visualization, historical data logging, and ICAO compliant reporting. The app receives data via the XBee module and stores it in a secure local database, generating alerts through visual and auditory cues when exposure exceeds safe limits. It also supports exporting audit ready reports for occupational health compliance, making it a valuable tool for both individual safety and institutional oversight.

Field trials conducted at Robert Gabriel Mugabe International Airport demonstrated the system's effectiveness in detecting radiation spikes during baggage scanning, successfully triggering alerts and logging data. Airport personnel reported increased confidence in safety protocols and improved awareness of radiation risks. Below is the abstract block diagram of the system.

Simulation results and performance comparison. A prototype arm band was developed using textile-integrated sensors and tested in simulated airport environments. Radiation sources included a cabinet X-ray scanner. Sensors were calibrated using known radiation sources. The system demonstrated sensitivity thresholds of:

$$X - ray: 0.01\ \mu Sv/h;$$
$$Radar: 0.1 mW/(cm^2).$$

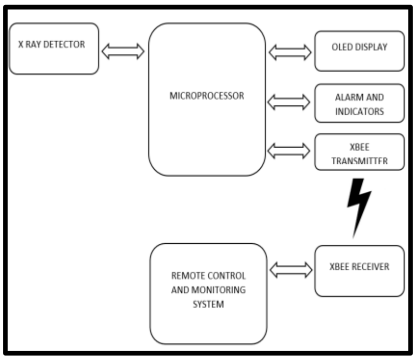

Figure 1 – Radiation Detection System Block Diagram

Field trials were conducted at Harare International Airport. The system successfully detected radiation spikes during baggage scanning and radar sweeps, triggering alerts and logging data. The system supports ICAO compliance by monitoring exposure levels, generating ready audit reports and providing real time alerts to prevent overexposure. Airport workers wearing the system reported increased awareness and confidence in their safety. The system enables proactive risk management and supports health surveillance programs. Sensor degradation due to humidity and mechanical stress remains a challenge. Future work will focus on encapsulation techniques and robust textile integration. Cost-effective mass production and integration into standard uniforms are necessary for widespread adoption. Collaboration with Civil Aviation Authority of Zimbabwe (CAAZ) and ICAO is essential for policy alignment and certification.

Conclusions. The wearable radiation detection system offers a practical solution to enhance safety in Zimbabwean airports. By aligning with ICAO standards and leveraging advanced sensor technology, the system empowers workers and protects passengers from radiation risks. Its successful implementation could serve as a model for other developing nations seeking to modernize aviation safety infrastructure.

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SUSTAINABLE RECOVERY OF HIGH-PURITY AMORPHOUS SILICA FROM LOCAL SAND DEPOSITS IN ZIMBABWE USING CITRIC ACID LEACHING PRE-TREATMENT

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Abstract. This study presents an alternate process for utilization of Zimbabwean silica sand to produce high-purity amorphous silica. The objective was to develop an optimum multi-stage purification that is environmentally friendly. The methodology starts with pre-treatment step with hydrochloric acid, followed by citric acid chelation stage to remove metallic oxide impurities. The pre-treated silica sand was then converted into sodium silicate intermediate through digestion with sodium hydroxide, from which high-purity silicic acid was precipitated using sulfuric acid. Studies on the chelation stage identified the optimal conditions for maximum impurity removal as a citric acid concentration of 4 M , a leaching duration of 4 hours, and a solid-to-liquid ratio of 1:4, all conducted at a temperature of 90 °C . Under these conditions, 70.3 g of high-purity amorphous silica was obtained from 100 g of silica sand. The results demonstrate that this approach, using organic acid leaching with a chemical conversion and precipitation route, represents a viable and effective pathway for upgrading lower-grade silica resources into a high-value precursor material suitable for semiconductor applications.

Keywords: High-purity silica, Amorphous silica, Zimbabwean sand, Citric acid leaching, precipitated.

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Introduction. "High-purity silica (SiO_2, >99.8 %) is important for modern technologies, as the precursor for semiconductor-grade silicon used in microprocessors, memory chips, and other electronic devices [1, 2]. Demand for high-purity silica is rising due to renewable energy, 5G, and consumer electronics, yet naturally occurring quartz meeting strict purity standards remains limited [4, 7] Focus on current research is on upgrading lower-grade silica sands, which contain impurities like Fe_2O_3, Al_2O_3, TiO_2, and alkali metals [9]. These contaminants can severely degrade the performance of the final products even at trace levels. Hence the need to development a robust and economically viable purification pathway. Traditional purification strategies are aggressive and detrimental to the environment, including high-temperature chlorination and leaching with strong mineral acids like hydrofluoric (HF) and sulfuric acid (H_2SO_4) [10]. Whilst effective, conventional processes are costly and hazardous, prompting the search for sustainable alternatives. This study explores purification using citric acid, a biodegradable chelating agent [13]. The leaching step is coupled with a subsequent conversion of the purified silica into a water-soluble sodium silicate intermediate. This chemical transformation, a cornerstone of industrial silicate production [14], facilitates a phase-separation purification, allowing for the removal of acid-insoluble mineral impurities before the final precipitation of high-purity amorphous silica. Transforming a relatively low-value raw mineral into a high-value industrial precursor can enhance economic returns and strengthen domestic supply chains for critical materials [8].

Experimental Procedure

Materials. Silica sand from Zimbabwe was used as the primary raw material. Analytical grade reagents (HCl 37 %, citric acid $C_6H_8O_7$, NaOH, and H_2SO_4 98 %) were used without further purification, and distilled water was employed for all solution preparations and washing.

Parametric Optimization of Citric Acid Chelation. A number of batch experiments were conducted to determine the best conditions for the removal of impurities using citric acid. For each experiment, a consistent starting mass of 20.00 g of sand, previously subjected to washing and HCl pretreatment, was used. The leaching process was carried out in a temperature-controlled reaction vessel with continuous stirring. The extent of impurity removal was quantified by gravimetric analysis, calculated using the equation:

Impurity Removal = ((Initial Mass-Final Mass))/(Initial Mass) × 100.

Experiment 1: Effect of Citric Acid Concentration

The effect of acid concentration on impurity removal was investigated by varying the molarity of the citric acid solution (1.0 M, 2.0 M, 3.0 M, 4.0 M, and 4.8 M). The following conditions were held constant: solid-to-liquid (S:L) ratio of 1:4, leaching time of 3 hours, and temperature of 90 °C [16].

Experiment 2: Effect of Leaching Time.

To determine the optimal reaction duration, the leaching time was varied (1, 2, 3, 4, and 5 hours). The experiment was conducted using the optimal concentration determined from the previous step (4.0 M citric acid), while maintaining a constant S:L ratio of 1:4 and a temperature of 90 °C [16].

Experiment 3: Effect of Solid-to-Liquid Ratio

The influence of the S:L ratio was examined by varying the ratio between the mass of sand and the volume of the leaching solution (1:1, 1:2, 1:3, 1:4, and 1:5). This series of tests was performed using the previously determined optimal conditions of 4.0 M citric acid and a 4-hour leaching time, at a constant temperature of 90 °C [16].

Results and Discussion.

Optimization of Impurity Removal by Citric Acid Leaching. The results of the parametric studies demonstrate a clear and systematic relationship between the leaching conditions and the efficiency of impurity removal.

Effect of Citric Acid Concentration. The first experiment showed that increasing citric acid concentration from 1.0 M to 4.0 M raised impurity removal from 1.50 % to 9.50 %, after which no further improvement was observed up to 4.8 M. The trend reflects enhanced chelation of Fe^{3+} and Al^{3+} impurities by citrate ions, with the levelling off at 4.0 M indicating equilibrium or limitations due to residual impurities.

Effect of Leaching Time. Experiment on effect of Leaching Time showed impurity removal rising from 2.50 % at 1 h to 10.00 % at 4 h, with only a slight increase to 10.15 % at 5 h. This indicates most surface impurities are removed within 4 h, after which leaching nears completion.

Effect of Solid-to-Liquid Ratio. Experiment showed that decreasing the S:L ratio from 1:1 to 1:4 improved impurity removal from 3.00 % to 11.00 %, with no further gain at 1:5. The optimal conditions were identified as 4.0 M citric acid, 4 h leaching, and an S:L ratio of 1:4. The plateaus observed suggest a leaching limit, with remaining impurities likely trapped in the quartz lattice or protected as mineral inclusions [7, 16].

Efficacy of the Integrated Purification Process. The 100 g scaled-up experiment provides a quantitative assessment of the entire purification flowsheet. The mass balance at each stage is summarized in tab. 1.

Table 1 – Mass Balance for the Production of Amorphous Silica from 100 g of Sand

Stage	Conditions	Mass Balance Result	Mass Loss (g)	Cumulative Mass Loss (%)
Initial Sample	100 g raw sand	100.0 g	–	0.0 %
After Washing	Washed with distilled water, dried at	98.0 g	2.0	2.0 %
After HCl Pretreatment	3 M HCl, 3 h, S:L = 1:4	94.7 g	3.3	5.3 %
After Citric Acid Chelation	4.0 M citric acid, , 4 h, S:L = 1:4	92.6 g	2.1	7.4 %

Mass balance analysis showed sequential impurity removal: 2.0 % by washing, 3.3 % by HCl pretreatment, and 2.1 % by citric acid leaching, totaling 7.4 g from 100 g sand. The sodium silicate step enabled selective dissolution–precipitation, separating silica from insoluble impurities. Digestion achieved 88.4 % efficiency, with 81.9 g silica reacted, yielding 70.3 g amorphous silica (75.9 % recovery). Overall, the process was effective, though digestion and precipitation remain key targets for optimization [14, 18].

Conclusion. This study developed a multi-stage hydrometallurgical process to purify Zimbabwean silica sand into high-purity amorphous silica. The results show that this integrated approach is promising, economically viable, and adds value to low-grade Zimbabwe silica resources, with potential applications in semiconductor industry.

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AN INVESTIGATION INTO THE POWER-PERFORMANCE TRADE-OFF IN MEMRISTOR-AUGMENTED SENSE AMPLIFIERS FOR NANOSCALE SRAM

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Abstract. As technology ramps up to high nodes, SRAM sense amplifiers struggle suffer from increasing static power. The paper proposes memristors as non-volatile, tunable loads in cross-coupled differential sense amplifiers