SELF-SUSTAINING WATER REMEDIATION & PREDICTIVE MODELING FOR WATERBORNE EPIDEMIC PREVENTION

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GLOBALLY, 3 BILLION PEOPLE LACK RELIABLE WATER QUALITY DATA, AND 2 BILLION LACK SAFE DRINKING WATER, LEADING TO 505,000 DIARRHEAL DEATHS ANNUALLY (UNEP, 2021; WHO, 2022). THIS PROJECT PRESENTS A SELF-SUSTAINING SYSTEM TO DETECT AND REMOVE FECAL PATHOGENS (E. COLI, SALMONELLA, VIBRIO CHOLERAE) AND HEAVY METALS (ARSENIC, LEAD, CADMIUM, MERCURY) IN VULNERABLE REGIONS LIKE THE YAMUNA RIVER (DELHI) AND EVEREST BASE CAMP (KHUMBU). BY INTEGRATING TEXTILE WASTE AS ADSORBENTS, THE SOLUTION ALSO TACKLES SOLID WASTE POLLUTION.

Methodology

SMART BUOY NETWORK:
- *DETECTION*: SURFACE-ENHANCED RAMAN SPECTROSCOPY (SERS) WITH SILVER-COATED SILICA NANOSPHERES (100 NM, 785 NM LASER) DETECTS PATHOGENS AT 10^1 CFU/ML AND METALS AT SUB-PPB. ADDITIONAL SENSORS MONITOR PH (6.2–8.5), TURBIDITY (50–300 NTU), CONDUCTIVITY (400–1200 MS/CM), AND ORP (150–300 MV).
- *OPERATION*: SOLAR-POWERED (10W PANELS), PIEZOELECTRIC, AND TRIBOELECTRIC ENERGY. GPS-GUIDED BUOYS TRANSMIT DATA VIA LORAWAN FOR AI-DRIVEN CONTAMINATION MAPPING.

PORTABLE FILTRATION UNITS:
- CERAMIC PRE-FILTER (0.2 MM, 2.3 LOG10 PARTICULATE REDUCTION) AND COLD PLASMA (6 KV CORONA DISCHARGE, NEEDLE-TO-CONE ELECTRODES) INACTIVATE 99.99% PATHOGENS IN 30 SECONDS. POWERED BY 9V BATTERY OR HAND-CRANK (0.01 KWH/L).
- IRON-ELECTROCOAGULATION: ADDITIONAL, USES STEEL SWARF ANODES, AIR-DIFFUSION CATHODE FOR 99.7% METAL REMOVAL (<10 PPB). PROCESSES 20 L IN 10 MINUTES, SOLAR/TRIBOELECTRIC-POWERED.

AI PREDICTIVE MODELING:
- MODELS: RANDOM FOREST/XGBOOST (>99% ACCURACY), LSTM/GRU (90% DISPERSION ACCURACY), TRANSFORMER-GRU FOR HOTSPOT AND EPIDEMIC PREDICTION.
- DATA: SERS, GEOSPATIAL (NASA SEDAC POPULATION, NOAA CLIMATE), HEALTH SURVEILLANCE (CHOLERA, TYPHOID).
- OUTPUTS: CONTAMINATION MAPS, 7–10 DAY OUTBREAK FORECASTS, PHYTOREMEDIATION RECOMMENDATIONS (E.G., WATER HYACINTH, OYSTER MUSHROOMS).

TEXTILE WASTE ADSORBENTS:
- COTTON/MIXED YARNS: HYDROTHERMALLY CARBONIZED, KOH-ACTIVATED FOR CARBON ADSORBENTS.
- DENIM: H_2O_2/OZONE-TREATED UNDER ALKALINE CONDITIONS TO TRAP CADMIUM.
- SILK: TANNIC ACID-MODIFIED FOR ENHANCED METAL ION ADSORPTION.
- WOOL: REUSABLE FIBERS FOR HEAVY METAL SORPTION, WASHED POST-USE.
- PROCESS: LAB-SCALE MODIFICATION AND ADSORPTION TESTS ON TEXTILE WASTE FROM LOCAL MARKETS.
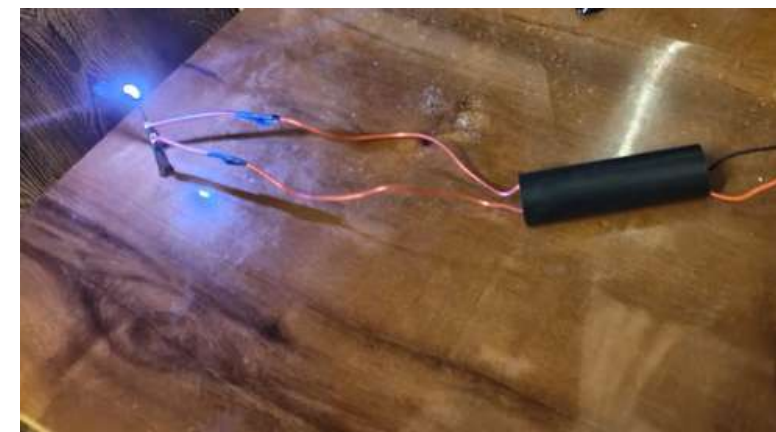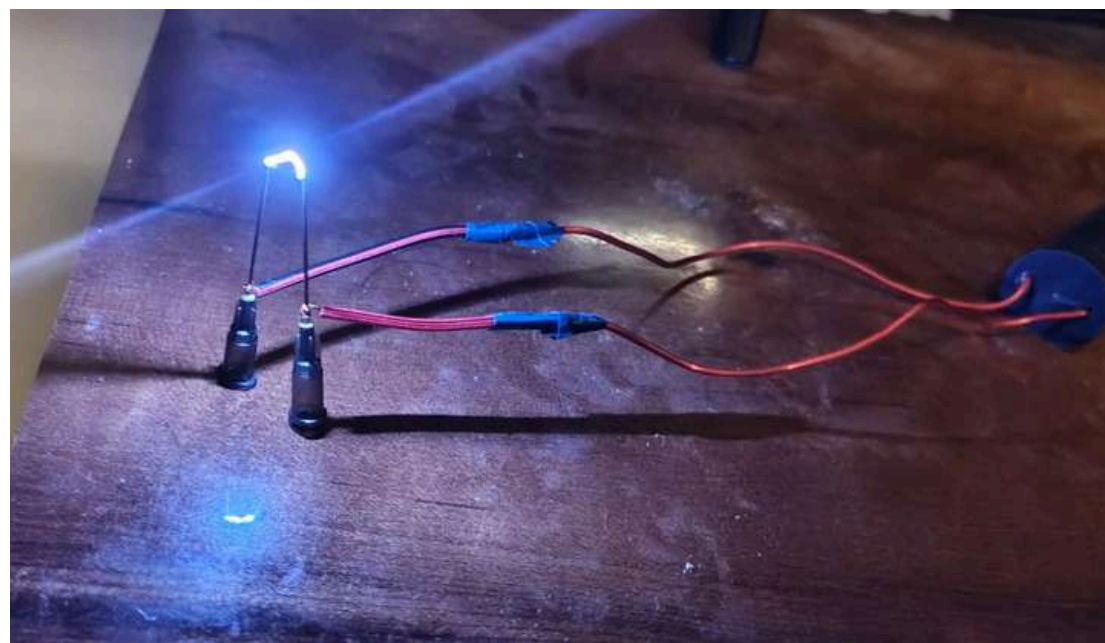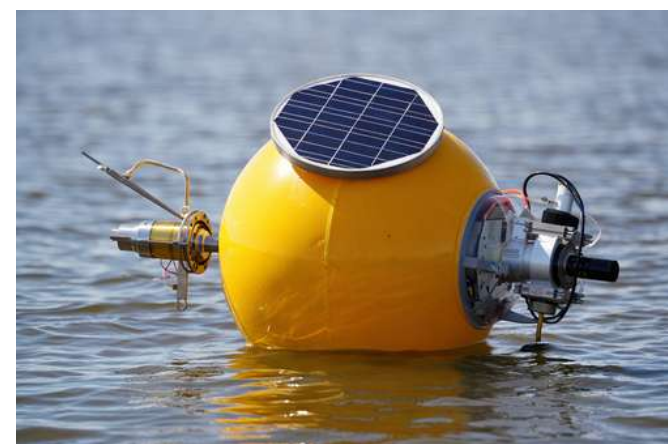
TESTING

- DETECTION: SERS ACHIEVED 10^1 CFU/ML FOR E. COLI, SUB-PPB FOR METALS, WITH 2X SIGNAL ENHANCEMENT VIA WHISPERING GALLERY MODES. BUOY DATA MATCHED ICP-MS WITHIN 5% ERROR.
- REMEDIATION:
  - COLD PLASMA ELIMINATED 99.99% PATHOGENS (E. COLI, VIBRIO CHOLERAE, CRYPTOSPORIDIUM).
  - ELECTROCOAGULATION REDUCED ARSENIC/LEAD TO <10 PPB (99.7% EFFICIENCY).
  - TEXTILE ADSORBENTS: COTTON REMOVED 85% METALS, DENIM 90% CADMIUM, SILK 80% IONS, WOOL REUSABLE FOR 5 CYCLES (85% EFFICACY).
- AI MODELING: HOTSPOT MAPPING (>99% ACCURACY), OUTBREAK PREDICTION (0.811 CORRELATION, CHOLERA DATA). PHYTOREMEDIATION REDUCED PATHOGENS BY 20% IN SIMULATIONS.
- PERFORMANCE: UNITS FUNCTIONAL AT –15°C, 300 NTU TURBIDITY, USING 50% LESS ENERGY THAN REVERSE OSMOSIS. COMMUNITY ICEBOX PROCESSED 2 L/MIN, BOTTLE 0.5 L/MIN.
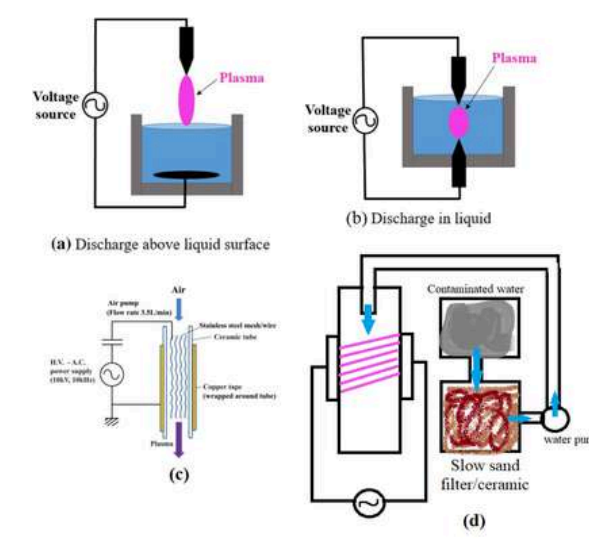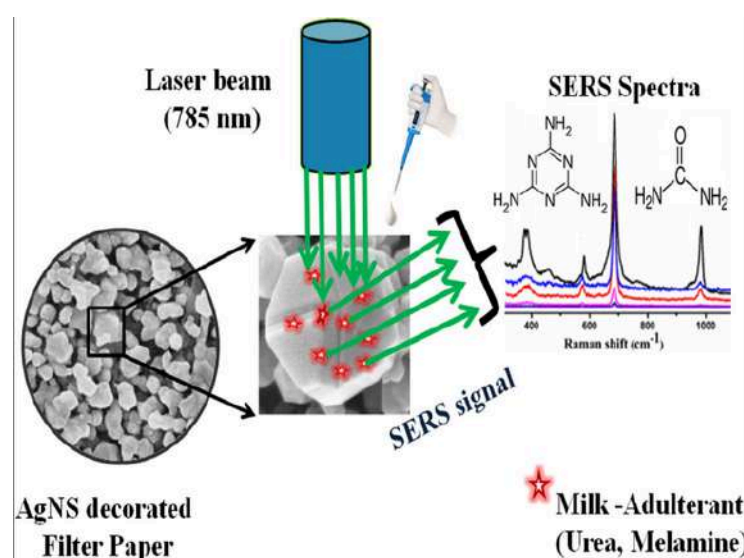
IMPACT

- SOCIETAL: DELIVERS SAFE WATER TO 3 BILLION, POTENTIALLY SAVING 505,000 LIVES YEARLY FROM DIARRHEAL DISEASES (WHO, 2022). EMPOWERS DELHI SLUMS AND KHUMBU LOCALS WITH EQUITABLE ACCESS.
- ENVIRONMENTAL: RESTORES WATER BODIES (YAMUNA, KHUMBU STREAMS), REPURPOSES TEXTILE WASTE TO REDUCE LANDFILL POLLUTION, AND USES PHYTOREMEDIATION FOR ECOSYSTEM HEALTH.
- WATER MANAGEMENT: REAL-TIME MONITORING, DECENTRALIZED PURIFICATION, AND AI PREDICTIONS REVOLUTIONIZE PRACTICES, SUPPORTING UN SDG 6 (CLEAN WATER AND SANITATION).
- CIRCULAR ECONOMY: TEXTILE WASTE ADSORBENTS AND STEEL SWARF USE PROMOTE SUSTAINABLE RESOURCE MANAGEMENT, REDUCING INDUSTRIAL WASTE.

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