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Case Report

Beware! Fungus Growth in Reverse Osmosis Filters: On Exposure to Direct Sunlight!!

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Abstract

Household drinking water purification systems used in f the urban elite families of late adopt reverse osmosis process for improving the quality of water for consumption. They do not give enough protection from fungi in drinking water as the current understanding of the risk on health of general low and therefore current maintenance process, monitoring and treatment may look sufficient.

Most common human fungal pathogen *Cryptococcus neoformans* depends upon the light for its growth and development. Light inhibits mating and haploid fruiting (morphological switch from a budding yeast form to develop hyphae and viable basidiospores resembling those producing by mating) of the fungi especially seen in *Cryptococcus neoformans*, that infect central nervous system. The process of haploid fruiting is not yet fully clear.

I report here a case of fungal growths in the RO filter exposed to sunlight through a window and falling directly on the filter. The source of our apartment complex of 143 apartments being the same, this solitary episode raised a question and is yet to be answered. The manufacturers customer support team kept on changing the filters and a change of the position of the equipment to avoid direct sunlight exposure on the unit resolved the issue. Though no untoward health effect of the level of contamination as seen by the colour of the water was dreadful, nothing happened. Unfortunately, the manufacturer had no clue, as to what may cause fungal growth, though they kept promising to replace the filters.

BWSSB monitors the Microbiological safety of drinking water by bacterial indices due to faecal contamination, though some viral agents, also cause gastro-intestinal illness. Non-endemic microbial contaminants like Fungi that cause health issues like allergies, opportunistic infections and intoxication have become known recently, but the mode of such infections is yet to be established by the scientific community.

Greater knowledge about the association between fungi and bacteria and if commonly measured bacterial counts of water quality are sufficient is desired.

Materials and Methods: This case report is based on the observation of an RO system water filter in our apartment, in two distinct positions over last 3 years. The manufacturers technical support teams' maintenance work limited to cleaning and replacing the filters and a written response from the manufacturer, saying that they have not come across such case earlier and will explore

Keywords: Reverse Osmosis; Carbon Filters; Trapping Organic Chemicals and Chlorine Ultraviolet Lamps for Sterilizing from Microbes; Bacterial Growth; Fungi

Introduction

A few studies have investigated the fungi found in treated drinking water. The numbers of fungi range from 1 colony forming units (CFU) to 5000 CFU per litre and majority were filamentous fungi among sixty-five fungi genera isolated for a review. The most isolated genera were *Cladosporium oxysporum*, *Penicillium spinulosum,* and *Aspergillus fumigatus* in RO filters.

While the location of primary water source, sun irradiation, temperature, ion composition and pH, determines the presence, colonization, and growth of fungi. Water's contamination due to organic material, dissolved oxygen concentration, water treatment, the materials used for water distribution systems add to the complexity of fungal growth. Biofilms are an important habitat for fungi in drinking water, whose development is dependent on temperature, nutrient concentration, pipe material and water flow rate.

Water treatment is expected to remove harmful bacteria and reduce the number of fungi in water. Melanized or dematiaceous fungi are ubiquitous organisms that inhabit the surface of plant materials and soli but accidentally contaminate water running through them and are recognized as important pathogens, are associated with chromoblastomycosis, mycetoma, and phaeohyphomycotic in the past 20 years. Multiple processes have different removal efficiencies though the most efficient method is still eluding.

Aspergillus and *Candida* have been isolated from treated drinking water and they are known to be pathogenic to humans. They are responsible for allergic disease, superficial and deep local infections, pneumonia, brain abscess, and disseminated infections among normal persons. In immunocompromised individuals, they are cause of allergic fungal sinusitis, and brain abscess. The field of mycology is the most neglected sub-discipline in microbiology. The melanised fungi are capable of surviving and thrive in the environment including high ionizing radiation. Some melanized fungi like *Rhinocladiella mackenziei* and *Horetea werneckii* were recovered from human beings. Fungi synthesize Melanin through DHN pathway. Melanin contributes to the virulence factor for these fungi. It was only in 2010 that it was proved that most of the human infections were caused by melanized Fungi. Nearly 70 genera of fungi are associated with human disease. These fungi also alter host immune response by inhibiting phagocytosis and cytokine production. Clinical assessment complimented by microscopic and pathological examination, help in clinching the diagnosis. Fungi is a totally natural microorganism that loves damp, moist spaces and out water filters are nothing but that's exactly what our water bottles and filter tanks are! - damp, moist space with very little air flow, providing an ideal home for mold. Among more than 1000 fungi, most are harmless but *Stachybotrys chartarum*, commonly known as black Mold that might appear in bottles and water filter tanks is toxic. However, there is little evidence that drinking water can be a source of infection. Individuals with immunocompromised status due to HIV/AIDS, chemotherapy, immunosuppressive therapy following transplants, cystic fibrosis or diabetes mellitus fall prey to severe invasive infections. Negligible invasive fungi infections have case fatality rates (50-100%) among such persons.

Reverse osmosis principle

Reverse osmosis is a special type of filtration that uses a semi-permeable, porous membrane, that separates ions, unwanted molecules, and larger particles from drinking water and only pure water is passes through the membrane for ready to use. An applied osmotic pressure is used to overcome pressure. It is a colligative property (ratio of the number of solute particles to the number of solvent particles in a solution and not the chemical species) a thermodynamic parameter. In Reverse osmosis filtration Chlorine is captured in the Granular Activated Carbon (GAC) filter of the RO system and thus the user gets chlorine free safe drinking water. UV is very effective at inactivating both bacteria and fungi, as compared to chlorine that is effective on bacteria alone.

Case Report

I relocated from New Delhi to Bengaluru in April 2018 and had fixed Aqua guard Reviva. While 2018 and 2019 was uneventful with 2 services and change of filters annually. In early 2020 we noticed a fungal growth in the filters and the local service mechanic changed the filter. No other apartment in the 140-apartment complex had such problem. Again after 6 months similar fungal growth was noticed. In his second visit on 7th May 2021, he suggested changing the location of the equipment as direct sunlight was falling on the equipment and may be the reason for fungal growth. We relocated the equipment to servant room (being used storeroom) with no sun-light access. On 13 October 2021 RO pump and SV was changed.

After the change now for nearly a year the problem is resolved. On 2nd May 22 in the annual service the filter candles were changed again.

The Pre-chlorination of water supply from the common pump house to an ultraviolet (UV) disinfection process of the RO system reduces the effectiveness of UV inactivation by absorbing UV radiation from Sunlight.

The manufacturers had no clue of such a possibility, as can be seen from the response (reproduced as is).

Response from the Manufacturer

Dear Mr. Suresh, 11 February 2022

Thank you for contacting Eureka Forbes Customer Support. Regarding your scientific studies related concern, we deeply regret to inform you that we do not have any information about the same. For product related information, you can visit our website www.eurekaforbes.com.

Regarding fungal growth-related concern, we would like to convey you that if you will face similar issue again then kindly revert us back accordingly. We will raise a service complaint for the same so that our authorized service technician will visit you & assist you accordingly. Please be assured, we will help you in the best possible way.

We appreciate your patience in the interim.

Figure 1

Figure 2: Original Location of the RO filter with bright sun from east through a window on 11th floor.

Figure 3: The green coloured water with Fungus.

Figure 4: Current location with no direct sunlight.

Discussions

The presence of fungi in water distribution system and the associated health risks are well documented in the scientific literature. However, inclusion of absence of fungi in the drinking water quality as a regulation is rare worldwide. Most national and international water quality guideline documents list fungi as the "nuisance organisms" causing odour problems, but do not include monitoring necessary.

The reverse osmosis process removes different types of dissolved and suspended chemicals, bacteria and fungi from sourced water to produce potable water, which is nothing, but the pure solvent molecules that passed through the filter freely.

Such RO systems typically include following steps:

- Two sediment filters one a Rust and carbonate and a second sediment filter with smaller pores. An activated carbon filter or a cellulose triacetate membrane to trap organic chemicals and chlorine.
- A reverse osmosis filter- a thin-film composite membrane, an ultraviolet lamp for sterilizing microbes that escape filtering by membrane and a second carbon filter or a cellulose triacetate membrane to capture chemicals that are not removed by the reverse osmosis membrane. The cellulose triacetate membrane will rot if not protected by chlorinated water. The thin-film membrane is made of synthetic material, that is prone to break down under the influence of chlorine and therefore chlorine must be removed before the water enters the membrane. Most OR instruments in Indian market use carbon filters as pre-treatment whose thin-film composite membranes have a higher rejection rate of 95–98% and a much more longer life than cellulose triacetate membranes.

The entire process of reverse osmosis filtration consumes lot of energy, and a lot of pressure is needed for deionization for further filtration. The water might become acidic because of deionising of all its mineral content, but the water must have some minerals to help the functioning and preventing mineral depletion of the body. Reverse osmosis performs two functions i) water softening and ii) water purification. Regular maintenance must be done when the machine is still operational. It is easy to adapt it efficiently working for filtration retaining ion particles that are allowed to enter through the semipermeable membrane.

The manufacturer claims that their equipment is ideal for homes with high TDS levels in water as it has a unique RO membrane to remove excess TDS and blocks impurities and chemical contaminants dissolved in water. It is equipped with a) most advanced Technologies Active Copper™ and Mineral Guard™ b) i-FilterTM removes suspended particles from the water c) Chemi-Block remove excess chlorine and organic impurities d) RO cartridge reduces hardness, pesticides and eliminates micro-organisms and e) Taste Enhancer removes residual organic impurities and enhances the original taste of water. However, it is silent on the issue of fungal growth when exposed to direct sunlight.

The manufacturer warns about:

- Aqua guard blinking red is a reminder to change the filter, it does not sense if the filter has been changed or not. When the red light is blinking, press and hold both up and down arrows until the red-light blinks RAPIDLY, release both for a second or two, and press and hold both again until it stops blinking.
- Mineral Guard™ Micro-controller-based Electronic Impulse Producer Tank Filling LED will blink blue at 0.5 sec rate Input Water Quality Usage Limitations: 1. If the input water iron content is more than 0.3 mg/ltr., use of iron remover* is recommended as a pre-treatment.
- RO water removes negligible amounts of calcium from the water and removes harmful nitrates to help preventing diseases. Only when the tap water we are supplied is as good as this purified water, should we think about drinking tap water directly".
- RO Technology for Water Purification; good TDS level-between 50-150. TDS above 1000 PPM, is unsafe and unfit for human consumption. All other Chemical parameters within IS 10500. No heavy metals like Lead, Arsenic, Chromium and anions like Fluoride and Nitrate are in excess (The above are manufacturer's instruction and copies for reference only and can't be changed).

TDS level chart for drinking water

Light and fungal growth in drinking water

Most common human fungal pathogen *Cryptococcus neoformans* depends upon the light for its growth, and development., but the

TDS in Water (measured in PPM)	Suitability for Drinking Water
Between 50-150	Excellent for drinking
150-250	Good
250-300	Fair
300-500	Poor, not good for drinking
Above 1200	Unacceptable

Table 1

mechanisms involved are not yet clear. A study recently reported that the white collar 1 homolog gene BWC1 mated equally well in the light or the dark, but deletion of candidate genes encoding had no effect on mating [4].

Drinking water sources can be contaminated with bacteria, viruses, protozoa, and fungi. Recently, researchers have reported the presence of fungi in drinking water (Goncalves., *et al*. 2006a; Pereira., *et al*. 2010) and have observed that these fungi affect the taste and odour of the water. Many varieties of fungi species have been isolated from drinking water, and. some of them are known to be strongly allergenic or may cause infections in immune-suppressed individuals (e.g., those suffering from AIDS, cancer, asthma, or other respiratory diseases, or recovering from organ transplants [2].

Non-endemic microbial contaminants like Fungi that cause health issues like allergies, opportunistic infections and intoxication have come to light recently. While their occurrence, ecology, and physiology, determine their presence in water distribution systems, and their effect on water quality and health risk to consumers have been of interest of scientific community in the recent decade [6].

The Sunlight consists of infra-red, ultra-violet (UV) and visible spectre of the light; among those, the effect of the UV-radiation causes the highest damage of cell mechanisms. Natural disinfection by inactivation of faecal bacteria, by exposure to sunlight is a proven technique for generating safer drinking water, However, the effect of sunlight on fungi is not well documented. The effect of solar UV-radiation DNA-damaging effect contributes to the thermal disinfection with raising the water temperature, therefore it varies with the time of a given day. The water temperature depends also on the depth, volume, and flow rate. If the temperature range shoots beyond 15°C and 25°C, the structure of fungal communities in surface water becomes stable. The sensitivity of thermotolerant *Aspergillus* and *Phialophora* species and yeasts during the summer, and filamentous fungi from the genera *Acremonium, Cladosporium* and *Penicillium* during the cold seasons are known to affect their infectivity in respective seasons [6]. Biofilms formed in drinking water are the main reservoir of microorganisms inside water distribution systems and are ecologically diverse. Filamentous fungi and bacteria do coexist inside the water carriage systems forming inter-kingdom biofilms.

The disinfection process of drinking water treatment units is aimed for safety of drinking water for humans from bacteria, viruses, algae, fungi. This is achieved by using chlorination, ozonation, UV irradiation, etc. In a study in 2013 By using UV radiation, the 2 log10 control of *A. flavus* was achieved after 30 seconds of irradiation. Chlorination was more effective than UV, where the 2 log was achieved at chlorine concentration of 0.5, 1, 2 and 3 mg/l, in contact time of 60, 5, 1 and 1 min, respectively. However, combined use (UV irradiation followed by chlorination) was more effective than using either UV or chlorination alone; 5 seconds UV irradiation followed by chlorination produced 4 log10 reduction of A. flavus at chlorine concentrations of 2 and 3 mg/l under a contact time of 15 min. The results indicated that efficiency of UV irradiation improves when followed by chlorination at low concentrations [3].

Perchlorinating of water upstream of an ultraviolet (UV) disinfection process may possibly influence the effectiveness of UV inactivation by absorbing UV radiation. Monochromatic UV light was more effective in degrading monochloramine whereas polychromatic UV light is more effective in degrading free chlorine, that might facilitate fungal growth [5].

Conclusion

Though no health problem was noticed, this case report alerts the water systems and public health research to determine the importance of drinking water as the source of fungal infection in general and among vulnerable or at-risk population groups. Clear understanding of the importance of ingestion versus inhalation or skin contact as exposure pathways for fungi will facilitate mitigation measures for at-risk patients.

Light Controls Growth and development of the Fungal Kingdom, as it inhibits mating and haploid fruiting of the human fungal

pathogen *Cryptococcus neoformans*, though the exact mechanisms involved are unknown. As the applied UV dose is much higher than for standard disinfection, the system can remove free chlorine, facilitating fungal growth.

Finally, further research into fungi in drinking water and their impact on health of the human beings is the need of the time.

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