ISSN: 2395-1680 (ONLINE)
DOI: 10.21917/ijme.2021.0204

AUTOMATED NANO-TECHNOLOGY BASED PARTICULATE FILTERS TO A CLEAN ENVIRONMENT IN ROOMS OF BIOMEDICAL APPLICATIONS

S. Gowri, Judith Justin and R. Vanithamani

Department of Biomedical Instrumentation Engineering, Avinashilingam Institute for Home Science and Higher Education for Women, India

Abstract

The products or the process of production are highly sensitive to contamination on the environment. In this regard, manufacturing of semiconductors and their related application plays a major cause. The airborne concentration of particulates like chemical vapours or dust compounds can be found even an enclosed environment. This accounts for pollution in clean rooms for the purpose of biomedical applications. These rooms should be monitored highly and should be protected from harmful substances and contamination risks. In this paper, we clean the air that is entering the room that is filtered with nano-particle based filters to eliminate the dust. The air is recirculated via nano-particulate high efficiency particulate air filter. These filters connected with nano-materials absorbs the contaminants. The implantable particulate filters are the edges of the room enables a clean environment. The experimental testing is conducted using several nano-filters that is connected with power design circuits to automatically control the entire environment. The results achieved show that the presence of microbials in the room is cleaned effectively.

Keywords:

Airborne Particulates, Pollution, Nano-Particle Filters, Clean Environment

1. INTRODUCTION

There are a variety of gadgets that are used in clean rooms. A separate system also provides the air supply in a cleanroom. It contains air dehumidifiers, pre-filter systems, air pressure control systems, heat and cooling systems, humidifier controls, and fire detection sensors to ensure that the air quality in the space is maintained to the highest standards. Pre-conditioned ducts or a plenum above the sealed ceiling of the cleanroom supply pre-conditioned air.

Nanoparticulate filters introduce conditioned air into the cleanroom envelope. Individually powered and pressure-controlled nanoparticulate filters could also be used as passive terminal nanoparticulate filters. Cleanroom envelopes are pressurized to a predetermined pressure and leakage air is replaced with a calculated volume of fresh air [1].

Pre-conditioning particle-controlled air for the entire space is the fundamental difference between a clean room and one that only has a clean workstation. Cleanroom requirements include providing an area where dirty clothing can be replaced or covered by clean apparel worn in the room. This outfit may be worn over usual attire in this location, or clothes could be changed.[2]. If the cleanroom's integrity is to be maintained, clear and well-thought-out protocols for cleanroom admission must be in place.

Nanoparticulate filters can be used in an air circulation system that allows for continuous circulation of room air. The capacity to recirculate water has two advantages. The air is constantly sanitized and disinfected. The amount of air that must be recirculated reduces the amount of air that needs to be recirculated. It reduces the need for heating, cooling, humidification, and ventilation. The cleanliness class of the room determines the amount of air that must be circulated in the room. The cleaner the room, the more recirculated air there is [11]-[13].

For a clean room, additional systems are required. An 85% filter system, a rough air intake filter system, dehumidifiers, and air circulation fans are just components that make up the air supply system. Other components include heating and cooling coils, hot and cold-water supplies; humidifiers; sensors for temperature and humidity; and exhaust air ducts [14]-[15].

Compared to clean laboratories, a clean room lacks the ability to accommodate a wide range of processes. In order to maintain a specific cleanliness level, all processes must be carried out according to protocols designed to do so. This will require the deployment of additional auxiliary systems for operations that do not necessitate such stringent procedures.

The most important operational limitation for a cleanroom is to restrict how many processes can be carried out at once. Non-compatible processes must be scheduled consecutively, which necessitates an effective scheduling strategy. Thus, more time is required for the completion of each step.

In most research programmes, this scheduling constraint is problematic, although it may be acceptable in some cases if it is not a limiting factor. Additional cleanrooms may be feasible if only two or three competing processes are involved. A clean laboratory should be considered for higher numbers of procedures since increasing the capacity of the air supply and control systems is substantially less expensive than the cost of creating multiple separate clean rooms.

2. BACKGROUND

In order to keep contamination to a minimum, a clean lab makes use of all available resources. As opposed to a clean room, a clean laboratory uses a systematic approach to incorporate clean components and clean rooms to enable a wide range of procedures. Each process can be supported by a facility that provides the proper cleanliness class, services, and space for the task at hand.

As a result, an efficient laboratory with flexible scheduling and better resource utilization is achieved. Cleaning a laboratory and cleaning a room have the same fundamental components [3]. By combining several clean rooms, transport corridors, support facilities for staff and special-purpose rooms into one facility, the clean laboratory achieves its stated goal of cleanliness. The clean laboratory idea makes this easier because variable room pressures can be used to steer particle flow away from rooms with the most stringent cleanliness standards and toward less stringent rooms.

Automated control systems are given more prominence in the clean lab paradigm. More precise testing methods are needed to monitor overall system performance as a result of this. Facility maintenance and spare component inventory management are put under a lot more strain as a result. The facility performance and operational readiness will suffer if these processes are not properly recorded and controlled [4].

It is possible to run multiple operations simultaneously in a single clean room rather than having to schedule them sequentially. Compared with the previous facilities, this one is designed to attain the appropriate level of cleanliness more rapidly and consistently than those.

The size of particles present in a room of a specific cleanliness class imposes the primary limitations on the clean laboratory. Instrument sensitivity, material purity, and reagent purity are more common than particle contamination in measuring blanks. The sensitivity limitations of many instrumental analytical techniques are rapidly increasing as a result of technological advancements.

In order to meet this need, we must either improve the cleanliness class or devise new methods for processing cleaner samples [5]. According to previous research, cleanliness can be enhanced more quickly than material science and reagent purification. As lower detection limits become more widely available, this trend will continue and even grow more pronounced.

An adequately built clean laboratory has a few operational limits beyond those imposed by the design limitations of individual components. Complexity means more resources are needed to maintain the system [6]-[10]. A deeper understanding of the design parameters is needed to quickly and efficiently identify and fix functional issues. A clean lab environment is necessary to get to the cutting edge of technology. This is the cost of operating a state-of-the-art facility.

3. METHODS AND MATERIALS

In order to build a clean bench and space, the choice of materials are carefully considered. Construction materials must not contain analytes of interest or offer a risk of contamination to meet the clean room's primary purpose. Galvanized iron ducting should not be used since it corrodes quickly. Aluminium with an epoxy paint coating can be used for ducting, doors, glass panels, and other applications since it does not corrode quickly and is fire retardant.

For ultra-nano analysis of metals such as aluminium, non-metallic construction is preferred. The corrosion caused by acids would be significantly more severe than air particulates and necessitate a more expensive cleanroom. Silicone or epoxy paint is coated over metal pieces if used in a project. Metal ducts coated with Teflon are expensive. These will be able to meet fire codes that are too stringent for polymeric ducts. As acids are used on the bench, the protective coatings must be checked regularly. Wood, laminated wood, or rigid polymers like polypropylene or PVC can be used to construct the workstations.

Aluminium separators should not be used with nanoparticulate filters in case of nanometal applications. Nanoparticulate filters with plastic separators or the variety without separators are preferred in a clean environment, but nuclear and isotopic laboratories can use these filters. A wooden or plastic frame should be used to hang the filters and prefilters. A plastic blower and an epoxy-coated motor are used to assure the machine's safety. HDPE or a comparable material is used to build the ducts. Taps and other fixtures should be made of PVC or HDPE, and only deionized water supplies are used in the taps. Non-metallic sockets should be used for lighting. Every measure must be taken in order to avoid the creation of metallic particles from the building components.

3.1 LABORATORY ANALYSIS

The borosilicate glass pipettes and burettes that are used extensively in traditional laboratories are not suited for use in nano analysis. At both extremes of pH, glass has been discovered to release micro elements (Na, Al, and B). Metal desorption and metal dissolution occur when the pH of the glass surface is too high or too low. Clean glass surfaces are also extremely reactive due to the presence of highly reactive Si-OH groups. As a result of their acidic character, these groups serve as excellent ion exchange materials.

A better but a little costly choice is vitreous silica made from the hydrolysis of silicon tetrachloride or tetrafluoride in the vapour phase. In order to remove any remaining surface contamination, acids can be used to thoroughly clean vitreous silica, which is nearly pure in the first place. It might be used at high temperatures since it has a practically zero coefficient of expansion at high temperatures. Silica ware made from silicon scraps from the electronics industry can also be used.

3.2 PLASTICS

Plastics are now widely employed in the manufacture of laboratory equipment, making it vital to make a well-informed choice of material when conducting nano analytics. Adsorption characteristics of polymers for analytes and contamination resulting from leftover catalysts and additives used in producing these plastics are considerations to consider in nano analysis [1].

Materials with low permeation are preferred in the vast majority of cases. Molecules migrate via small spaces between the polymer strands to achieve permeability [1]. Polymers absorb materials in part as a result of migration within the polymer matrix. The migration of material into the polymer matrix is a common cause of discoloration in plastic containers. Permeation can move items out of a container in one of two ways. Permeation of water occurs when solutions are stored for an extended period in containers that were not designed for that purpose.

If the sample had not been weighed before storage, the consequent variation in analyte concentration might go undetected. Analytes in equilibrium with some volatile species, such as ammonium and sulphide salts, can cause a second problem. Wall equilibrium will restore the gaseous products to penetrate out of the container, even if a small amount of ammonia or hydrogen sulphide leaks out. Whether these containers could be dried at high heat is another physical consideration. For ultra-nano analytical applications, vitreous silica and PTFE ware are highly recommended.

3.3 REAGENTS PURIFICATION

It has been determined that water with a resistance of 18 megaohms cm is adequate for ultra-nano work after filtering it using an appropriate purification technique. The purifying system uses deionized water as a starting point. Sub-boiling or isothermal distillation in vitreous silica should be used to purify commercially available analytical reagent grade acids further. Organic reagents must be pre-validated before they are used. Purification is desired for organic solvents and other reagents for preconcentration/separation operations. Certificates of analysis are provided for reagents purified by sub-boiling distillation from a variety of sources. Each lot of reagents are supported by a nano element analysis.

4. WORKING

All procedures in clean facilities with controlled environments must be well planned and conducted to avoid contamination of work surfaces, samples, and even the analyst. Maintaining and certifying the cleanliness of working areas in a clean laboratory is essential. In order to run and maintain a clean room facility successfully, a set of protocols need to be adopted. Instructions must ensure that the facility is always operable and clean. Original design standards have to be adhered to when operating in a cleanroom facility.

The facility management and appropriate cleanroom support, such as engineering, maintenance, and staff, should examine and approve any change to this set of criteria. The facility's initial specs and uses should also be documented for future use. The facility or a portion of it may become unusable if changes are made to the present engineering. Humidity management in a facility affects the instrument's life expectancy.

When it comes to operational protocols in clean facilities, size is a significant determinant, ranging from the most basic laminar flow/workbench in an ordinary lab to a state-of-the-art, multi-dedicated clean laboratory with numerous rooms. The level of facility automation and control also influences operational procedures. The protocols need to be tailored to the specific use of the facility in question. In order to conduct research, training, service, and production safely, these institutions must adhere to strict procedures.

There will be different protocols for instrumentation rooms than for sample digestion and chemical separations. These hazardous materials necessitate extra precautions for handling. There is the opportunity to designate a specific room in a multi-room facility. As the clean area would be used for several analytical processes that may interfere with each other, single-room facilities necessitate highly stringent regulations. Managing a multi-user facility necessitates a high level of responsibility and engagement with the end-user to define standards for specific uses.

4.1 MONITORING NANO SENSORS

Monitoring crucial facility metrics regularly is the best way to assure the cleanliness of the facility/room. Additional maintenance is needed when some parts, such as filter media, have reached the end of their useful life, which can be detected more easily with differential records.

- Particle counts, which measure the amount and size of particles in the air, can efficiently monitor cleanroom characteristics. These measurements are compared with the predicted value in the US Standard 209E or the new ISO 14644-1 for a given class of cleanliness. Air management is handled in more advanced clean rooms by a central ventilation system that is either automated or semi-automated. Maintaining and calibrating ventilation systems is essential.
- Laboratory conditions such as humidity, temperature, and illumination can make or break a successful experiment. Sensors or low-cost hand-held thermometers and hygrometers can easily automate their measurement. Systems such as humidifiers, dehumidifiers, or even whole air-conditioning systems need to be installed. Humidity control and temperature control are necessary in rooms where expensive and sensitive instruments are housed, which would extend the instruments' life expectancy.
- When a cleanroom or facility has been completed, a final acceptance test should be conducted and documented for future use. Particle counts in a work area with the laminar flow could be a basic test.
- Work orders and changes to the engineering: Cleanrooms are powered by highly complex engineering. By obstructing or intentionally altering the facility airflow path, the facility performance can be adversely affected. Whenever operational parameters of the facility are altered, it should be recorded for future reference to facilitate system troubleshooting if necessary.
- There must be a record of all changes, upgrades, and upkeep. As long as feasible, records should be filed. As before, the use of differential records can help uncover potential issues.

5. ANALYSIS

The laboratory conditions are set up in a college environment to study the cleanliness of the laboratory under the spread of nano filters. Table.1 shows the average efficiency of nanoparticulate filters in obtaining clean rooms, which are given for different objects in the laboratory.

Table.1. Average Efficiency of Nanoparticulate filters in cleaning the dust in laboratory

Objects in Laboratory	Efficiency
Pleated	11.25%
Deep Pleated	49.66%
Fibre Glass	1.92%
Washable Materials (burette, pipette, etc)	5.85%
Electronic	95.23%

The Table.2 shows the mean efficiency of nanoparticulate filters in obtaining clean rooms compared to various other filters conventionally used in the laboratory. The simulation results show that the nanoparticulate filters provide a higher amount of efficiency in providing the cleanest environment than other filters.

Table.2. Comparison of Efficiency with other filters used in laboratory environment

Filters in Laboratory	Efficiency
Pocket filter- SwissAire	91.25%
Pocket Filter - Precision XDH	92.54%
Pocket Filter - Precision Pak	95.02%
Nanoparticulate filters	98.25%

Table.3. Comparison of efficiency with various dust loads

Filters in Laboratory	Dust Load (μm)		
	25%	50%	75%
Pocket filter- SwissAire	79.32%	75.25%	70.16%
Pocket Filter - Precision XDH	82.88%	81.17%	75.98%
Pocket Filter - Precision Pak	85.48%	83.39%	80.29%
Nanoparticulate filters	97.82%	96.84%	95.25%

Table.3 shows the average efficiency of nanoparticulate filters in obtaining clean rooms compared with dust loads. The simulation results show that the proposed method has a higher degree of efficiency over various dust loads like 25%, 50%, and 75% than existing methods. The results show that all the filters perform with lesser efficiency when the dust loads increase.

6. CONCLUSION

In this study, nano-particle-based filters filter and eliminate dust. The air is recirculated via a nano-particulate high-efficiency particulate air filter. These filters connected with nan-materials absorb the contaminants. The implantable particulate filters are the edges of the room enables a clean environment. The experimental testing is done using several nano-filters connected with power design circuits to control the entire environment automatically. The results achieved show that the microbial presence in the room is eliminated effectively.

REFERENCES

[1] Kalpana, V. N., & Devi Rajeswari, V. (2018). A review on green synthesis, biomedical applications, and toxicity studies of ZnO NPs. *Bioinorganic chemistry and applications*, *2018*.

[2] Teaima, M. H., Abdelnaby, F. A., Fadel, M., El-Nabarawi, M. A., & Shoueir, K. R. (2020). Synthesis of Biocompatible and Environmentally Nanofibrous Mats Loaded with Moxifloxacin as a Model Drug for Biomedical Applications. *Pharmaceutics*, *12*(11), 1029.

[3] Arif, U., Haider, S., Haider, A., Khan, N., Alghyamah, A. A., Jamila, N., ... & Kang, I. K. (2019). Biocompatible polymers and their potential biomedical applications: A review. *Current pharmaceutical design*, *25*(34), 3608-3619.

[4] Rastogi, S., Sharma, G., & Kandasubramanian, B. (2020). Nanomaterials and the Environment. *The ELSI Handbook of Nanotechnology: Risk, Safety, ELSI and Commercialization*, 1-23.

[5] Jiang, F., Yan, D., Lin, J., Kong, H., & Yao, Q. (2021). Implantation of multiscale silk fibers on poly (lactic acid) fibrous membrane for biomedical applications. *Materials Today Chemistry*, *21*, 100494.

[6] Song, W., Wang, Y., Wang, B., Yao, Y., Wang, W., Wu, J., ... & Zou, Z. (2020). Super stable CsPbBr3@ SiO2 tumor imaging reagent by stress-response encapsulation. *Nano Research*, *13*(3), 795-801.

[7] Sajjadi, M., Ahmadpoor, F., Nasrollahzadeh, M., & Ghafuri, H. (2021). Lignin-derived (nano) materials for environmental pollution remediation: Current challenges and future perspectives. *International Journal of Biological Macromolecules*.

[8] Liu, Z., Liu, Y., Shen, S., & Wu, D. (2018). Progress of recyclable magnetic particles for biomedical applications. *Journal of Materials Chemistry B*, *6*(3), 366-380.

[9] Fu, X., Cai, J., Zhang, X., Li, W. D., Ge, H., & Hu, Y. (2018). Top-down fabrication of shape-controlled, monodisperse nanoparticles for biomedical applications. *Advanced drug delivery reviews*, *132*, 169-187.

[10] Afsheen, S., Tahir, M. B., Iqbal, T., Liaqat, A., & Abrar, M. (2018). Green synthesis and characterization of novel iron particles by using different extracts. *Journal of Alloys and Compounds*, *732*, 935-944.

[11] Gundo, S., Parauha, Y. R., Singh, N., & Dhoble, S. J. (2021, May). Eco-friendly synthesis route of silver nanoparticle: A review. In *Journal of Physics: Conference Series* (Vol. 1913, No. 1, p. 012052). IOP Publishing.

[12] Sakthivel, M., Franklin, D. S., Sudarsan, S., Chitra, G., Sridharan, T. B., & Guhanathan, S. (2019). Gold nanoparticles embedded itaconic acid-based hydrogels. *SN Applied Sciences*, *1*(2), 146.

[13] Raipuria, V., Rani, N., Sharma, V. P., & Naiya, T. K. (2018). Use of nanoparticle derived from natural source and its application in drilling fluid. *International Journal of Oil, Gas and Coal Technology*, *19*(3), 283-295.

[14] Demissie, M. G., Sabir, F. K., Edossa, G. D., & Gonfa, B. A. (2020). Synthesis of zinc oxide nanoparticles using leaf extract of lippia adoensis (koseret) and evaluation of its antibacterial activity. *Journal of Chemistry*, *2020*.

[15] Osman, E. (2020). Nanofinished Medical Textiles and Their Potential Impact to Health and Environment. *Nanoparticles and Their Biomedical Applications; Springer: Singapore*, 127-145.