Elemental Analysis of Satluj River Water Using EDXRF

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Abstract: A systematic study was carried out to explore the concentration of different low-Z elements present in the water samples of Satluj River in Himachal Pradesh, India. Water samples from four different locations were collected and analyzed for elemental analysis. In this study, energy dispersive x-ray fluorescence (EDXRF) technique has been employed. The degree of elemental pollution and the suitability of the river water for drinking purpose were assessed. A close look at the elemental concentration in water samples of different locations shows variation in concentrations but elements are within the safe limits as prescribed by Bureau of Indian Standards (BIS) and World Health Organization (WHO). The concentration of Ca and Fe is little higher. "[Nature and Science. 2010;8(3): 24-28]. (ISSN: 1545-0740)".

Keywords: EDXRF, Water Quality, x-ray tube, Pollution, Elemental Analysis

1. Introduction

Water is one of the most important natural resources. It is said to be our life because we need it for drinking, bathing, relaxing, fishing and irrigating purpose. Water is also used to produce energy and also we navigate in it. The water quality undergoes rapid changes due to contamination. The quality of ground water is continuously changing as a result of natural and human activities. River pollution has been a matter of global concern. Water is polluted due to different phenomenon [Sharma, 2004; Gupta *et al* 2009]. As a result of this, there is an increased emission of the dangerous elements into water, soil and air as well. The natural elements, which cause water pollution are gases, soil, minerals, humus materials, waste created by animals and other living organisms present in water. Several stomach, lever and skin diseases spread due to polluted water. Many investigations have found a correlation between cardiovascular deaths and water composition [Olı´as *et al*, 2004]. The disorder of teeth and bones is due to consumption of fluoride-rich water [Susheela, 1999].

Satluj River rises from beyond Indian borders in the Southern slopes of the Kailash mountain near Mansarover lake from Rakas lake, as Longcchen Khabab River in Tibet. It is the largest among the five Rivers of Himachal Pradesh. It leaves Himachal Pradesh to enter the plains of Punjab at Bhakhra, where the world's highest gravity dam has been constructed on this river. The upper tracts of the Satluj valley are under a permanent snow cover. The prominent human settlements that have come on the banks of the Satluj River are Namgia, Kalpa, Rampur, Tattapani, Suni and Bilaspur. The Satluj River is well fed with surface inflows of water and the under water springs contribute significantly to its water quantity and quality. Satluj is multipurpose in character and has great bearing on the socio-economic conditions of Himachal Pradesh. The River receives toxic metals, organic and inorganic pollutants from different sources like soil erosion, illegal construction activities and many other activities. The present study was motivated to substantiate the importance of the cleaning operation by analyzing the four water samples collected from different locations of Satluj River.

EDXRF technique is a powerful, fast and non-destructive multi-elemental technique in the basic and applied research to determine the elemental composition of various types of samples, e.g., archaeological, biological, geological or environmental samples and is capable of detecting elements up to the limit of ppm [He *et al*, 1991]. This technique uses x-rays to cause characteristic fluorescence emission from the specimen atoms. Those characteristic signals are detected to identify which elements are present, and their relative intensities can be used to quantify the amounts of those elements. This technique has been used for a long time for the elemental analysis [Abraham *et al*, 1999; Malmqvist, 1990; Cahill *et al*, 1990] of the specimen from biological sciences, archaeology, environmental science and earth-science.

2. Review of Literature

Joshi et al. [Joshi *et al*, 2006] have used EDXRF technique has been employed to determine the concentrations of different elements in water samples collected from different locations of famous Nainital Lake including tap water and spring water sample from Nainital (Uttarakhand). Bandhu et al. [Bandhu et al, 2000] have studied the elemental concentration of the aerosol samples collected from industrial, commercial and relatively cleaner zones from the city of Chandigarh using EDXRF and PIXE techniques. Negi et al. [Negi *et al*, 1987] have reported the urban aerosol composition for both major and trace elements, determined using EDXRF technique, in four major cities of India, namely, Bombay, Banglore, Nagpur, and Jaipur. The study on the sandflies of the Satluj

river valley [Sharma *et al*, 2009] and the snow and glacier melt in the Satluj River at Bhakra Dam in the western Himalayan region [Singh *et al*, 2002] are available in the literature.

3. Experimental details

3.1 Sample collection and preparation

Water samples from the four different locations of the Satluj River at Rampur (slnram), Tattapani (slntat), Suni (slnsun) and Bilaspur (slnblp) in Himachal Pradesh were collected in plastic containers of 5000 ml capacity. The sample containers were cleaned thoroughly with distilled water before using. Each sample was passed through a coarse 2 mm screen to remove organic debris and then through a 250 lm nylon screen into a pre-cleaned plastic container. These samples were prepared within two days from time of collection. Each sample was dried in an oven at constant temperature of 50°C. After drying, each sample was ground using a freezer-mill. The thin samples were prepared by mixing and pressing the powder. Each sample was glued onto a Mylar film. To be sure that the sample holder was not going to introduce analytical errors, blanks were previously checked. A total of 12 samples (three from each location) were analyzed, corresponding to a minimum of three replicates per sample, to reduce the risk of analytical error.

The water samples were analyzed using EDXRF technique, available at Panjab University, Chandigarh, without any chemical pre-treatment. The targets were mounted into a target holder specially made for irradiation of thin target. The targets were irradiated using a Cu anode x-ray tube (Panalytical x-ray generator, model PW 3830 4kW). The tube voltage was kept at 29 kV and current 12 mA. The spectra were recorded using a Le(Ge) detector coupled to a PC based multichannel analyzer (MCA) through a spectroscopy Amplifier. The resolution of the Le(Ge) detector is about 143 eV at 5.89 keV. Measurements were carried out in vacuum of 10^{-2} Torr for optimum detection of elements. This set-up resulted in considerably improved peak-to-background ratio in the region of Rayleigh and Compton-scatter peaks. Three spectra were taken for each target using a PC-based multichannel analyzer (Canberra, Model S-100). Further to minimize the systematic errors, different spectra for each target were taken from different positions of the same target and on different occasions. The background spectrum in the region of elastic and inelastic-scatter peaks, taken with no target placed at its position, was found to be smooth. The partial x-ray spectrum of one water sample from Bilaspur is shown in Figure 1.

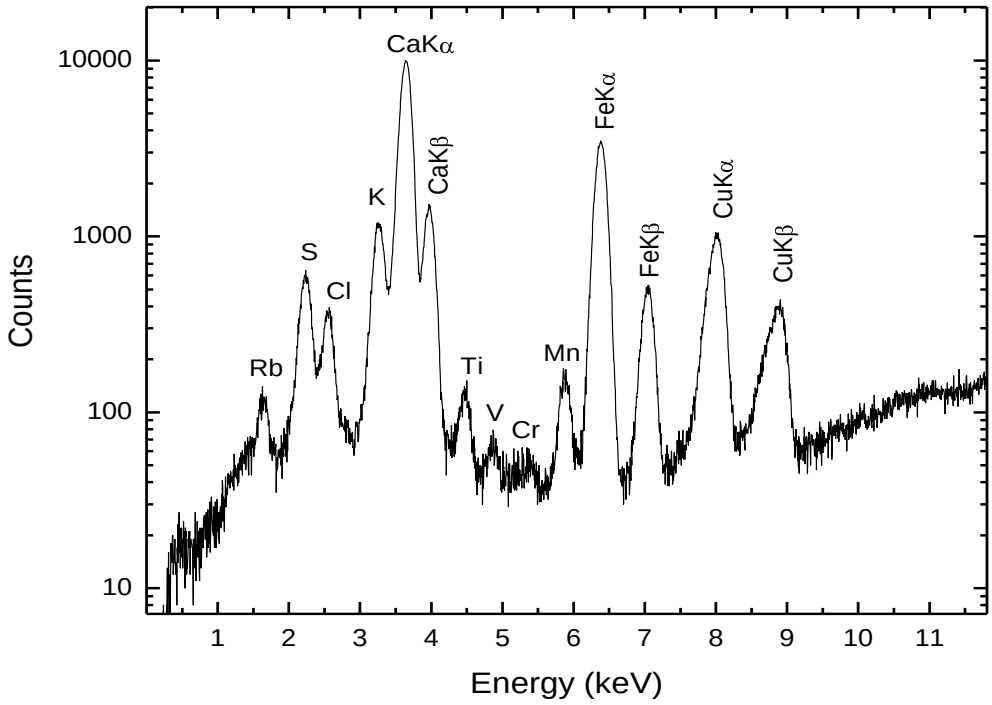

Fig.1 EDXRF spectrum of Bilaspur water sample

3.2 Data Analysis

The energies of the characteristic x-rays were used to identify the elements present in the water samples. The photopeak areas in each spectrum were analyzed using the indigenously developed computer code PEAKFIT [Singh *et al*, 1995]. The concentration

of the elements was calculated using the iteration on the masses of the samples and the relation

$$m_j = \frac{N_{ij}}{I_o G \varepsilon \sigma_{ij} \beta_i} \qquad (1)$$

where m_j is the concentration (μg/cm^2) of the element j present in the sample, Nij is the net counts per unit time for ith group of x-rays of element j, I_oG is the intensity of the exciting radiation incident on the sample visible to the detector, ε is the detector efficiency for the jth element, σ_{ij} is the theoretical x-ray fluorescence cross-section at the incident photon energy. These cross-sections were interpolated from the tabulations of Puri et al. [Puri *et al*, 1995]. All the calculations were done using more intense Cu Kαβ incident photon energy from Cu x-ray tube.

The $I_oG\varepsilon$ values were determined over the energy range 1-8 keV by measuring the $K\alpha$ and $K\beta$ x-rays from the different targets excited by the Cu *K* x-rays and using the relation

$$I_o G\varepsilon = \frac{N_{KX}}{m\left[\sigma_{KX}^{\alpha}\beta_{KX}^{\alpha} + \sigma_{KX}^{\beta}\beta_{KX}^{\beta}\frac{(I_oG)_{\beta}}{(I_oG)_{\alpha}}\right]} \qquad (2)$$

where N_{KX} is the counts/s under the $K\alpha$ or $K\beta$ x-ray peak of the element in the spectrum. The superscripts α and β correspond to the incident Cu $K\alpha$ and $K\beta$ x-rays, respectively. σ_{KX}^{i} ($i = \alpha, \beta$) is the *K* x-ray fluorescence cross-section for the target element at the Cu $K\alpha$ and $K\beta$ x-ray energies, respectively, and has been interpolated from the tables of Puri *et al.* [Puri *et al*, 1995]. $\frac{(I_oG)_{\beta}}{(I_oG)_{\alpha}}$ is ratio of intensities of the $K\beta$ and $K\alpha$ x-rays emitted from the Cu x-ray tube. The $I_oG\varepsilon$ values obtained in measurements using the Le(Ge) detector are shown in Figure 2. The self-absorption correction factor (β_i), which accounts for absorption of the incident and emitted photons from the target, was evaluated using the relation

$$\beta = \frac{1-\left[\exp(-1)\left(\mu_1 \sec\theta_1 + \mu_2 \sec\theta_2\right)m\right]}{\left(\mu_1 \sec\theta_1 + \mu_2 \sec\theta_2\right)m} \qquad (3)$$

where μ_1 and μ_2 are the total mass-attenuation coefficients (cm^2/gm) of the target element corresponding to the incident and emitted photon energies, respectively. θ_1 and θ_2 are the angles formed by the incident and the emitted photons with normal to the target surface respectively, *m* is thickness of the target in gm/cm^2. For the geometry used in the present measurements, θ_2 is taken to be 0° as the fluorescence x-rays are presumed to strike the detector perpendicular to its surface. The values of μ_1 and μ_2 were taken from the tables of Hubbell and Seltzer [Hubbell *et al*, 1995], and Storm and Israel [Storm *et al*, 1970]. The beta correction is about 0.999 as thin samples were used.

4. Results and discussions

The EDXRF analysis applied in elemental analysis of water samples from Satluj River. Elements such as S, Cl, Ca, Ti, V, Cr, Mn and Fe are measured. The final concentration of the elements present in the different samples is given in Table 1. The Cu Kα and Cu Kβ peaks are of the x-ray tube anode used. It can be seen from the peak heights that there is no variation between the fractions for elements such as K, Ca, Ti and Fe. In regard to the concentration change of the heavy metals along the Satluj River, water samples showed the little higher concentrations of Ca and Fe. The concentration of calcium may be due to nearby prevalence of mountain chains with high calcium contents. Calcium is responsible for the hardness of the water. The hardness of the water leads to encrustation of water supply structure. It can be explained that dilution, precipitation, adsorption to sediments and local anthropogenic input probably affect metal concentrations in the Satluj River water.

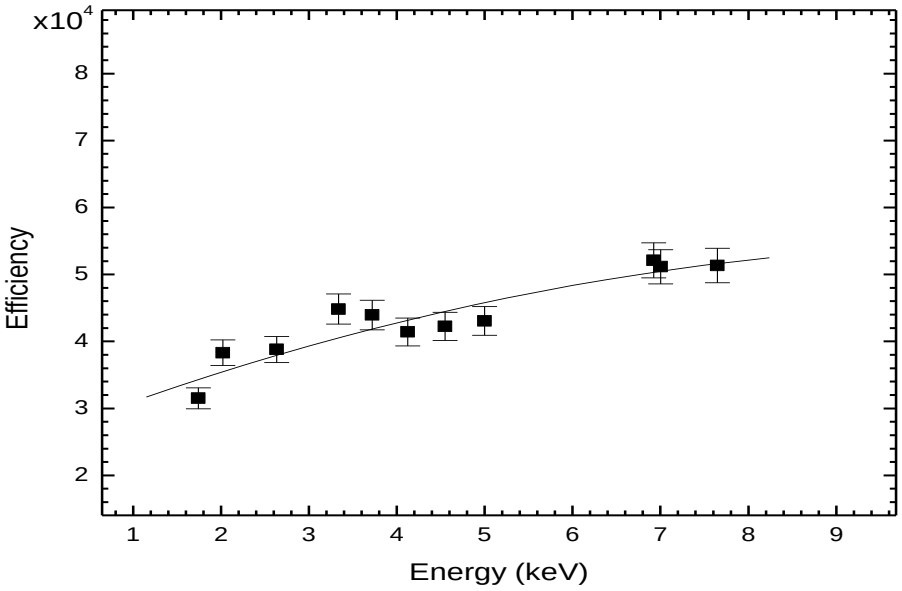

Fig.2 Plot of loGε Vs the detected photon energy

Table 1. Elemental concentration in Satluj River water at different locations

Element	Slnram	Slnsun	slntat	Slnblp
S (μg/cm^2)	46.4	40.9	70.2	38.2
Cl (μg/cm^2)	8.7	16.1	13.2	14.3
Ca (μg/cm^2)	188.4	151.9	169.9	176.9
Ti (μg/cm^2)	ND	.29	ND	.96
Cr (μg/cm^2)	.062	ND	ND	ND
Mn (μg/cm^2)	.043	ND	ND	.54
Fe (μg/cm^2)	3.4	3.8	2.178	14.2

ND → not detected

The energies of elements observed in the present work are given in the Table 2. Samples were analyzed using EDXRF technique without any chemical pre-treatment. A close look at the elemental concentration in table for water samples of different locations shows variation in concentrations but all elements are within the safe limit. The EDXRF method has proven to be a useful tool for elemental analysis of water samples. The strength of the technique relies on simple preparation of the samples, a reasonable time of measurement, and a non-complicated data analysis. Besides, the calculated concentrations are accurate and reliable.

Table 2. Energies of K x-rays of the elements observed in the present work

Atomic number	Element	Kα (keV)	Kβ (keV)
16	S	2.307	2.468
17	Cl	2.621	2.815
20	Ca	3.690	4.012
22	Ti	4.508	4.931
23	V	4.949	5.427
24	Cr	5.411	5.947
25	Mn	5.895	6.492
26	Fe	6.400	7.059

5. Conclusions

It is always necessary to monitor the environment, for essential as well as toxic elements in order to understand the correlation of the environment with the biological system. The EDXRF analysis of water samples of Satluj River at Rampur, Tattapani, Suni and Bilaspur in Himachal Pradesh, India, shows that the concentrations of toxic

elements are less than the safety limits. Our study confirms that cleaning operation has reduced the contents of toxic elements from the Satluj River water, which is now quite safe for drinking as well as irrigation purpose. The indigenous technologies should be adopted to make water fit for drinking after treatment such as defluoridation, desalination, etc. These evaluations seem to be helpful in planning future experiments to achieve high accuracy for important elements in water solutions. EDXRF analysis can, therefore, be used to monitor River water quality and provide useful information for regulatory organizations, such as regional councils and governmental bodies. Our study reveals that EDXRF can be used to measure the elemental concentrations in different water samples.

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