave of the electromagnetic wave's electric component, it alternately contracts and expands in phase. A photon from incident light can pair with an electron in a specific vibrational mode, creating scattered photons with a different frequency. The dispersed light also comprises a little quantity of light from Raman scattering in addition to the conventional Rayleigh scattering. The various vibrational modes of a molecule can absorb some of the energy of photons that contact with it. The dispersed light makes the sub-atomic motions lose their energy, as displayed in Figure 5 (Stirs up Raman Impact). On the off chance that the energy from a particle is sent to the dissipated light, the scattering molecule has more energy than the underlying occurrence light (hostile to Stirs up Raman impact). The scattering molecule should currently be charged for this to work. Since this is an unprecedented occasion, Stirs up Raman dispersing is essentially more grounded than anti-Stokes dissipating in ordinary applications. Raman lines are frequently quite weak because Raman scattering only scatters a small portion of photons. Most of the scattered light offers similar photon energy as the first info light. Since it discharges more scattered photons and is a strong monochromatic source of light, a laser is utilized as a light source [14].

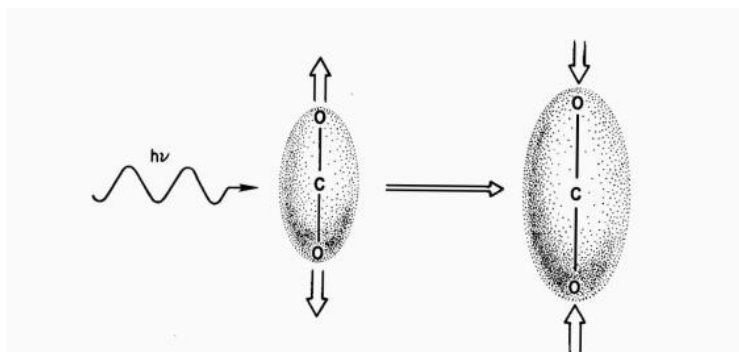


Figure (5) Change in Polarizability

Since both the Stokes line and the anti-Stokes line contain a similar vibrational energy differential, the distinction between the incident light recurrence and the dispersed recurrence is something very similar in Stokes and anti-Stokes scattering (Figure 5). That is, there is a balanced contrast in recurrence among Stokes and anti-Stokes scattering.

## 5. Materials And Method

The materials, tools, and techniques used in the experimental portion have been listed below.

### 5.1. Materials

Ten surface water samples were taken in the northern Sudan from five different places in order to conduct this analysis. This area has been targeted for the large number of agricultural activities, in which the use of pesticides is frequent, as well as industrial activities and random gold mining.

All this increases the pollution of the water, which in turn increases the risk of kidney disease, cancer and other serious diseases

### 5.2. Instrumentations

The Laser Raman Spectrometer model Horiba Lab Smash HR 3D was employed in this study to capture the Raman spectra of the materials and depicted in Figure 6. It is an incredible asset utilized in material physics and chemical labs to recognize a wide assortment of mixtures.

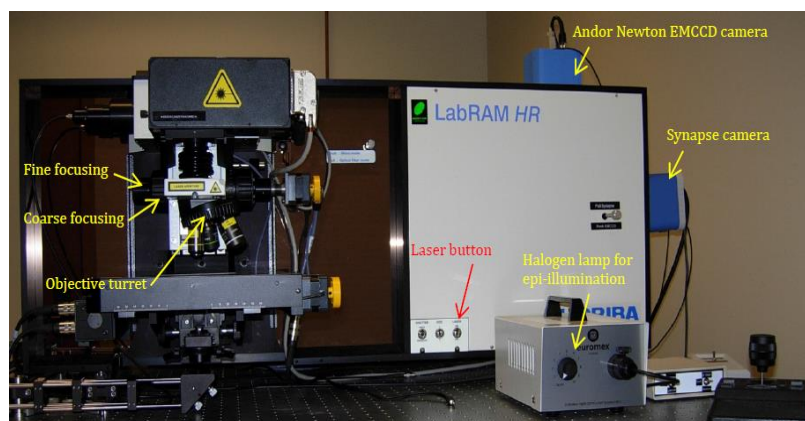


Figure (6): Model RAM HR D3 of the Horiba Lab Laser Raman Spectrometer

A Raman spectrometer illuminates a sample with monochromatic light and examines the light reflected by the sample without harming it or requiring any sample preparation. Figure 7 shows the Horiba Lab Slam HR D3 Raman spectrometer's calculated design.

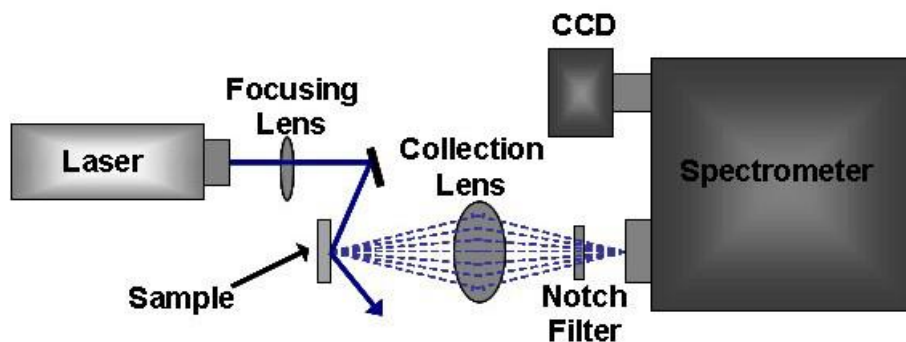


Figure (7): Horiba LAB RAM 3D Raman spectrometer schematic illustration

### 6. Results

According to the findings, these samples also include other hazardous chemicals in varying levels in addition to the water.

It was found that the Raman spectra of sample 1, as shown in figure 8, clearly exhibits peaks at the wave numbers (1270 and 2403 cm<sup>-1</sup>), when compared to the vibrations noted in various publications. As stated in Table 1, these vibrations were found to match those of water molecules and a few other materials' components.

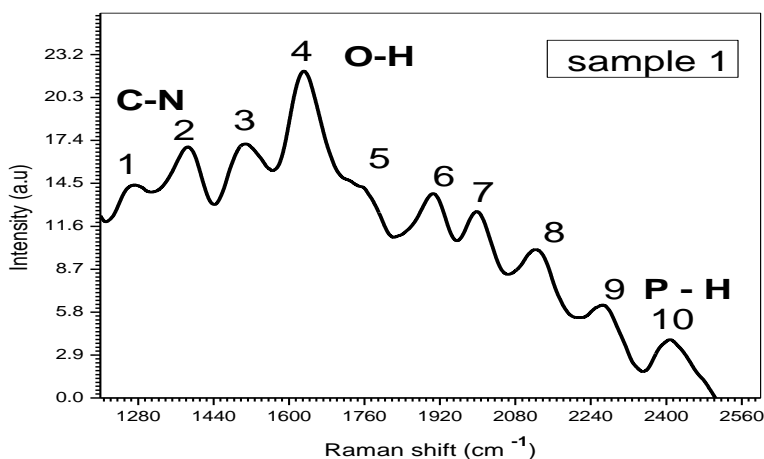


Figure (8) Surface water sample 1's Raman spectrum.

Table (1) Components of other materials exist in sample 1

| No of Peak | Raman shift cm <sup>-1</sup> | Intensity (a.u) | Group of Function | Reference  |
|------------|------------------------------|-----------------|-------------------|--|
| 1          | 1270                         | 14.51           | $\nu(C-N)_\beta$  | (Ćiric-Marjanović, G., et al., 2008)             |
| 4          | 1636                         | 22.18           | OH bending        | (Durickovic, I. and Marchetti, M., 2014)         |
| 10         | 2404                         | 4.03            | PH                | (Edwards HG.,2005), (Robert, M.S., et al., 2005) |

The Raman spectra of a sample 2 are displayed in Figure 9. Clear peaks were noticed, and after comparing them to vibrations identified in earlier research and other sources, I found that they accurately depict the vibrations of several other materials, some of which are included in Table 2, as well as the vibrations of water molecules.

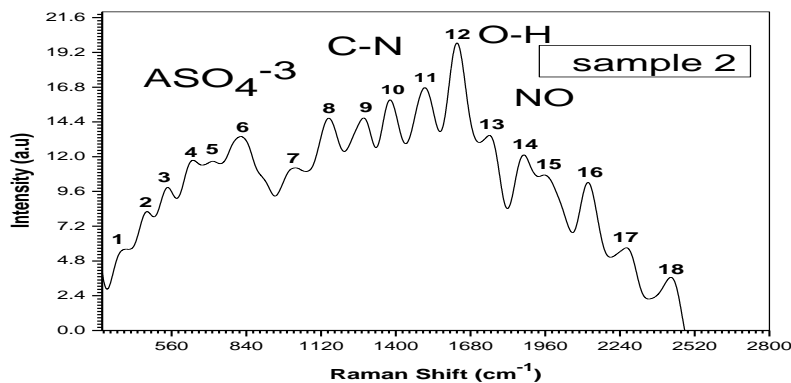


Figure (9) Sample 2's Raman spectrum



Table (2) Components of other materials exist in sample 2

| No of peak | Raman shift $\text{cm}^{-1}$ | Intensity (a.u) | Group of Function                          | References                               |
|------------|------------------------------|-----------------|--|--|
| 6          | 822                          | 13.45           | $(\text{ASO}_4)^{-3}$ symmetric stretching | (Frost, R.L., et al., 2006)              |
| 9          | 1270                         | 14.75           | $\nu(\text{C}-\text{N})_{\beta}$           | (Ćirić-Marjanović, G., et al., 2008)     |
| 13         | 1634                         | 19.97           | OH bending                                 | (Durickovic, I. and Marchetti, M., 2014) |
| 14         | 1876                         | 13.23           | None                                       | (Gang Li, Guoping Zhang, 2006)           |

Figure 10 depicts the Raman spectra of sample 3 in the 1600 to 2439  $\text{cm}^{-1}$  region. In addition to the water molecule vibrations, there were other vibrations visible in the spectrum. According to Table 3.

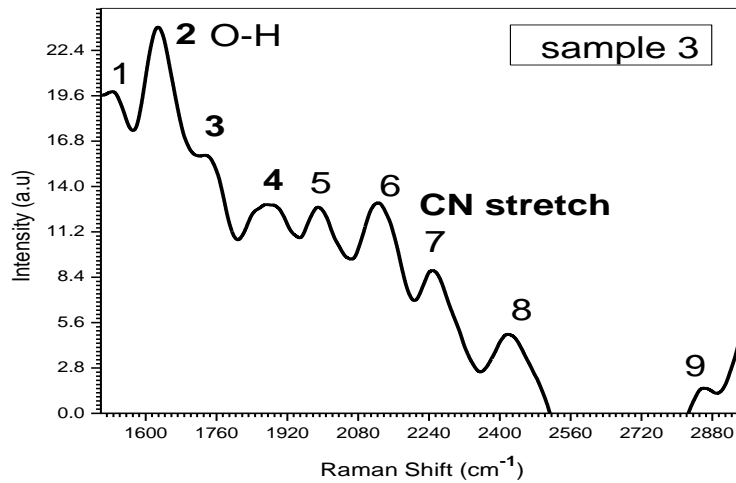


Figure (10) Sample 3's Raman spectrum

Table (3) Components of other materials exist in sample 3

| No of Peak | Raman shift $\text{cm}^{-1}$ | Intensity (a.u) | Group of Function                | Reference                                |
|------------|------------------------------|-----------------|----------------------------------|--|
| 2          | 1735                         | 24.91           | OH bending                       | (Durickovic, I. and Marchetti, M., 2014) |
| 7          | 2238                         | 7.94            | $\text{C}\equiv\text{N}$ stretch | (Ito, K., Kato, T. and Ona, T., 2002)    |

In the same way, in the Raman spectra of sample 4 in the range of 1600 to 2439  $\text{cm}^{-1}$ , as shown in figure 11, a different vibration could be seen in addition to the water molecule vibrations. As displayed in Table 4

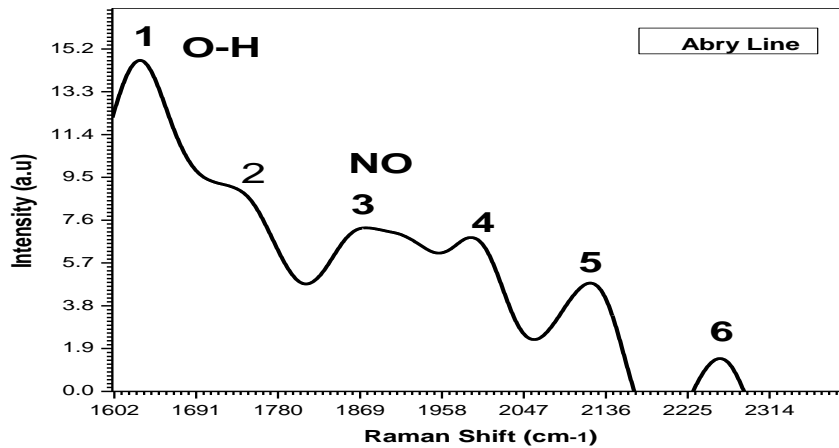


Figure (11) Sample 4's Raman spectrum

Table (4) Components of other materials exist in sample 4

| No of Peak | Raman shift $\text{cm}^{-1}$ | Intensity(a.u) | Group of Functional | Reference                                |
|------------|------------------------------|----------------|---------------------|--|
| 1          | 1636                         | 14.77          | OH bending          | (Durickovic, I. and Marchetti, M., 2014) |
| 3          | 1878                         | 7.33           | None                | (Gang Li, Guoping Zhang, 2006)           |

The water components and a few other elements are clearly depicted in Figure 12 and Table 5, which are used to demonstrate the analysis of this spectrum in sample 5.

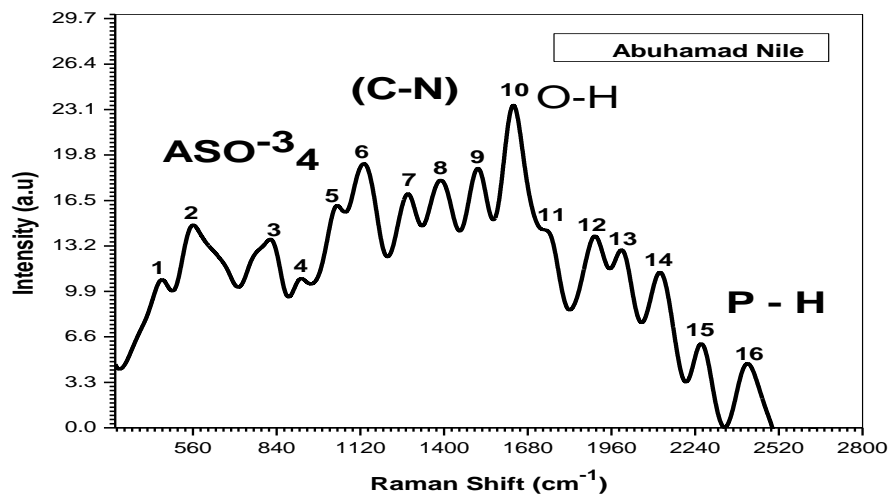


Figure (12) Sample 5's Raman spectrum

Table (5) Components of other materials exist in sample 5

| No of Peak | Raman shift $\text{cm}^{-1}$ | Intensity (a.u) | Group of Functional                        | Reference   |
|------------|------------------------------|-----------------|--|---|
| 3          | 822                          | 13.80           | $(\text{ASO}_4)^{-3}$ symmetric stretching | (Frost, R.L., et al., 2006)                       |
| 7          | 1270                         | 17.10           | $\nu(\text{C}-\text{N})_{\beta}$           | (Ćirić-Marjanović, G., et al., 2008)              |
| 10         | 1636                         | 24.57           | OH bending                                 | (Durickovic I. and Marchetti, M., 2014)           |
| 16         | 2311.7                       | 5.78            | PH   | (Edwards HG.,2005), (Robert, M.S., et al., 2005), |

The Raman spectrum of a sample 6 is depicted in Figure 13, and clear peaks were found. By comparing these peaks to the vibrations seen in prior research and in certain sources, it was discovered that these peaks correlate to the vibrations of water molecules and some other materials listed in Table 6.

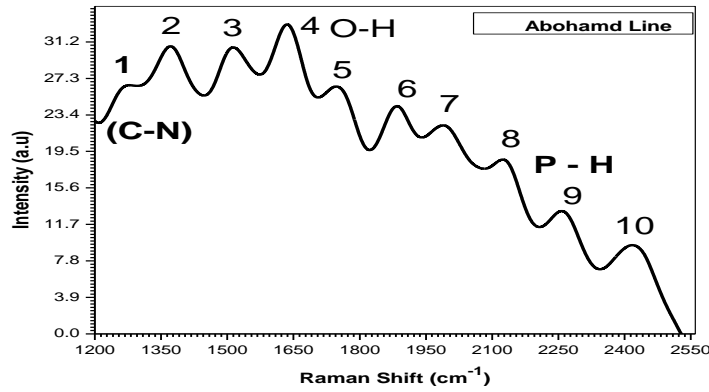


Figure (13): Sample 6's Raman spectrum

Table (6) Components of other materials exist in sample 6

| No of Peak | Raman shift $\text{cm}^{-1}$ | Intensity(a.u) | Group of Functional | Reference  |
|------------|------------------------------|----------------|---------------------|--|
| 1          | 1270                         | 26.72          | $\nu(C-N)_\beta$    | (Ćiric-Marjanović, G., et al., 2008)             |
| 4          | 1635                         | 33.22          | OH bending          | (Durickovic I. and Marchetti, M., 2014)          |
| 9          | 2411.7                       | 9.61           | PH                  | (Robert, M.S., et al., 2005), (Edwards HG.,2005) |

Figure 14 displays the sample 7's Raman spectrum. Other vibrations showed in the spectrum in addition to the water molecule vibrations According to Table 7.

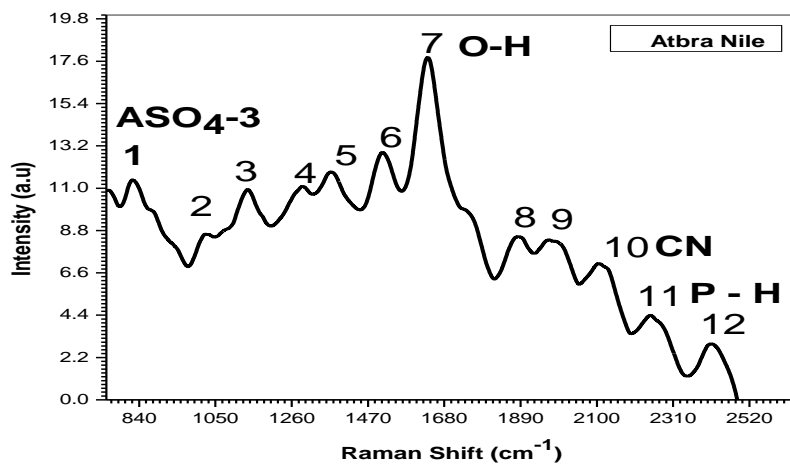


Figure (14) Sample 7's Raman spectrum

Table (7) Components of other materials exist in sample 7

| No Peak | Raman shift $\text{cm}^{-1}$ | Intensity (a.u) | Group of Functional | Reference |
|---------|------------------------------|-----------------|---------------------|-----------|
|---------|------------------------------|-----------------|---------------------|-----------|

|    |        |       |  |  |
|----|--------|-------|--|--|
| 1  | 822    | 11.49 | $(\text{ASO}_4)^{-3}$ symmetric stretching | (Frost, R.L., et al., 2006)                      |
| 7  | 1636   | 17.87 | O-H bending                                | (Durickovic I. and Marchetti, M., 2014)          |
| 11 | 2238   | 5.49  | $\text{C}\equiv\text{N}$ stretch           | (Ito, K., Kato, T. and Ona, T., 2002)            |
| 12 | 2412.6 | 3.98  | PH   | (Edwards HG.,2005), (Robert, M.S., et al., 2005) |

Figure 15 shows the water sample 8's Raman spectrum. The analysis of this spectrum is listed in Table 8.

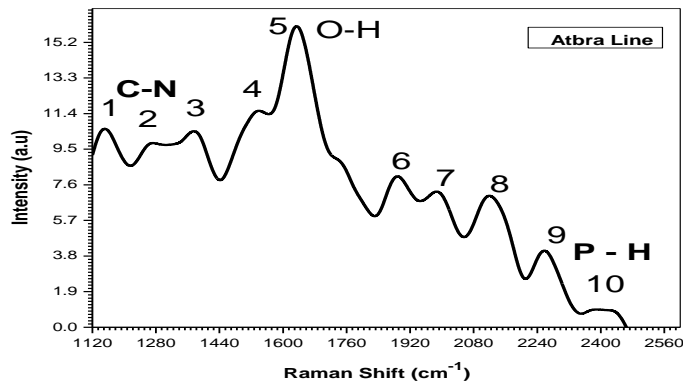


Figure (15) Sample 8's Raman spectrum

Table (8) Components of other materials exist in sample 8

| No of Peak | Raman shift $\text{cm}^{-1}$ | Intensity (a.u) | Group of Functional              | Reference  |
|------------|------------------------------|-----------------|----------------------------------|--|
| 2          | 1270                         | 9.91            | $\nu(\text{C}-\text{N})_{\beta}$ | (Ćirić-Marjanović, G., et al., 2008)             |
| 5          | 1636                         | 16.15           | OH bending                       | (Durickovic I. and Marchetti, M., 2014)          |
| 10         | 2404                         | 2.06            | PH                               | (Robert, M.S., et al., 2005), (Edwards HG.,2005) |

Figure 16 shows the water sample 9's Raman spectrum. The analysis of this spectrum is listed in Table 9.

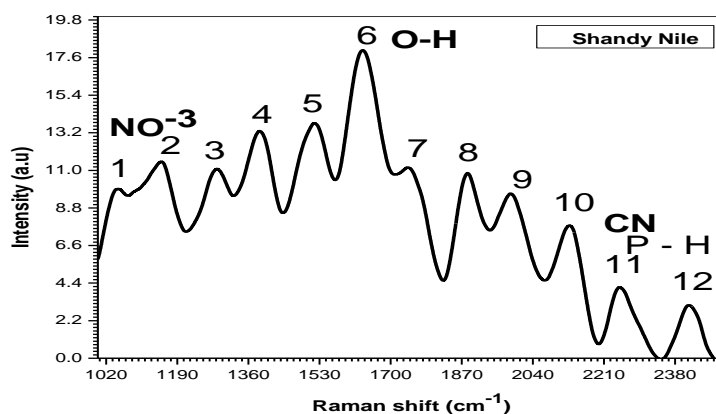


Figure (16) Sample 9's Raman spectrum

Table (9) Components of other materials exist in sample 9

| No of Peak | Raman shift $\text{cm}^{-1}$ | Intensity (a.u) | Group of Functional | Reference                                |
|------------|------------------------------|-----------------|---------------------|--|
| 1          | 1053                         | 9.98            | $\text{NO}^{-3}$    | (Durickovic, I. and Marchetti, M., 2014) |

|    |        |       |             |  |
|----|--------|-------|-------------|--|
| 6  | 1636   | 18.11 | OH bending  | (Durickovic I. and Marchetti, M., 2014)          |
| 10 | 2238   | 5.23  | C≡N stretch | (Ito, K., Kato, T. and Ona, T., 2002)            |
| 12 | 2311.7 | 4.18  | PH          | (Edwards HG.,2005), (Robert, M.S., et al., 2005) |

Figure 17 shows the sample 10's Raman spectrum in the 1250 to 2411.6 cm<sup>-1</sup> region. The analysis of this spectrum is listed in Table 10.

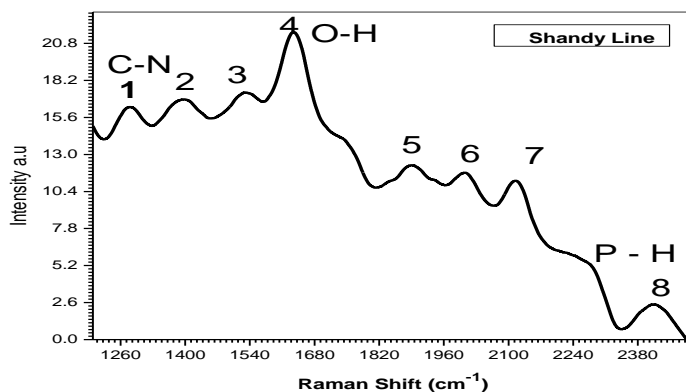


Figure (17) Sample 10's Raman spectrum

Table (10) Components of other materials exist in sample 10

| No of Peak | Raman shift cm <sup>-1</sup> | Intensity (a.u) | Group of Functional | Reference  |
|------------|------------------------------|-----------------|---------------------|--|
| 10 1       | 1270                         | 16.43           | $\nu(C-N)_\beta$    | (Ćirić-Marjanović, G., et al., 2008)             |
| 13 4       | 1636                         | 21.73           | OH bending          | (Durickovic I. and Marchetti, M., 2014)          |
| 18 8       | 2411.7                       | 2.61            | PH                  | (Robert, M.S., et al., 2005), (Edwards HG.,2005) |

## 7. DISCUSSION

The findings revealed that the water samples collected from five distinct locations in northern Sudan, contained a number of other compounds in varying levels in addition to the water.

Raman spectra (fingerprints) contain peaks that represent certain chemicals and intensities that represent the concentration of those molecules in the samples.

By comparing the Raman spectra of all samples with the vibrations described in certain publications, it was discovered that all samples exhibit distinct peaks at wave numbers 1635cm<sup>-1</sup>.

Also, the results show that all the water samples taken from the northern Sudan region contain molecules of (C≡N,  $[\text{ASO}_4]^{-3}$ , P-H and  $\text{NO}^{-3}$ ) in varying quantities, as indicated by the spectra recorded by Raman spectroscopy, as each peak refers to a specific molecule.

These pollutants are found in water samples in different amounts. Each sample contained at least one of the pollutant molecules, some samples contained two and others three. It was found that, Cyanide was the most common pollutant present in the samples which was found in nine water samples, and then the Phosphine that was found in seven samples. These findings could be attributed to the fact that while cyanide is frequently used in mining of minerals and phosphine is an important constituent of fertilizers and pesticides used in the

regions of northern Sudan. Table 11 shows the amount of pollutants studied in all the 10 water samples.

Table (11) the different amounts of pollutants in water samples

| Samples   | $\nu(C-N)_\beta$ | P – H    | $NO^{-3}$ | $ASO_4^{-3}$ , |
|-----------|------------------|----------|-----------|----------------|
| Sample 1  | 14.51 a.u        | 4.02 a.u | -         | -              |
| Sample 2  | 14.75 a.u        | -        | 12.23 a.u | 13.45 a.u      |
| Sample 3  | 8.93 a.u         | -        | -         | -              |
| Sample 4  | -                | -        | 7.32 a.u  | -              |
| Sample 5  | 17.10 a.u        | 4.79 a.u | -         | 13.80 a.u      |
| Sample 6  | 26.72 a.u        | 9.60 a.u | -         | -              |
| Sample 7  | 4.48 a.u         | 2.99 a.u | -         | 11.49 a.u      |
| Sample 8  | 9.90 a.u         | 1.05 a.u | -         | -              |
| Sample 9  | 4.22 a.u         | 3.19 a.u | 9.99 a.u  | -              |
| Sample 10 | 16.43 a.u        | 2.60 a.u | -         | -              |

The molecules presented in the table are toxic and dangerous to human life and all life forms in that area.

Drinking polluted water with cyanide that comes from pesticides used in agriculture or through inhalation may cause diseases that can lead to death. Clinical manifestations vary greatly, depending on the dose and method of exposure, and may range from slight irritation in the upper airway to the collapse of the cardiovascular and death within minutes.

Cyanide stops phosphorylation from being oxidized, which is a process by which oxygen is used to create the fundamental cellular energy sources known as ATP. In order to stop the mitochondrial transfer chain, it links to the cytochrome C oxidase enzyme. Then there is cellular hypoxia and ATP fragility, which results in metabolic acidosis. Weak vital processes are followed by oxygen being used by tissues [15].

Contaminated drinking water is the most frequent cause of long-term exposure to arsenic poisoning. Mining and agriculture both have the potential to contaminate with arsenic. Additionally, the soil and air may contain it.

Less than 10 to 50 g/L are advised for water (10–50 parts per billion). These proportions cannot be exceeded, thus drinking water needs to be treated because it is consumed on a daily basis [16].

Drinking water with arsenic concentrations of 0.0017 mg/L (1.7 ppb), 0.00017 mg/L, and 0.000017 mg/L has a lifetime risk of skin illness of 1 out of 10,000, 1 out of 100,000, and 1 out of a million, respectively, according to estimations from the US Environmental Protection Agency. At a water level of 0.01 mg/L (10 ppb), the WHO estimates that there is a 6 in 10,000 lifetime risk of developing skin malignant development, however this level of chance is acceptable [17].

The "largest mass hurting of a group in history"[18] was described by the World Health Organization as one of the worst incidents of arsenic harm from well water in Bangladesh, and it was noted as a major general medical issue. Both the Padma-Meghan fluvial fields in Bangladesh and the Ganga-Brahmaputra waterway fields in India demonstrated adverse consequences of pollution on human wellness.

Throughout the world, arsenic water pollution is a dangerous threat to environmental health. Continuous exposure to arsenic is a serious health danger since it increases the chance of a wide range of conditions, including kidney damage, diabetes, neurotransmitter damage, and cardiovascular abnormalities. Additionally, exposure to arsenic has an effect on liver function. Studies have shown that lung, bladder, and skin cancer are all encouraged by prolonged exposure to arsenic [19].

Toxicity of Phosphine when mixed with drinking water is well known, and even its danger to plants, animals and soil.

Similar to the symptoms seen after acute phosphine inhalation, non-specific symptoms brought on by metal phosphide eating appear within a few hours. These include effects on the heart, kidneys, liver, neurological system, and respiratory system [20].

Surface water is polluted with nitrates as a result of human agricultural activities and use of fertilizers that people use in agriculture.

Drinking water contaminated with nitrates causes human diseases such as weight loss, as well as that are harmful to plants and animals.

## 8. Conclusion

Raman spectroscopy is a spectroscopic technique that can perfectly identify the vibrational patterns of particles, although rotational and low-frequency patterns of the systems can be observed. And through it, the components and structure of materials can be identified.

The Raman spectra intensity of molecules is directly proportional to its concentration. It is very easy to quantitatively calculate the molar concentrations of components in water.

The water in those areas is very polluted, so the recommendations proposed to the officials to improve the quality of water

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Data Availability Statement

The database generated and/or analysed during the current study are not publicly available due to privacy, but are available from the corresponding author on reasonable request.

Declarations

Author declares that all works are original and this manuscript has not been published in any other journal.

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