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Original Research Article

Modified advanced oxidation technology for toilet sanitation at world largest human gathering Kumbha mela 2019-an eco-friendly technology

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ABSTRACT

Background: In India, world biggest Hindu gathering event "Kumbh mela" will be organised every twelve years in Prayagraj city where sanitation and hygiene was one of the biggest challenges. The present research made an attempt to suggest the cost-effective sanitation solution to prevent disease transmission at public toilets, bathing area at Kumbh mela premises.
Methods: Modified advanced oxidation aqueous solution (MAOS) were developed using peroxide and ozone with iron oxides as a catalyst which enhances the hydroxyl radicals. Biocide activity of MAOS were carried out on faecal originated bacteria. Impact of MAOS on volatile organic compounds (VOC) were carried out at public toilets and determined using VOC sampler and GC method. After the detailed investigation on MAOS, the present technique were transferred to field application during Kumbh 2019.
Results: Biocide test of MOAS on Faecal originated microorganism showed that 99.6% of test organisms were deactivated rapidly. Impact on volatile organic compounds in public toilets indicates that the volatile organic compounds were decreased after the application of MAOS, controlled the filthy odor. The MAOS technique were applied to the field in public toilets and successfully achieved the odor free environment during Kumbh 2019. The hospital record showed that the disease infection burden were decreased from 33% to 21% respectively.
Conclusions: The detailed laboratory investigation and field observation revealed that modified advanced oxidation solution (MAOS) removed the volatile organic compounds in the toilet pits and successfully achieved the odor free Kumbh 2019 which is cost effective and eco-friendly technology for toilet sanitation at any human gathering event.

Keywords: Kumbh mela 2019, Eco-friendly, Biocide, Odor control, Sanitation, Pubic health

INTRODUCTION

Mass gathering either organized or spontaneous that attracts people globally and exposes them to health risks. Many communicable diseases such as respiratory, faecal-oral, vector-borne, zoonotic and blood-borne been identified previously in mass gathering.[1] Kumbh Mela is a world largest Hindu gathering fair organised at confluence Sangam of the Ganges and the Yamuna and the mythical Saraswati at Prayagraj city, the Godawari at Nasik, and Shipra at Ujjain. The fair is held places every twelth year at any one of the four places by rotation: Haridwar, Prayagraj, Nasik and Ujjain. The mela attracts a large number of tourists and pilgrims, looking forward to washing their sins off in the holy river at the time of the mela, which is spread over a period of 45 days.[2] The peak years of cholera in Uttar Pradesh have mostly coincided with the years in which these Kumbh mela were held. With the aware of cholera incidents during mela time, the state and central government initiated the control measures for cholera since 1945. Besides, the state government in Allahabad reported that 330 numbers of cases of gastro-enteritis admitted in hospital and 240 vibrio cholera encountered at early fair between January to February, 1954. Such epidemic conditions were reported till march with an average of 50 cases per day.

The outbreak of gastro-enteritis in the Kumbh fair, Allahabad, remained localised and scattered all over. Cases were received from all sectors of the fair area where flies were present.[3]

Nearly 2000 cholera cases were reported on main bathing day during the year 2001 and patients were treated by the mobile telemedicine system. The epidemics have been reduced since 2003 results from the use of telemedicine during the mela for evading cholera epidemics.[4] During the year 2013, 35000 toilets were constructed, ranging from designated open air defecation fields to simple pit latrines and bio-digester toilets. The water and sanitation systems set up was followed almost all of the minimum universal standards, such as toilets at a safe distance from water sources, around 15 people per toilet, incorporating cultural preference toilets, adequate quality and quantity of water. Even though, the diarrhoeal cases were recorded with the main causes of inadequate hygiene at toilets. The sacred city of Prayagraj observed Ardh Kumbh mela from 14th January, 2019 to March 4, 2019. With this context, the state and central government of India decided to adopt the clean and eco-friendly technology for better sanitation facilities to deal with this overarching range of health problems and hazards during Ardh Kumbh 2019 (Kumbh 2019). The present study illustrate the technology being adopted for safe sanitation and public health during Ardh Kumbh days.

METHODS

Study area

Prayagraj Ardh Kumbh mela, 2019 was the Kumbh Mela held at Triveni Sangam in Prayagraj, Uttar Pradesh, India from 15 January, 2019 to 4 March 2019. The Kumbh Mela 2019 is spread over an area of 3,200 hectares of land that nearly 700 hectares more than the area utilised during the 2013 maha Kumbh. The setup city in the huge mela area, has 250 km long roads and 22 pontoon bridges been constructed which is the largest temporary city of the world. The mela area has been divided into three temporary tent arrangements namely Arial side, Jhusi side, city side and Triveni Sangam ghat.

Preparation of advanced oxidation solution

For preparation of modified advanced oxidation solution was prepared by aerating ozone (10 mg/hr) in to 6% peroxide solution. Ozone gas phase were generated using ozone generator model TL03 at a fixed voltage (230 V), and a constant flow rate of 20 L h-1.[5] The ozone generator is generates the ozone, based on the principle of corona discharge technique. A dry oxygen is passed through the closely spaced electrodes one of which coated with dielectric material under a nominal applied voltage potential of ~10kV.[6] The generated ozone was passed through Teflon tube into 6% peroxide solution under cold condition at 20^0C. The active ozone concentration in peroxide solution (85 mg/L=0.08 mg/ml) was determined by modified indigo method and stored in dark room for biocide test.[7]

Preparation of modified Fenton's

Modified Fenton's compounds were prepared by dissolving iron oxide (FeO) in to hydrochloric acid. The whole content were warmed at 28^0C and ferrous sulphate ($FeSo_4$) were added and stored in dark room.[8]

Preparation of modified advanced oxidation solution (MAOS)

Modified advanced oxidation solution was prepared by diffusing gaseous ozone (concentration 12 mg/l) was aerated into high pure water in a cold condition. The ozone was generated by passing oxygen through an Ozone generator model AQ03 at a fixed voltage (230 V), and a constant flow rate of oxygen about 20 L h-1.[5] The ozone generator is generating the ozone, based on the principle of corona discharge technique. A dry oxygen were passed through the closely spaced electrodes one of which coated with dielectric material under a nominal applied voltage potential of ~10kV.[6] The generated ozone was passed through Teflon tube into double distilled water containing 6% hydrogen peroxide under cold condition at 20^0C, because a fall in the temperature of the aqueous medium increase's ozone solubility, augmenting its availability in the medium (Figure 1). A pinch of modified fentons solution were added into ozone aerated peroxide solution. The prepared modified oxidation solution were stored at cold condition for further biocidal analysis.[9,11]

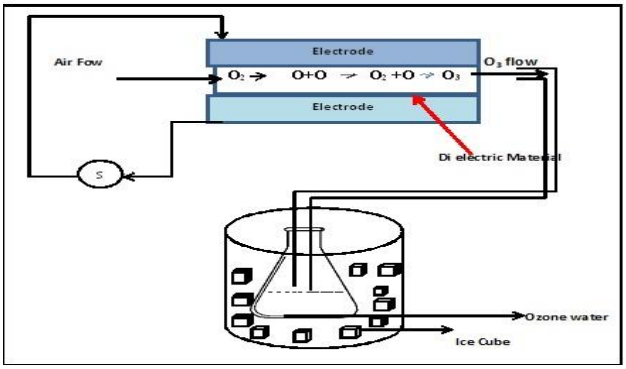

Figure 1: Schematic diagram of ozone water generation.

Antimicrobial property of MAOS/ contact and kill time assay

Antibacterial activity of MAOS was tested with faecal originated Bacteria in a laboratory condition. Laboratory strains *of E. coli, P. aeruginosa B. subtilis* and *S. aureus* were acquired from microbial type culture collection and gene bank, Chandigarh, India (MTCC). The *E. coli, B. subtilis*, and *E. coli* isolates were maintained on MacConkey agar while the *S. aureus* and *P. aeruginosa*

isolates were maintained on full strength tryptic soy agar (TSA). For liquid inoculation, a single colony was picked from the respective agar plate, transferred to 50 mL of the appropriate growth medium and incubated at 37°C for 24 hours for contact and kill assay.[10] Laboratory standard broth contains 600 CFU/mL of *E. coli*, 750 CFU/mL of *P. aeruginosa*, 650 CFU/mL of *B. subtilis* and 502 CFU/mL of *S. aureus* were determined as per the standard method by APHA, 2000. Advanced oxidation solution was activated by adding 2 ml of Fenton's reagent and stored in normal room temperature for the study. Different concentration of activated MAOS ranging from 1 ppm to 5 ppm were prepared and mixed with 10 ml of bacterial strains and incubated at 37°C at different incubation time (1, 2, 3, 4, 5 up to 30 mins). The treated bacterial cell broth was dispersed on the nutrient agar and incubated at 37^0C for 24 hours in sealed condition. The results are observed under digital colony counter.[11]

Characterisation of effect of MAOS on volatile organic compounds

Impact of MAOS on volatile organic compounds were examined APM model 802 (Envirotech, New Delhi) and gas chromatography technique. MAOS solution were applied in public toilets and air sampling were carried out at a 200 ml/min for 50 min. Sampler collects the air samples in adsorbing activated charcoal tube in Tedlar bags and traps volatile organic compound (VOC), expressed in mg/m^3. The test MAOS solution was applied in the toilet pit and sprayed in the corner, center of the rooms, allowed to react for 10 minutes.

The presence of volatile organic compounds was analyzed by thermal desorption method. The sampled charcoal tubes are brought to laboratory, the tubes were opened, glass wool was removed and 100mg activated charcoal is transferred into a 2-ml vial. And 0.9 ml of each standard solution is added, by means of a micro-syringe, as many times as necessary, once transferred 2-ml vials, are placed on a mechanical shaker for thirty (30) minutes as well as then analyzed by the gas chromatography.[12]

World largest temporary toilet set up

The Uttar Pradesh government is hosted one of the biggest religious congregations at Prayagraj Kumbh Mela with the theme of 'Swachh Kumbh, Surakshit Kumbh'. In order to the theme, the Kumbh Mela authority has installed 1, 22,000 toilets which includes 20,000 urinals, 41500 community toilets in the mela area. Several public health incident at Kumbh Mela during 1980,2003,2013 and National Swach Bharat mission made a driven force for adequate sanitation, toilets, dormentry establishment to control the disease outbreak.

Installation of sanitation solution preparation plant

Adequate sanitation is a priority in Kumbh mela, the mela authority, health department, Prayagraj and sanitation expert from department of environmental science, Bangalore university has decided to set up a 20 sanitation solution preparation plants for 20 sectors across the mela area. The main criteria for site selection to install the sanitation plants is i. convenient road connectivity to all the toilets, ii) isolated place from visitors darmentry iii) faceable storage capacity iv) away from fire source namely homa activity, cooking and fire camp etc., v) convenient water and electrical facility.

Table 1: Sector wise toilet allocation and sanitation solution preparation plants.

Sectors	Total toilets	Location	Toilet allocation	Urinal's allocation	Estimated vol (litre) of sanitation solution/ day	No. of sanitation plant installed
Sector 1	2800	Parade area	1800	1000	2800	1
Sector 2	3140	Parade area	2140	1000	3140	1
Sector 3	4950	Sangam aera	2450	2500	4950	1
Sector 4	2870	Sangam aera	1800	1000	2870	1
Sector 5	1150	Ganga island	800	350	2150	1
Sector 6	4600	Bakshi bandh	3100	1500	4600	1
Sector 7	3000	IERT	2200	800	3000	1
Sector 8	480	Phaphamau	280	200	480	1
Sector 9	2100	Jhunsi	1600	500	2100	1
Sector 10	2300	Jhunsi	1800	500	2300	1
Sector 11	2900	Jhunsi	2100	800	2900	1
Sector 12	3100	Jhunsi	2200	900	3100	1
Sector 13	3600	Jhunsi	2500	1100	3600	1
Sector 14	4040	Jhunsi	2840	1200	4040	1
Sector 15	4200	Jhunsi	3000	1200	4200	1
Sector 16	2720	Jhunsi	2220	500	3720	1
Sector 17	3200	Jhunsi	2000	1200	3200	1
Sector 18	2590	Arial	2090	500	3450	1
Sector 19	4610	Arial	3110	1500	4300	1
Sector 20	600	Arial	400	200	600	1

Equipment and accessories

The primary equipment for advanced oxidative technology is Ozonator (20 no's) is procured with regulator was hired from Bharat Gas agency, Prayagraj and Standard Gas agency, Prayagraj. Oxygen active chemicals (peroxide) was procured from National peroxide, Kolkata, India (Figure 2). The sanitation solution preparation plant setup been completed in different locations in different sector within a week. The instrumental efficiency and quality of sanitation solution were examined periodically.

Figure 2: Installation of sanitation solution preparation plant.

Onsite training for volunteers

Several technical and non-technical human sources were involved in sanitation solution preparation and application. An average of 45 human resource includes 2 scientists from department of environmental science, Bangalore university, 2 ozone engineers from Aqua safe Instruments, 3 mechanical and electrical engineers from Prayagraj electricity Board and 35 post graduate students from CMP college, Allahabad university deployed for sanitation solution preparation. The Prayagraj city municipal corporation authority also deployed 1500 swachagrahis for operational, maintenance and monitoring the public toilets at Kumbh area. Each plant was managed by one chemist, two helpers for solution preparation and packing. Five number of graduate active volunteers was deployed for supervising to ensure the sanitation solution application at every toilet's points.

Monitoring and identification of loopholes in toilet sanitation was big challenge during past mela fair in Prayagraj. According to the knowledge, it is first in kind of Kumbh history that the mela administration and Pryagraj health department come out with advanced information technology to monitor the cleanness, odour, water availability at toilet complex. Special mobile application been developed for Android smart phone was used to monitor the following sanitation at toilet complex: Cleanness status, odor complaints, lamp availability, water/ mug availability, presence of allotted Swachagaris, septic tank filling status, sludge suction status and toilet door lock functioning status

The volunteers divided to 20 teams for 20 sectors, they visited every toilet pits in their respective sector by shift basis (morning, evening and late night) and share the sanitation status data through specially developed mobile application. All the data being received at Central sanitation monitoring cell which was situated at office of the additional health, Prayagraj. Based on the data received from monitoring team and the information been shared to respective sector sanitation chemist to take appropriate action for the odour control in the toilet complex.

RESULTS

Contact/kill time (CT) assays

Killing time assays were carried out to determine the biocide efficiency of modified advance oxidation solution. The results indicates that the MAOS rapidly reduced the viable bacterial count (Table 1). After the exposure, 600 CFU/mL of *E. coli* were reduced to 2 CFU/ml, 750 CFU/mL of *P. aeruginosa* were reduced to 5 CFU/ml. Similarly, 650 CFU/mL of *B. subtilis and 502* CFU/mL of *S. aureus* were reduced to 4 CFU/ml and 1 CFU/ml at 1 ppm exposure of advanced oxidative solution (Figure 3). Surprisingly, none of the bacterial colony were sustained at 2 ppm, 3 ppm, 4 ppm and 5 ppm concentration of MAOS (Figure 4). The killing assay revealed that the MAOS act as biocide on fecal originated bacterial culture namely *E. coli*, 5 CFU of *P. aeruginosa*, 4 CFU of *B. subtilis* and 1 CFU of *S. aureus*.

Table 2: Inhibition effect of advanced oxidation sanitation solution on water borne pathogenic bacteria.

Name of the organisms	Initial bacterial colony count (CFU/ml)	Bacterial cell count after exposure with oxidative biocide					Over all inhibition rate (%)
		1 ppm	2 ppm	3 ppm	4 ppm	5 ppm	
E. coli	600	2	S	S	S	S	99
Pseudomonas aeruginosa	750	5	S	S	S	S	98.5
Staphylococcus aureus	502	4	S	S	S	S	99.2
Bacillus subtilis	650	1	S	S	S	S	99.5

S-Sensitive

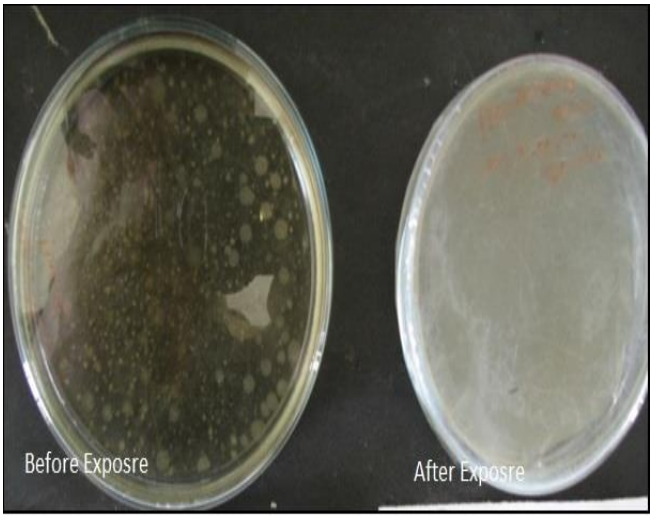

Figure 3: shows the inhibition potential of MAOS on fecal originated pathogen.

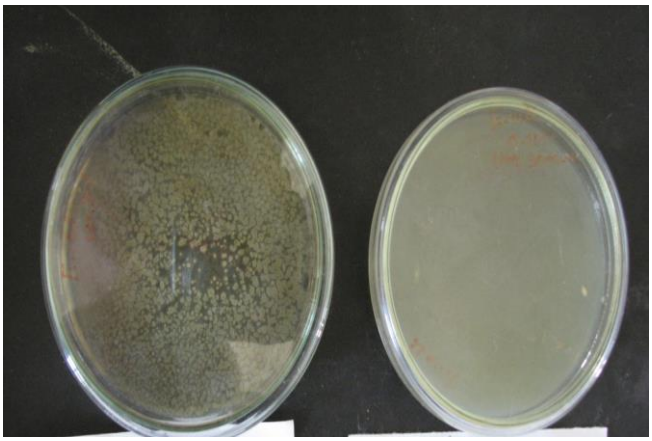

Figure 4: Microbial inhibition of advanced oxidation solution on *E. coli*.

Impact of MAOS on volatile organic compounds

Many volatile compounds are responsible for bad odor in indoor and outdoor environment. So, volatile organic compound profile was determined before and after application of MAOS in toilet indoor environment. Totally Nine different volatile organic compounds in toilet environment were measured and found that VOC's include Di-chloro Ethane, methylene chloride, chloroform, hexane, p-xylene, formaldehyde, acetone, butanol and carbon disulphide are detected (Figure 5 and 6). This result shows that the experimental site is contaminated by VOC's from the source of frequent application of phenol based solution for sanitation of floor, chlorine based detergents, microbial activity and air exchange between solvent stored inside laboratory and experimental site. After the application of MAOS solution, the number VOC's decreased gradually. This result attracts the indication that perhaps the MAOS destroy the VOC present in the toilet indoor environment.

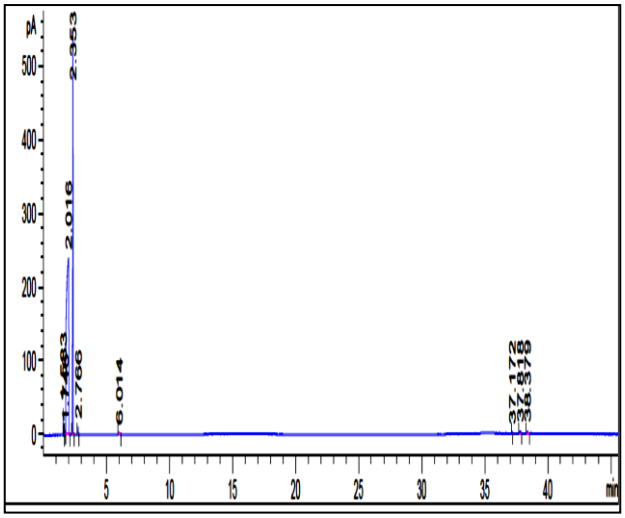

Figure 5: Chromatogram of VOC before the application of AOS.

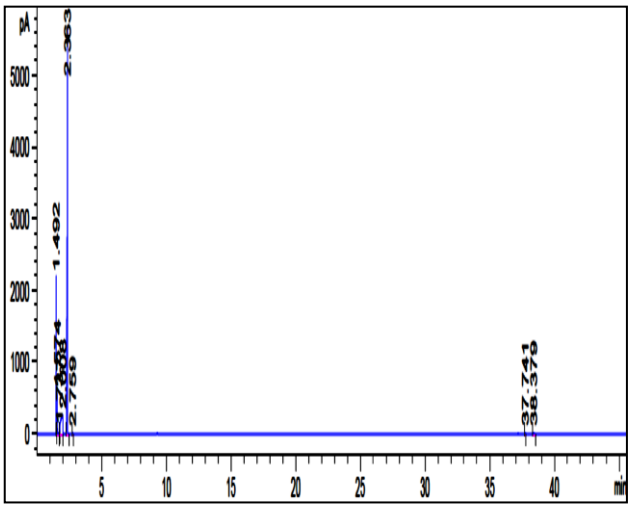

Figure 6: Chromatogram of VOC after the application of AOS.

Technological outcome of advanced oxidation solution at Kumbh 2019

After the detailed laboratory study on MAOS, the present technology been adopted for public toilets at Kumbh 2019. Based on the data obtained from sanitation monitoring cell revealed that, the advanced oxidation sanitation solution is resulted the odour free environment at toilet complex in all 20 sectors in mela area (Figure 7). Significant results were observed on Paush purnima that 96.8% of the toilets were odour free. Eventually, 96.1% odour free toilet was achieved on Mauni amavasya which is main royal bath in Kumbh celebration. On Basanth panchami and Maghi purnima it was 96.9% and 95.9%. Similarly, 87.2% of toilets are odour free achieved on Maha shivaratri is also one of the important bathing days (Table 2). With this result, it is evident that Kumbh mela 2019 was 91% of odor free achieved by advanced oxidation sanitation solution used in toilets.

Table 3: Percentage of odour free toilets achieved using advanced oxidation sanitation solution during main bathing days of Kumbh.

Main bathing days	Odour free toilet (%)
Makara sankranthi	Data is not received
Paush purnima	96.8***
Mauni amavasya	96.1***
Basant panchami	96.9**
Maghi purnima	95.9
Maha shivaratri	87.2

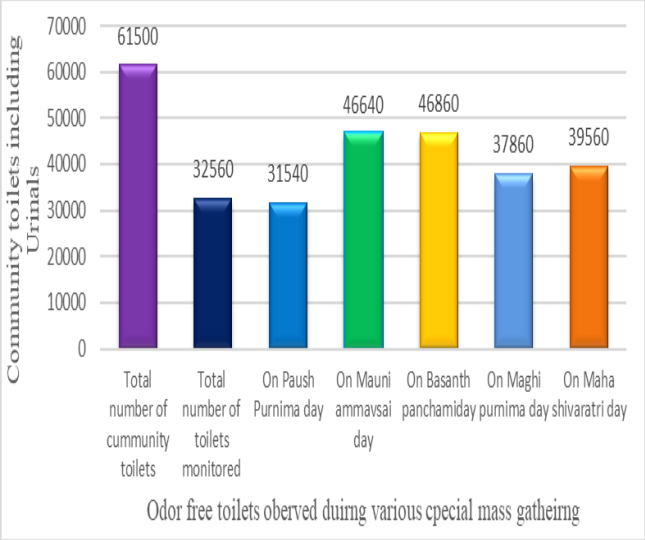

Figure 7: Status of odor free toilets achieved on various special gathering at Kumbh 2019.

DISCUSSION

Several studies have confirmed the antimicrobial activity of peroxide and peroxide-based products. But, many microbial inhibition study on peroxide stated that lacto peroxidase and thiocynate ion are present in the bacteria which protect them from peroxide.[14] similarly, minimal concentration of ozone is sufficient to deactivate the bacteria by rupturing the cell walls and cytoplasmic membranes.[15] Pascaul et al and Rebecca et al study found that ozone is strong oxidizing agent which potentially disinfected the surface and food processing unit. Gas of ozone and ozone in water are used to clean the microbial biofilm in water pipeline and indoor air sterilization.[16,17] The present study of MAOS believe that the combination of peroxide and ozone has significant biocide property on microorganisms.

Human urinals contribute the 2-methylthio-ethanol, phenol, isobutanol, 2-methyl-1-butanol, dodecanol are primary VOC in indoor environment. Presence of microorganisms in toilets plays the important role in VOC emission by degradation and transformation.[18] These organic compounds are responsible for the odor in public toilets which is not maintained properly. After application of MAOS, the VOC number was decreased from 9 to 8 in experimental site. The results indicate that the AOS oxidized the long residence VOC into short residence VOC. The present study also confirmed the biocide activity on bacteria and reduced the VOC emission by suppressing microbial activity. This result proves that MAOS controls the odor by preventing the microbial population in public toilets. Previous episodes of Kumbh mela faced the many hygienic issues includes toilet and urinal odors were the pilgrims and public are hesitated to visit the world largest Hindu ritual gathering.[19] Maintenance of hygiene and sanitation of public toilets set ups at olympics and cultural event are big challenge, because of many numbers of user in short period.[20] Many commercial deodorant, odor control kit, soaps and detergent are chemical agents which may pollute the environment and also causes the allergies for sensitive person. But, the proposed technology is removed the odor instantly and also cost effective without any allergic development.

CONCLUSION

Based on the results, the study conclude that modified advanced oxidation solution efficiently controlled the toilet odor, pathogen in public toilets at world biggest human gathering Kumbh 2019. Advanced oxidation technology and digital sanitation monitoring system are the technical tool have been used first kind in Kumbh history which played a crucial role in successful public health and sanitation at Kumbh 2019 Prayagraj city. The compiled results of toilet monitoring dashboard showed that the advanced oxidation process achieved the 90 to 95% of odor free toilets in mela area. The 2 advanced technology: i. advanced oxidative sanitation technology, ii. Mobile app-based monitoring system are significantly contributed for odor free Kumbh. Further the study found that modified advanced oxidation technology is eco-friendly and cost-effective technology to maintain the odor free, pathogen free toilet environment at public gathering.

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