International Journal of Current Science Research
www.drbgrpublications.in

Effect of Fireworks and related industries on Indian traditional medicinal plants around Anaikuttam - A quantification based case study of Alkaline earth metals (Ba^{2+}, Sr^{2+}, Mg^{2+}) and Titanium

B. Ganeshwari[1], M. Bhavanieshwari[1], T. Jeyakumaran[2] and T. Victor Athisayam[1*]

[1]*Department of Biotechnology, Sri Kaliswari College (Autonomous), Sivakasi, Tamilnadu, India*

[2]*Department of Physics, Sri Kaliswari College (Autonomous), Sivakasi, Tamilnadu, India*

[*]*Corresponding Author e-mail id: athisayam.victor@gmail.com*

Abstract

Sivakasi, often branded as "Little Japan" due to its year-round manufacturing of matchboxes, firecrackers, and printing materials, confronts environmental challenges. The matchbox and fireworks industries rely heavily on minerals and metals to produce colorful products. Barium (Ba^{2+}), Strontium (Sr^{2+}), Copper (Cu^{2+}), and combinations of Titanium (Ti^{4+}), Magnesium (Mg^{2+}), and sodium salts (Na^{2+}) contribute to the vibrant colors in firecrackers. However, the release of these metal ions as particulates during testing and use pollutes the air, soil, and crops. Despite Sivakasi's limited agricultural production, various roadside and Indian traditional medicinal plants have grown around these industries. Likewise, Anaikuttam, a village has fireworks and match box industries surrounded by many medicinal plants. Among the traditional medicinal plants, Phillanthus niruri L. in Tamil (Keela nelli) has been checked to accumulate significant amounts of heavy metals, including Ba^{2+}, Fe^{2+}, Sr^{2+}, Mg^{2+}, Zn^{2+}, Ti^{4+}, Cu^{2+}, and Mn^{2+} from the cracker industries. The Raman spectra of the samples confirm that the Keelanelli medicinal plant strongly absorbs Ba, Sr, Mg, and Ti ions in the vicinity of the Sivakasi cracker industry area.

Keywords: Heavy Metals, Minerals, Accumulation, Sivakasi, Fireworks

Introduction

Sivakasi is a city in Virudhunagar district in the Indian state of Tamil Nadu. In the World Japan is the leader in the production of electronics. Similarly Sivakasi is the leader in the production of Printing products, Firecrackers and Safety match boxes. So, the name “Little Japan” was given to the “Town of Sivakasi”. In Sivakasi the first firework industry was started earlier in the 20^{th} century. The economy of Sivakasi is dependent on three major factories including Firecrackers, Match box manufacturing and Printing industries. In 2020 there are around 1070 registered firecracker manufacturing companies in Sivakasi and 8 lakh people were directly and indirectly employed by the industry. In 2011, the combined estimated turnover of the firecracker, match box and printing industry in the city was around $20 billion. Approximately 70% of the firecrackers and match boxes produced in India are from Sivakasi. The hot and dry climate of the city is conductive to the firecracker and match box industries (Nandhakumar *et al.*, 2023).

The firecracker and match box industries used mainly metals as a source of colour for making crackers and match sticks. Especially *Calcium Chloride, Sodium Nitrate, Barium Chloride, Copper Chloride, Magnesium Chloride, Strontium, Titanium Zinc Chloride* metals are leads to attractive colours in the crackers. Calcium is regularly used to deepen a variety of different colours in crackers. Copper compound produce blue colours in crackers. Iron is used to produce sparks. The heat of the metals determines the colour of the sparks. Sodium is used for giving a bright gold or yellow colour to firecrackers. However the brightness of the colour can easily overshadow other colours. Barium is involved in the production of green firecrackers and can stabilize some other volatile elements involved in firecrackers production. Similarly, Lithium and Stronium are used to produce red colours in firecrackers and stabilizing a variety of more volatile firecrackers mixtures. Magnesium is used to improve the brilliance of firecrackers. Titanium metal can be burned as powder or flakes to produce silver sparks (Yang *et al.*, 2005).

Firecrackers can indeed contribute to heavy metal accumulation in soil due to the metals present in their compositions. When firecrackers are ignited, they release fine particles containing heavy metals such as lead, copper, barium, and strontium into the air. These particles eventually settle into the soil surface or may be carried by rainwater. The repeated bursting of firecrackers can lead to the buildup of heavy metals in the soil. Once deposited, these metals can persist for long periods, especially in soils with low organic matter content or in areas with limited microbial activity to break them down. Heavy metal accumulation in soil can have detrimental effects on soil quality, ecosystem and animal health. High concentrations of heavy metals can interfere with soil microbial activity, disrupt nutrient cycling processes, and potentially harm soil-dwelling organisms. Additionally, these metals can leach into groundwater, posing risks to aquatic ecosystems and human health if contaminated water sources are consumed. Efforts to mitigate heavy metal accumulation in soil from fireworks may involve limiting the use of heavy metals in fireworks compositions, implementing cleanup measures after firecrackers displays, and promoting the use of alternative materials that are less harmful to the environment. Additionally, proper soil management practices, such as soil testing and remediation techniques, can help reduce the impact of heavy metal contamination in affected areas (Singh *et al.*, 2011).

Apart from the soil, these smoke and metals not only pollute the air, soil but does accumulate metals in crop plants. Firecrackers residue can lead to the accumulation of heavy metals in soil and plants. Once deposited in the soil, these metals can be taken up by plant roots and translocated to various plant tissues. As a result, heavy metal concentration in plants can increase, posing risks to plant health and potentially affecting ecosystems where these plants are located. Excessive accumulation of heavy metals in plants can lead to physiological stress, reduced growth, and impaired nutrient uptake. Additionally, heavy metals can accumulate in the food chain, posing risks to animals and humans while consume contaminated plants. These metals can affect the plant growth, metabolism and yield by affecting the chlorophyll pigments, chloroplast ultrastructure and disorganization of mitochondria. Overall, heavy metals have a wide range impact on plant growth and physiology (Yadav, 2010).

The heavy metals also affect human health and animals, if exposure occurs, either directly or indirectly. Fine particles containing heavy metals from fireworks can be inhaled, especially during and immediately after fireworks displays. Inhalation of these particles can lead to respiratory irritation, exacerbate existing respiratory conditions such as asthma, and potentially cause long-term lung damage. Heavy metals deposited onto surfaces, soil, or water sources can contaminate food and drinking water. If crops or water sources are contaminated with heavy metals from fireworks residue, consumption of these contaminated foods or water can lead to heavy metal poisoning. Chronic exposure to heavy metals like lead, cadmium, and mercury can cause neurological damage, kidney damage, and other health problems. Direct contact with fireworks residue, particularly through skin contact, can potentially lead to skin irritation or allergic reactions, especially in individuals with sensitive skin. Agricultural practices, industrial activities, and pollution are major contributors to heavy metal contamination in the environment (Chaudhary *et al.*, 2004).

Although Sivakasi is not a major productive for agriculture but some medicinal plants were grown in between and around the firework industries. Some medicinal plants available in field are *Senna Alexandria mill.* (Avuri), *Senna auriculata (L). Roxb* (Avaaram), *Phyllanthus niruri L.*(Keelanelli), *Catharanthus roseus (L).G.Don* (Nithyakalyani), *Hibiscus Rosasinensis L.* (Sembaruthi), *Morinda tinctoria Roxb* (Manjanathi), *Solanum torvum SW. (*Sundakkai), *Vitex negundo.L* (Nochchi), *Lawsonia inermis L. (*Marudhani), *Acalypha amaranthus L.* (Kuppaimeni). Here we focused on keelanelli (*Phllanthus niruri* L.) alone for the analysis of metals uptake.

Materials and Methods

Plant Sample Collection

The plant samples were collected from firework industries located in Anaikuttam village, Sivakasi, Virudhunagar district, Tamil Nadu. The medicinal plants (Keelanelli) collected from the place and its location was showed in the Table 1.

Table 1: Medicinal plant name, collected place and its distance from the fireworks Industries

S.No.	Plant Name (Local Name)	Scientific Name	Plant samples collected from the place	Fireworks location from the plant sample collected area
1.	Keelanelli	*Phyllanthus niruri L.*	Anaikuttam	Within 2 Km

Plant Sample Preparation

The collected plant samples were split into leaf, root, shoot, seeds and flowers and kept for drying in room temperature for two months.

Preparation of Powdered Samples

The dried samples were grind with the help of mixer individually. The plant parts are the leaf, flower, stem, root, pod grind in the use of mixer.

Raman Spectroscopy Analysis

Shimadzu UV Raman spectrometer was used to collect spectra from different kinds of plant tissues. For each spectral acquisition, the powdered plant tissue was gently positioned at the nozzle of the spectrometer. Acquisition time was 1 s; laser power was 495 mW. Baseline correction was performed automatically by the spectrometer. These conditions were found to be non-destructive as no visual damage of plant leaves was evident after spectral acquisition (Sanchez *et al.*, 2019). A total of 10 spectra were collected from different tissues of three different medicinal plants.

Results

Sample collection and preparation

The Keelanelli medicinal plant parts are taken from the Anaikuttam and dried completely. The plant parts are kept separately dried and sent for Raman spectra analaysis.

Table 2: Keelanelli samples kept for drying

S.No.	Plant Name	Botanical Name	Different Plant Tissues				
			Seed	Root	Stem	Leaves	Flower
1.	Keelanelli	*Phyllanthus niruri L.*	✓	×	×	✓	×

Figure. 1: Keelanelli from Anaikuttam, Sivakasi. *Phyllanthus nirurii L.*: (leaves & stem)

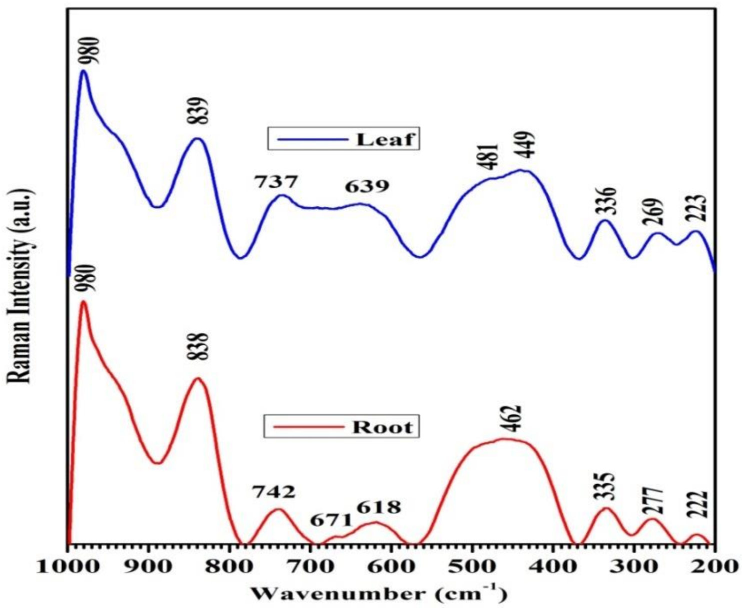

Figure 2: Raman spectra of leaf and root parts of the Keelanelli plant

Figure 2 represented the Raman spectra of different parts of the Keelanelli plant in the wavenumber range of 200-1000 cm^{-1}. The strongest peaks observed around 980 and 839 cm^{1}, and weak peaks located around all the samples at 335 and 222 cm^{-1}correspond to the Ba-O bond vibrations (De Waal *et al.,* 1998). The broad peaks around 400 to 530 cm^{-1}, and weak peaks located around all the samples around 269 cm^{-1} correspond to the Mg-O and Sr-O bond vibrations respectively (Maria Dekermenjian *et al.,* 2023; Luciano *et al.,* 2021). The broad peak appearing from 580 to 780 cm^{-1} and the weak peak located around all the samples at 222 cm^{-1} correspond to the Ti-O bond vibrations (Toshiaki Ohsaka *et al.,* 1978). The peak present around all the samples around 737 cm^{-1} corresponds to the NO_2 band (Christian Hess *et al.,* 2003). The broad peaks in the ranges from 380 to 570 cm^{-1} and 580 to 770 cm^{-1} are due to multiple vibrations appearing within those ranges. All of the observed results support with earlier reports. The Raman spectra of the samples confirm that the Keelanelli medicinal plant strongly absorbs Ba, Sr, Mg, and Ti ions in the vicinity of the Sivakasi cracker industry area.

Raman spectroscopy analysis

The medicinal plant, *P. niruri* for the initial prediction of heavy metals in the plant tissues by Raman Spectroscopy. For the Raman analysis, the samples were sent to Physics Department, SRM University, Kaatankulathur, Chennai with the help of our Physics

Department Assistant Professor, Dr. T.Jeyakumaran. The analysis was carried out in the instrument UV-3600Plus Series, Model (S/N): UV3600 (A12015600584.

Recently, Raman spectroscopy extensively used for the study of plant tissues (Agarwal, 2006). Raman microscopy is widely used to study plant cell wall composition (Gierlinger, 2017) and xylem cells in different plants (Prats Mateu *et al.*, 2016; Horbens *et al.,* 2014; De Meester *et al.,* 2018; Hanninen *et al.*, 2011; Szymańska-Chargot *et al.*, 2016).

Discussion

Keelanelli (*Phyllanthus niruri* L), a medicinal plant known for its hepatoprotective properties, has been found to accumulate high amounts of heavy metals. Raman spectroscopy, a non-destructive analytical technique, provides insights into how these metals interact with plant tissues at the molecular level. This study discusses the uptake mechanism, potential environmental implications, and the plant's role in phytoremediation (Puttaraju *et al.*, 2025).

Plants absorb heavy metals primarily through their root systems from contaminated soil or water. *Keelanelli* exhibits hyperaccumulation tendencies due to, High-affinity metal transporters in roots, complexation of metals with organic acids and secondary metabolites and effective compartmentalization in vacuoles to reduce toxicity. The ability of *Keelanelli* to absorb Ba, Sr, Mg, Ti may give positive and negative effects. Possibly this plant can be used for decontaminate the polluted firework area and make the soil become fertile. On the other side, the plants grown in firework chemicals contaminated soil, may introduce the toxic metals into the food chain when we used as herbal medicines (Hlihor *et al.*, 2022).

Conclusion

The presence of Ba, Sr, Ti, and Mg heavy metals in the medicinal plant *P. niruri* were predicted through Raman Spectroscopy analysis. Further to confirm the determination of Ba, Sr, Ti, and Mg, EDAX study is essential. Raman spectra analysis provides strong evidence of Keelanelli's ability to uptake and bind heavy metals. While this property makes it a potential candidate for phytoremediation, further studies are needed to assess its safety in medicinal applications. Understanding metal accumulation mechanisms at the molecular level can help optimize its use for environmental and health benefits.

References

Agarwal, U.P (2006) Raman imaging to investigate ultrastructure and composition of plant cell walls: Distribution of lignin and cellulose in black spruce wood (*Picea mariana*). *Planta* 224: 1141-1153.

Chaudhary, P., S.S Dudeja, K.K Kapoor, (2004). Effectivity of host-Rhizobium leguminosarum symbiosis in soils receiving sewage water containing heavy metals. *Microbiological Research*, 159 (2): 121-127

Christian Hess and Jack H. Lunsford. (2003). NO2 Storage and Reduction in Barium Oxide Supported on Magnesium Oxide Studied by inSitu Raman Spectroscopy J. Phys. Chem. B. 107: 1982-1987.

De Meester, B., de Vries, L., Özparpucu, M., Gierlinger, N., Corneillie, S., Pallidis, A., Goeminne, G., Morreel, K., De Bruyne, M., De Rycke, R. (2018). Vessel-specific reintroduction of CINNAMOYL-COA REDUCTASE1 (CCR1) in dwarfed ccr1 mutants restores vessel and xylary fiber integrity and increases biomass. *Plant. Physiol*. 176: 611-633.

De Waal, K.-J. Range, M. Konigstein and W. Kiefe, (1998). Raman spectra of the barium oxide peroxide and strontium oxide peroxide series. *Journal of Raman Spectroscopy*. 29: 109-113.

Gierlinger, N., Schwanninger, M. (2006). Chemical imaging of poplar wood cell walls by confocal Raman microscopy. *Plant. Physiol*. 140: 1246-1254.

Hanninen, T. Kontturi, E. Vuorinen, T. (2011). Distribution of lignin and its coniferyl alcohol and coniferyl aldehyde groups in Picea abies and Pinus sylvestris as observed by Raman imaging. *Phytochemistry* 72: 1889-1895.

Hlihor RM, Roșca M, Hagiu-Zaleschi L, Simion IM, Daraban GM, Stoleru V. (2022) Medicinal Plant Growth in Heavy Metals Contaminated Soils: Responses to Metal Stress and Induced Risks to Human Health. *Toxics*. 10(9):499.

Horbens, M., Feldner, A., Höfer, M., Neinhuis, C. (2014). Ontogenetic tissue modification in Malus fruit peduncles: The role of sclereids. *Ann. Bot*. 113: 105-118.

Luciano F. Filho, Fernando N. N. Pansini, Fábio A. L. de Souza (2021). Size and shape effects on the stability, electronic structure, and Raman spectroscopy of (SrO)n nanoclusters. *Int. J. Quantum Chem*. 121: e26642.

Maria Dekermenjian, Andreas Peter Ruedigerb and Alexandre Merlen, (2023). Raman spectroscopy investigation of magnesium oxide nanoparticles *RSC Adv*., 13: 26683.

Nandhakumar, R., & Venkatesan, K. (2023). A process parameters review on selective laser melting-based additive manufacturing of single and multi-material: Microstructure, physical properties, tribological, and surface roughness. *Materials Today Communications*, 35: 105538.

Prats Mateu, B., Hauser, M.T., Heredia, A., Gierlinger, N. (2016). Waterproofing in Arabidopsis: Following Phenolics and Lipids In situ by Confocal Raman Microscopy. *Front. Chem*. 4: 10.

Puttaraju, T. D., Soundarya, T. L., Al-Sadoon, M. K., Nagaraju, G., & Manjunatha, M. (2025). Eco-inspired synthesis of ZnO/CuO nanocomposites using Phyllanthus niruri: unveiling superior photocatalytic, antibacterial efficacy against Escherichia coli and Staphylococcus aureus, and latent fingerprint applications. *Brazilian Journal of Chemical Engineering*.

Sanchez, L., Pant, S., Mandadi, K. et al. (2020). Raman Spectroscopy vs Quantitative Polymerase Chain Reaction In Early Stage Huanglongbing Diagnostics. *Sci Rep* 10: 10101

Singh, Dr. Jiwan & Kalamdhad, Ajay. (2011). Effects of Heavy Metals on Soil, Plants, Human Health and Aquatic Life. *International Journal of Research in Chemistry and Environment*. 1: 15-21.

Szymańska-Chargot, M.; Chylińska, M.; Pieczywek, P.M.; Rösch, P.; Schmitt, M.; Popp, J.; Zdunek, A. (2016). Raman imaging of changes in the polysaccharides distribution in the cell wall during apple fruit development and senescence. *Planta* 243: 935–945.

Toshiaki Ohsaka, Fujio Izumi and Yoshinori Fujiki. (1978). Raman Spectrum of Anatase, TiO. *Journal of Raman Spectroscopy*, 7(6): 32.

Wilschefski SC, Baxter MR. Inductively Coupled Plasma Mass Spectrometry: Introduction to Analytical Aspects. *Clin Biochem Rev*. 2019 Aug; 40(3):115-133.

Yadav, S.K. (2010). Heavy metals toxicity in plants: An overview on the role of glutathione and phytochelatins in heavy metal stress tolerance of plants. *South African Journal of Botany*, 76 (2): 167-179.

Yang, Xiaoe, et al. (2005). Molecular mechanisms of heavy metal hyperaccumulation and phytoremediation. *Journal of trace elements in medicine and biology* 18(4): 339-353.