



Air to All, Inc. Air One Powered Air-Purifying Respirator (PAPR)

Air to All, Inc. provides affordable medical devices and personal protective equipment (PPE) to underserved communities.

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Air to All, Inc. Air One PAPR

Abstract

Air to All, Inc., a volunteer-led nonprofit, has developed an affordable Powered Air-Purifying Respirator (PAPR) to meet the needs of underserved communities (low income, rural, indigenous, and immigrant) and to address limited PAPRs and PPE for emergency stockpiles and everyday shortages. Designed to meet or exceed the core functionality of leading PAPRs currently available in the marketplace, the **Air One PAPR** is priced at \$500, well below other models.

1. An Affordable, Rechargeable & Reusable Powered Air-Purifying Respirator (PAPR)

The COVID-19 pandemic has revealed urgent gaps in personal protective equipment (PPE) especially in underserved communities (low income, rural, indigenous, and immigrant). According to the World Health Organization, 41% of 158 countries do not have national standards for medical devices¹ and severe PPE shortages continue well into the pandemic² including in HIC (High-Income Countries)³. The PPE regulatory framework across all income-level countries is patchy at best thus constraining the ability to procure and provide adequate PPE for healthcare personnel.⁴ The lack of PPE also prevents healthcare professionals from providing the necessary medical care to patients in a safe environment, and indeed, can result in higher death rates of medical staff. Beyond the pre-pandemic challenges of providing PPE to underserved communities across the world, in early 2020, many hospitals in high-income and low-income countries faced additional PPE shortages due to increasingly high cost and lack of availability resulting from supply chain disruptions.

Driven by the urgency to alleviate this global crisis and to ensure fair access to safe and affordable PPE, Air to All, Inc. (A2A) quickly mobilized more than 500 volunteers who donated their talents - engineers, supply chain management, quality control, communications and advancement - and crowd-sourced their capabilities to design a low-cost, rechargeable, reusable Powered Air-Purifying Respirator (PAPR).

¹ https://www.who.int/gho/health_technologies/medical_devices/en/

² <https://www.who.int/teams/health-product-and-policy-standards/access-to-assistive-technology-medical-devices/medical-devices/priority-medical-devices-for-covid/ppe-covid>

³ <https://thehill.com/policy/healthcare/public-global-health/538678-hospitals-face-continued-ppe-shortages-other-supply>; <https://www.healthcarefinancenews.com/news/covid-19-shortages-protective-equipment-insufficient-tests-plague-hospitals-oig-finds>

⁴ <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7195610/>



The A2A cross-functional team developed this affordable and safe PPE for healthcare and frontline workers and other essential workers - especially those in underserved communities. And, the **A2A PAPR** is designed to be easily manufactured, at scale, worldwide. The **A2A PAPR** will not only mitigate everyday shortages of PPE but can also be stockpiled for future emergency use.

2. Design Philosophy: Core Functionality

The A2A “Core Functionality” design philosophy prioritizes key performance functionality over features that add complexity and weight. Air to All, Inc. also leverages, to the extent possible, easily-sourced, off-the-shelf components. This approach not only supports superior cost performance but also greater speed to market, manufacturing scalability, and resilience to supply chain challenges.⁵

3. Air One PAPR Features

According to a survey conducted by the U.S. Conference of Mayors to measure the shortage of different categories of medical equipment, first responders ranked PPE as the most required protective equipment.⁶ Inspired by the daunting need to protect populations, A2A advanced the design of the **Air One Powered Air Purifying Respirator (Air One PAPR)**.

PAPRs integrate protection of multiple areas (head, eyes, face and respiratory) into one NIOSH-approved product which frees facilities from ongoing procurement challenges and shipment delays associated with single use masks, and significantly reduces the environmental burden of disposable masks and face shields. Additionally, the **Air One PAPR** was carefully designed and developed to ensure a high level of protection and comfort for wearers, ultimately advancing safety and increasing productivity all while maintaining a low price point.



Figure 1. **Air One PAPR** Airbox containing a HEPA filter, a PWM fan, and a Lithium ion (Li+) battery pack

⁵ See also <https://link.springer.com/article/10.1007/s13243-018-0065-7>

⁶ <https://www.usmayors.org/issues/covid-19/equipment-survey/>



The **Air One PAPR** has been designed with a number of features that safeguard wearers. These features include higher air filtration performance, elevated safety features, clearer field of vision face shield, flexible size accommodation, longer battery life, shorter recharge timeframes, smart and comfort features, quality and regulatory standards, and competitive pricing.

High Filtration Performance

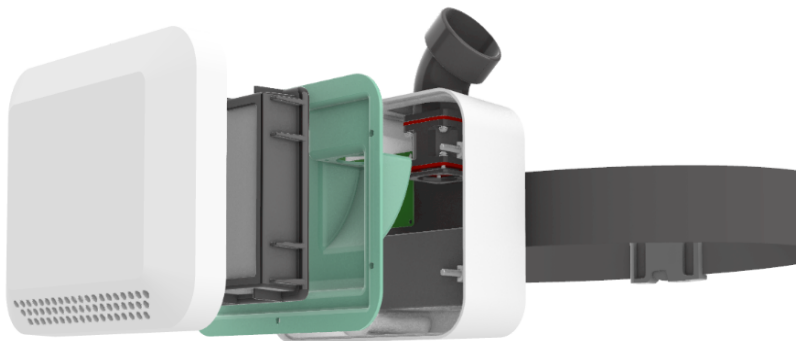


Figure 2. Interior of **Air One PAPR** Airbox showing how ambient air is drawn through small holes at the base of the Airbox through the HEPA filter

Within the **Air One PAPR** Airbox (Fig. 2), ambient air is drawn through a HEPA filter that is 99.97% efficient against > 0.3 -micron particles, using a Pulse Width Modulation (PWM) fan. The **Air One PAPR** provides up to 6 cubic feet/minute (CFM) airflow to the hood with positive pressure controlled by a custom printed circuit board (PCB) thus protecting the wearer's eyes, nose, ears, mouth and head from environmental and viral contaminants.

And, thanks to the superior performance of the HEPA filter, the Air One PAPR provides greater filtration and performance than N95 and other masks.

Integrated Safety Features

The **Air One PAPR's** smart, integrated design eliminates the need for wires and cables thus minimizing the weight of the **Air One PAPR** and allowing free movement of the wearer.

In the event of low battery power, the battery alerts the wearer to remaining battery life both visually and audibly and allows the wearer to continue to breathe through the filter as the purified air is



completely sealed off from ambient air. Additionally, the **Air One PAPR's** Airbox is encased in high density polyethylene (HDPE) which offers high durability, UV protection, chemical resistance, and serves as a rigid shell to protect the Airbox from mechanical damage.

Each **Air One PAPR** sub-assembly is easily detached and cleaned.

The anti-kink design of the air hose featured in the **Air One PAPR** prevents the loss of airflow and allows free movement of the wearer while ensuring seal and reliability.

Clear Field of Vision

An unobstructed field of view and clear visibility are essential to maintain productivity of the wearer in fast-paced working environments. The **Air One PAPR** uses a face-piece (hood) that both allows the use of stethoscopes as well as providing a 180 degree field-of-view which permits users to perform a variety of functions in a more natural posture, and supports full view of the wearer's face. The clear vision feature enhances communication among all wearers, staff and patients at environmental and viral contamination sites.

Flexible Sizing

The **Air One PAPR's** reusable hood accommodates a range of head sizes and can be comfortably worn over eyewear, facial hair and headwear.

Each size-flexible battery belt attaches to the Airbox held at the back of the user to allow them to comfortably position the device behind them and easily detach the battery belt from the front for quick release after use.

Long Battery Life and Short Recharge Timeframes

The **Air One PAPR** is powered by a rechargeable Li+ battery with an 8-hour shift cycle and additional reserve battery life and can be recharged in less than 2.5 hours. This feature is critical to reducing worker downtime and maintaining a productive workflow.



Smart and Comfort Features

The **Air One PAPR** includes visual and audible alarms to alert the wearer of low battery life, plus an interface that allows the user to adjust the airflow to accommodate for various altitude conditions or breathing requirements.

Once the **Air One PAPR** is successfully positioned on the wearer, there is little to no additional hand-to-face adjustment needed.

Quality and Regulatory Standards

Air to All, Inc. will submit the **Air One PAPR** for NIOSH testing and certification.

The **Air One PAPR** also uses one of the industry's highest standard filter media which provides 99.97% protection from airborne particles, one of the industry's highest protection rates.

Competitive Cost Analysis

The **Air One PAPR** has the lowest cost per day compared to other PAPRs currently available in the marketplace and also compared to the use of N95 masks combined with face shields. Both the filter and the hood are replaceable. Hoods are typically personal to each individual using a PAPR while the Airboxes are shared. See Table 1 below.

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| PPE | Device Cost | Parts Cost/month | Cost per Day |
|-------------------|-------------|------------------|--------------|
| Ford PAPR | \$700 | \$183* | \$6.99 |
| 3M Versaflo™ PAPR | \$900 | \$30 | \$2.21 |
| N95 + Face Shield | - | \$63 | \$2.07 |
| Air One PAPR | \$500 | \$20 | \$1.37 |

Table 1: Cost Comparison of Air to All, Inc.'s **Air One PAPR** compared to other PAPRs and N95 masks + face shields

*Ford PAPR filter cannot be replaced - filter lifespan is estimated at 1000 hours. Hoods for the 3M Versaflo™ and the Air One PAPR are estimated to last three months (100 uses) and it is assumed that the filters for the Versaflo™ and the Air One are replaced every two months (500 hours of use). It is assumed that N95 masks last one day and face shields last one month.

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4. Benchmark Analysis

The **Air One PAPR** functionality meets or exceeds the functionality of PAPRs manufactured by Ford and 3M as shown in Table 2 below.

| Model: | Air One PAPR | Ford PAPR | 3M Versaflo™ TR300+ PAPR |
|---------------------|-------------------------|-----------------------|--------------------------|
| HEPA Filter: | Yes | Yes | Yes |
| Replaceable Filter: | Yes | No | Yes |
| Alarms: | Low Battery | Low Battery | Low Battery + Low Flow |
| Battery Type: | Lithium-Ion | Lithium-Ion | Lithium-Ion |
| Run Time: | ~ 8-10 hours | ~ 8-10 hours | ~ 8-12 hours |
| Charge Time: | < 2.5 Hours | ~ 2.5 hours | < 3.5 Hours |
| Blower Weight: | < 3.5 lbs. with battery | 6.3 lbs. with battery | < 1.7 lbs. with battery |
| Price: | \$500 | \$700 | \$1200 |

Table 2: Feature and cost comparison of Air to All, Inc.'s Air One PAPR with leading PAPRs.

5. The Strength of the Air to All, Inc. Community

In line with our mission, the members of the Air to All, Inc. community work every day in an effort to systematically lower PPE costs and increase access to PPE for underserved communities. We aim to accomplish this goal by making our PPE more cost-efficient and sanitary than single use items; by designing certified rechargeable and reusable equipment; and, by delivering at quantities required for each unique community.



We also engage the best and brightest volunteer engineers, supply chain and creative professionals, crowd-source our ingenuity and open-source our technology, and work with partners who share our vision of equal access to affordable medical devices and PPE for all communities.

Air to All, Inc. does not and shall not discriminate on the basis of race, color, religion (creed), gender, gender expression, age, national origin (ancestry), disability, marital status, sexual orientation, or military status, in any of its activities or operations. Air to All, Inc. fully supports and engages in efforts that support diversity, equity and inclusion in our workplace.

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