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**EXTREME COLD WEATHER HEALTH RISKS AND
ASSESSMENTS**

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Extreme cold weather (ECW) poses unique challenges for health and safety among personnel working there. Occupational health risks are not well categorized, nor are methods used to assess them understood. All operations in the extreme cold will have unique protocols which can completely adjust a person's health risks. Data collected suggests the remote nature and extreme cold have negative effects on sampling abilities for environment, safety, and occupational health (ESOH) purposes. This paper compares thermal desorption tubes, Tedlar® bags, and passive sampler data from ECW data stored in the Defense Occupational Environmental Health Readiness System (DOEHRS). These data suggest that passive samplers and Direct Read Instruments (DRI) are promising sampling technology in ECW, with more studies needed in multiple areas. There are future studies that could be conducted such as issues with respirators, battery life which is essentially negligible in the cold, the "Crud," and the combustion profile and related health effects of AN8 jet fuel for which little information exists about the fuel in general. A key takeaway from interviews is the absolute remoteness of the assignment which effects morale and has significant supply chain issues that impact everything.					
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1.0 SUMMARY

Extreme cold weather (ECW) operations (-60 degrees Fahrenheit (°F)) within the Air Force will require new modes of operation which we have previously not experienced. While the Air Force has several installations that experience ECW sporadically, their scope and operations are designed for hardened locations with temperatures typically more temperate than the arctic climate. Sustaining operations from a temporary location, such as an arctic research station or humanitarian relief, will lead to new limitations in every operation we currently perform such as airfield operations, personnel support, and protecting the health of Airmen. These limitations breed new operations, and between the new procedures and the environment there are new risks to the Airmen that are not yet characterized. This study provides initial environmental health data and observations from an ECW environment using data from the Defense Occupational and Environmental Health Readiness System (DOEHRS) involving the 109th Air National Guard (ANG) mission with LC-130 aircraft.

2.0 INTRODUCTION

ECW military operations differ from our current mindset within the Department of Defense (DoD). Our force is primarily equipped to handle a conflict experiencing extreme heat, as opposed to extreme cold, and the transition from one battleground to the other introduces complexities which can only be addressed by observation and training within that environment. Each section of military life will need to adjust to these conditions, from construction and utilities to food preparation. Some of the primary issues when working in this climate have to do with human health.

The Air Force is comprised of many specialties which ultimately keep our aircraft capable of executing their mission. In a deployed location it is possible to have only a single person who can meet a mission need and if they are incapacitated, could result in mission stoppage. This is why Environmental, Safety and Occupational Health (ESOH) concerns are considered a primary need during the establishment and continuation of operations. Life in extreme cold climates carries certain health and safety risks which we have not dealt with extensively, but working in one introduces even more new variables which can have long and short-term impacts on the mission.

Some initial questions that arise are regarding jet fuel. What type of jet fuel is being used in these environments? Does it contain additives not found in other fuels? Does this affect the combustion profile? And does the cold air affect the exhaust products? It's clear how wind can spread a gas around the area, but with climates like these we do not always have prevailing winds. Sometimes the wind will push exhaust right into the cargo bay, sometimes it has a headwind that lowers the exposures. This study sought to provide insight to these questions for ESOH professionals, answering some and providing clear needs for future studies while investigating ESOH concerns for military personnel operating in extreme cold environments.

We conducted an Occupational, Environmental, Health Site Assessment (OEHSA) for an area of consistent Air Force operations. This led to sampling of LC-130 exhaust as part of service members health risks. The purpose of this paper is to provide initial results for LC-130 exhaust exposures for airfield operations, primarily loadmasters and crew chiefs, in an extreme cold environment. Sampling included Tedlar ® bag grab samples, XploSafe ® media measured with Gas Chromatograph/Mass Spectroscopy (GC/MS) method TO-17, SKC Umex 100 ® Formaldehyde samplers, and SKC volatile organic chemical (VOC) Cheks ®.

3.0 BACKGROUND

Initial questions for a new location stem from the OEHSA which involves an ESOH professional identifying hazards present at the location in question. This includes the environment and the mission being accomplished and is typically a very specific assessment for a location. The methodology used for an OEHSA is no different from standard industrial hygiene or environmental health procedures, which is the basic premise of this study. The first step is to collect any pre-existing ESOH data on the area.

During the planning stages of this study, it became apparent that there is a major lack of ECW ESOH data related to aircrews. This may be because the areas are immediately considered to have abnormal hazards, and rather than assessing the risk workers are simply protected to the best of their ability. Employees in these regions are commonly associated with the petroleum or fishing industry, which are jobs that commonly feature periodic work for weeks to months at a time followed by time at their home station (Heavy Duty Field Oiler (rotational schedule) - Prudhoe Bay, AK).

Keeping in line with industry standards, there is a hierarchy of controls within health and safety which are followed: engineering, administrative, and personal protective equipment (PPE). The goal is to use them in order from engineering, administrative, and PPE to the maximum extent feasible. An engineering control removes the hazard completely, including substituting the process, replacing a human worker with a machine, or building a ventilation system to remove all of the hazard. Administrative controls are process oriented, utilizing work rest cycles or specific trainings to prevent or minimize a hazard. PPE is the least preferred option, utilizing gloves, respirators, boots, earplugs, etc. to protect the worker (Morris and Cannady, 2019). The key similarity is that they must have an associated hazard to work

effectively. A process cannot be replaced if the underlying risk is not understood, nor can proper trainings or PPE be selected, and this is where the study begins.

Most of the “famous” health risks have large data sets to pull their health risks from. These stem from hazards that used to be extremely prevalent, like asbestos. Asbestos has been mined for thousands of years, and used by the general population enough to produce the data used to tie asbestos to disease outcomes and determine which protection is needed when it is used (Ross and Nolan, 2003). When studying a population as small as “aircrews that operate in ECW” there is not a large enough population to generate the resources needed to adequately identify the differences between them and aircrews from temperate climates. Data on C-130 exhaust streams were found in a published Air Force Institute of Technology thesis, and this provided some means for comparison.

Additionally, it is currently unclear just how well the equipment used in these assessments will work within ECW environments. Equipment like air pumps, direct reading instruments (DRI), and passive samplers are designed for a range of temperatures, and none are currently rated for the extreme cold with a common National Institute for Occupational Safety & Health protocol testing them from 10-100 °C (Harper & Guild, 1996). Based on common equipment ratings, there are almost no methods capable of providing these assessments. Utilizing occupational health data collected from 109th ANG members and pulled from DOEHRS, as well as interviews with personnel who are experienced with operations in ECW, this study summarizes the available information for future occupational health concerns in ECW.

4.0 METHODS

The first step was to conduct a series of interviews with members of the 109th ANG. The results of these interviews will be summarized in the discussion section of this report as many of the true outcomes are subjective in nature.

The methods used are stored within DOEHRS and are accessible by the Stratton ANGB Bioenvironmental flight for the purposes of tracking. The media types and their analysis methods used are listed in Table 1. Sampling was conducted between 13 – 27 December 2022 repeating as frequently as possible. All direct read media was collected, and all personal air sampling was conducted on aircrews, maintainers, or sampling personnel themselves when needed. Certain media required freezer storage per the manufacturer's instructions, and all media was capable of being stored under freezer conditions. This was accomplished using a Yeti ® 65-quart cooler. This cooler was packed with leak resistant ice packs and was checked as luggage aboard the airline. A Govee® wireless thermometer was placed in the cooler to track the temperature throughout travel. At each hotel, the samples and ice packs were moved to the in-room freezer to keep them at their temperature.

TABLE 1. Media part number, manufacturer, analyte sampled and analysis method

Manufacturer	Media Part Number	Analyte	Analysis Method
Draeger	6733181	Ozone (0.05-1.4 ppm*)	Direct Read
Draeger	CH21001	Ozone (10-300 ppm)	Direct Read
Draeger	8103691	Benzene (0.25-10 ppm)	Direct Read
Draeger	8101751	Formaldehyde (2-40 ppm)	Direct Read
Draeger	6719101	NO ₂ (2-100 ppm)	Direct Read
SKC	575-001A	VOC	NIOSH 1501
SKC	575-002A	VOC	NIOSH 1501
SKC	226-117	Acrolein	OSHA 52/68
SKC	231-01	VOC	TO-15
SKC	500-100	Formaldehyde	OSHA 1007
SKC	225-401	Elemental Carbon	NIOSH 5040
SKC	226-01	VOC	NIOSH 1501/1550
XploSafe	OSU-6	VOC	TO-15

*ppm = parts per million

14 December 2022 SAMPLING

Samples taken at the ECW location focused on VOCs and DRI. Three sampling events were conducted. The first was conducted on 14 December 2022 and consisted of samples listed in Table 2, along with the validity of the sample. Certain sampling equipment failed on site, which may or may not be attributable to the environment. All samples were taken through personal air sampling, with associated media blanks. Passive air samplers were clipped to the hood of aircrews working in/around the rear of the aircraft within an approximately 5-meter (m) radius of the rear cargo door. This places the samplers between 5-20 m of the engines while running.

Thermal Desorption (TD) Tubes were sampled using an SKC touch ® sampling pump, calibrated with an SKC Chek-Mate ® and a low-flow adapter to 200 milliliters (mL)/minute (min). Three pumps were used, however they failed shortly into sampling. The aircraft was on the ground for approximately 30 min, with the passive samplers being opened from their packaging for a total of 50 min each: 10 min before landing, 30 min on the ground, 10 min after take-off. Tedlar ® bag (stainless steel valve type) samples were collected by using a Hamilton 86312 air syringe to collect 1 liter of air while standing in the exhaust stream behind the aircraft approximately 40 feet behind the right side of the aircraft. At the same time, a MultiRAE pro was used to measure VOC, CO, Oxygen by holding it in the exhaust stream at the same location.

15 December 2022 SAMPLING

All methods used on 15 December 2022 are identical to 14 December 2022, except all were taken from the sampler's personal breathing zone. He stood about 40 feet behind the aircraft to collect MultiRAE, Tedlar ®, passive, and TD-tube samples. Samples collected are listed in Table 3.

TABLE 2. 14 December 2022 Samples

Samples Taken	Manufacturer	Part Number
1	Draeger	6733181
1	Draeger	CH21001
1	Draeger	8103691
1	Draeger	8101751
1	Draeger	6719101
4	Xplosafe	OSU-6
3	TD TUBES	307682 307665 307629
4	SKC	575-001A
4	SKC	575-002A
3	SKC	231-01
3	SKC	500-100

TABLE 3: 15 December 2022 Samples

Samples Taken	Manufacturer	Part Number
4	Xplosafe	OSU-6
3	TD TUBES	307440 306810 307573
4	SKC	575-001A
4	SKC	575-002A
3	SKC	231-01
4	SKC	500-100

16 December 2022 SAMPLING

The samples taken were passive samplers clipped to aircrew collars, or active samplers using an SKC touch ® sampling pump, calibrated with an SKC Chek-Mate ® and a low-flow adapter to 100 mL/min. Samples are listed in Table 4. These samples were collected over the same 50-min time frame as the 14 and 15 December samples.

TABLE 4. 16 December 2022 Samples

Samples Taken	Manufacturer	Part Number
2	SKC	226-117
1	SKC	225-1713/226-30-04
4	SKC	575-002A
3	SKC	500-100

22-25 December 2022 SAMPLING

A series of samples collected at Williams Field, including Jet-A/BTEX using SKC 226-01 and Elemental Carbon using SKC 225-401 are also recorded in DOEHRS. These samples were collected from crew chiefs, maintenance tower workers, engine shop, and aero repair workers as available. The pumps were clipped to their belts, and the sample placed in their breathing zone. Samples were collected for approximately 10 hours, shortly into the start of their shift and then shortly before shift end. Each maintainer was instructed to perform their operations as normal, with the explanation of what these pumps would measure. Xplosafe samplers were also used for each maintainer, by clipping it to their collar at the beginning of each shift.

Sample Transport

All samples were stored in a freezer set to 25 °F. Each was placed into an independent sandwich bag and labelled with the time and date it was sampled. These were transported home in the same manner as they were transported to the test site, in a sealed YETI ® cooler with ice packs. Upon arrival in the United States, samples were moved to a freezer set to 21°F, to await shipment. These samples were shipped to XploSafe and U.S. Air Force School of Aerospace Medicine.

Thermal Desorption GC/MS

Analysis was performed on a Trace Ultra GC connected to an ISQ single quadrupole mass spectrometer (ThermoFisher, Waltham, MA, USA). A Markes International TD100xr in line with the GC was used to desorb volatiles from the TD tubes for 10 min at 310 degrees Centigrade (°C) with a flow path temperature of 160 °C. Volatiles were purged with nitrogen for 1 min at 50 mL/min. Any injection with an internal standard was automatically loaded onto the TD tube with 1 mL of the standard. The volatiles were separated on a Restek Rxi-624Sil MS 60 m x 0.32-millimeter, 1.8 micrometer capillary sized column with a constant flow of 99.9999% helium (Restek) at 2.0 mL/min. The GC's initial temperature was 40 °C, was held for 1min, and then ramped up at 10 °C per min until it hit a temperature of 240 °C. This temperature was maintained for 20 min. The ion source temperature was set to 275 °C and the ISQ transfer line was 230 °C. The spectra were acquired every 0.15 seconds at a range of 30-300 atomic mass units.

Standard Loading on to Empty Tubes

With empty tubes, twenty-five mL (45.45 parts-per-billion volume) of the EPA TO-15 65 component mix (1ppm each, Airgas) was loaded with the use of a 50 mL gas tight syringe (Hamilton, Reno, NV, USA). A Markes International Standard Loading Rig was used to transfer the mix with 60mL min^{-1} 99.999% N_2 . The TD tubes were capped and were run via the TD-GC-MS method as described previously. All data was analyzed with the use of ThermoScientific Tracefinder Software (version 4.1) to extract ion peak areas of Ethanol (4.72 min, 46 mass-to-charge ratio (m/z), Acetone, (5.21 min, 43 m/z), Toluene (10.32 min, 91 m/z), p-Xylene (12.45 min, 106 m/z), Undecane (16.10 min, 156 m/z), and nonane (16.94 min, 128 m/z). Peak areas and retentions times were then exported from the software for further analysis.

5.0 RESULTS

The results of the personal air sampling are attached in Attachment 1. Results for the MultiRAE are listed in Table 5.

TABLE 5. Dormitory and Test Site MultiRAE Results Showing the Highest Measurements

Compound	Test Site (14 Dec)	Test Site (15 Dec)	Dormitory
Oxygen	20.9%	20.9%	20.9%
CO	14 ppm	12 ppm	0
VOC	300 ppm	360 ppm	60 ppm

Summary results for VOCs sampled are in Table 6, with individual samples in Attachment 2.

TABLE 6. Comparison of Tedlar ® Bag, Thermal Desorption Tubes, and XploSafe VOC Measurements

Compound	Tedlar ® Bag	Thermal Desorption Tubes	Xplosafe
Toluene	7.181 ppb*	3.486 ppb	10.47 ppb
p-Xylene	BQL ⁺	BQL	ND [#]
Acetone	26.306 ppb	8.436 ppb	147.09 ppb
Ethanol	90.673 ppb	32.332 ppb	1.09 ppm
Undecane	ND	BQL	ND
o-Xylene	ND	ND	ND
Nonane	ND	ND	BQL

*ppb = parts per billion; ⁺BQL = Below Quantifiable Limit; [#]ND = not detectable

6.0 DISCUSSION

First and foremost, there is a need to discuss the data gathering behind the study.

Literature reviews are quite difficult for this topic as there is little available on the very specific population being studied. As such, a lot of data was collected via personal interviews. This entire study began with a phone call to the 109th Aerial Port Squadron who was able to connect me to the 109th Bioenvironmental Engineering office. This was the start of conversations continuing to this day, constantly asking questions, and learning which still needed answers. The specific details of daily operations, environmental conditions, and health hazards are commonly summarized in public affairs approved bulletins but when getting to know the unit there was a flood of information not captured elsewhere. This provided much needed context to our study,

since the goal was to understand the routine health risks which could mean anything. Interviews were handled very informally, often arising randomly.

These data are only the beginning of our understanding of the long term ESOH considerations for ECW. Ultimately, our findings show that exposures are different between a temperate and an ECW region, but this is limited by many factors. One consideration is the fleet of LC-130s, which has a wide age range from the 1950s to the 1980s, and in various stages of upgrades. Therefore, exposures may vary according to aircraft age and crews. When we consider that other planes are in use, like the twin otters, we can see that there are gaps in knowledge due to the variety of aircraft.

However, these data do suggest that our methods are functional in these environments in some capacity. Since our sampling time was very limited, less than 45 min, it is unclear how well (or useful) traditional air sampling equipment and protocols will function. The cold introduces battery life issues for any electronics, which was clear with the MultiRAE ® which lasted approximately 25 min on an 80% charge at -40 °C. This suggests that the viability of any portable meters is severely hampered but does still provide a means to test an environment. This is also a readily available device in use by industries around the world, and can perform an assessment of up to 5 gases at one time. Battery powered equipment functions well indoors and away from the cold, showing that a direct read instrument can be effective if a sample of air can be collected in the cold, then brought indoors.

The results suggest some interesting differences between ECW exhaust and temperate exhaust. One compound, acetone, was identified in all our tested VOC methods as well as previous studies attempting to characterize C-130 exhaust. All samples, except for the TD tubes, were consistent with previous studies though much lower. The most prominent chemical

previously identified were acetone, methyl ethyl ketone, benzene, toluene, and cyclohexane. Ethanol was not identified in these previous studies; however our study found a noticeable amount (Page, 2017). Ethanol was not detected at temperate climates either but was detected in all three of our samples. At a minimum, these data suggest that the exposures for aircrews are different in ECW at altitude than those in more hospitable climates.

The scope of this research was limited primarily due to logistics. One of the initial goals of using a HAPSITE ER ® for location specific testing fell through when the carrier gases were unable to get through customs. We tried to obtain them from Inficon © and bases around the world but the supply lines were too thin and there were no means to receive them on time. Multiple flights between staging and ECW were cancelled, as well as on ice sorties, due to weather or maintenance issues.

One limitation of the data gathered on aircrews in ECW is the lack of time for sampling. Inconsistent weather and maintenance are a severe limitation of ECW, so it becomes difficult to get a thorough assessment. With only a few days available to complete this study there were compromises in the quality of the sampling outcome. This is typical for those who frequent the ECW.

Part of the ESOH mission includes ergonomics. This was considered briefly during the team's assessment through interviews and observation, and it should be noted that ECW presents some concerning hazards. The constantly changing temperatures, heavy lifting, and awkward positioning of working on an aircraft parked on an ice sheet do lead to some uncomfortable positions and exertion for most people and will add to the mental and musculoskeletal stress of team members (Peteri, 2017). The additive effects from each stressor will have a noticeable cost in manpower available as well as long term health for ECW workers.

Something related to consider is that few planes can land on an ice runway, and the amount that can will vary throughout the year (Klokov and Shiraishi, 1997). Additionally, fuel is completely essential to survive these environments and many locations in ECW are inaccessible except by air. This means that fuel transport becomes paramount and pushes every other item further down the priority list and makes the likelihood of prioritizing ergonomic aides low.

There are additional compounding factors that may be/are at play in austere environments. The ECW uniform is highly rated among those I interviewed, but there is a considerable issue between working at -65 °F and 0 °F. A garment that works well in one will not function well in the other (Sullivan-Kwantes et al., 2021), which is why the ECW uniform is worn in layers. However, the layers are added and removed constantly depending on the circumstances. Mobility is reduced and energy is expended to sustain aircraft maintenance operations, adding another layer of fatigue to a remote environment. The constant sunlight does not allow for a proper circadian rhythm either, making restful sleep a luxury (Arendt, 2012). The road to the airfield is also long and rough, taking 20-45 min with constant pits in the ice and snow roads used.

To summarize the day for the 109th ANG aircrews and maintainers, it involves an artificial sleep pattern leading to around 30 min of aggressive rocking on their ride to the airfield. They mostly have a condition known locally as the “Crud” which is a general illness like a cold, featuring aches, a persistent cough, and mild headache which has no identified cause. Their mission is always busy and involves handling cold and heavy metals. The ground is slippery due to ice and snow, but they must perform the same tasks needed at other airports. Based on interviews, an engine change on the ice shows the differences. There is no hangar on the ice, meaning there is no hoist. The plane is also parked on frozen ocean with a top layer of snow.

Functionally the job is no different from a home station engine replacement, but the reality is that this is being done on unstable ground using a crane while wearing extremely thick clothing after a lack of sleep and minimal opportunities for comfortable rest. Mental and physical fatigue have been studied in the arctic before (Haggarty et al., 2000), but the toll it takes on the upkeep of an airfield and its aircraft are limiting factors that should be studied.

Another area of research involves the fuel used by almost every operation within ECW environments, AN8. This fuel is used due to a very low freezing point, which is an identified issue with other jet fuels (Edwards, 2020, Haehnel et al. 2017). This is something that is extremely common amongst the aircrews who operate in ECW. During interviews, it was always called “jet-fuel” but there is a unique chemistry to AN8. To me, this highlights the importance of getting into the environment you are studying, beyond the purely laboratory conditions. The team specifically brought media to sample for Jet-A, the differences in risks between the two fuels would be a separate research project making this a wonderful area of study for AFRL in my opinion.

Based on aircrew interviews, it was somewhat surprising to find that the exhaust streams were not hypoxic. The symptoms described by LC-130 loadmasters were consistent with mild hypoxia (headaches, shortness of breath, symptoms resolving quickly when using onboard oxygen) and the rapid fuel consumption requires rapid oxygen consumption, and it was thought that there may be a lack of oxygen in the exhaust. Aircrews have reported headaches and dizziness after working in the exhaust, which is often relieved by using the liquid oxygen system. The exhaust had a healthy amount of oxygen, but the altitude may have an effect as well. This is another variable that is not perfectly accounted for, as the test site elevation is 9,300+ feet above sea level.

OEHSA was completed as intended, documenting the location of inherent hazards within the environment for future use. The data has been saved in DOEHRS and is included in this report as Attachment 3.

7.0 CONCLUSIONS

At the conclusion of this study, there are several takeaways. First, is that all operations in the extreme cold will have unique protocols which can completely adjust a person's health risks. Despite limitations in research, data collected suggests that the remote nature and extreme cold have a negative effect on sampling abilities for ESOH purposes, and will require modified procedures to function (i.e., an emphasis on short term sampling, local analysis). However, DRI appear to function with a primary issue being the battery life.

Based on our study, the Xplosafe OSU-6 media seems to be extremely stable at these temperatures and shows a lot of promise as an ECW VOC sampler. Tedlar ® bags and TD tubes are not ideal for this type of sampling, with neither being designed for long distance travel in the first place. Freezing these samples did produce some results, but it is unknown how much of the analytes leaked from their media or broke down under strenuous conditions. One compound found between all 3 methods was ethanol, which was measured about 10 times higher than the Tedlar ® samples. Acetone is another chemical found in all three methods, and the OSU-6 result was about 6 times higher than the Tedlar ® bag samples.

Another conclusion that I would like to draw is that ECW aircrew and base operations are too sophisticated to simply read about. Particularly, the daily life aspects including facilities, logistics, and workflow considerations. I left this project with more questions than before as there are far too many moving pieces to be able to integrate their requirements with most research from afar in my opinion. Ideally, the researchers that conduct ECW studies in more

temperate zones would be granted opportunities to experience working in the extreme cold at one or both earth's polar regions. Remote airports operate like small cities, centered around an airfield and its operation. This involves housing, feeding, and entertaining personnel, as well as equipping them with adequate tools and supplies to accomplish their individual mission. Due to the multitude of changes, I feel the most valuable experience for a researcher is to observe these processes in-person.

There are a few areas that are ripe for future studies that stand out within my interviews and observations. The first deals with respiratory protection, as there seems to be no viable respirator in ECW, as they have a flexible plastic seal that hardens at these temperatures. Plastics in general are avoided by the workers as they are often too brittle at these temperatures, meaning cloth and metal often serve in their place. With the universal use of plastics elsewhere, this may lead to small and unexpected failures within equipment. The lack of cooperation with the weather will also change the need for this drastically, due to the reports from pilots that a strong tailwind on the ground will cause the cockpit to fill with fumes causing eye-watering and respiratory discomfort as the loadmasters.

Lithium-ion battery life for devices is essentially negligible at these temperatures. The simple solution is to utilize body heat to minimize exposure to ECW and prolong the device's life, but this will not be an option for equipment much larger than a cell phone. An alternative method is to have a separate battery for devices that is kept under the ECW clothing and routing the power to the outside of a garment.

Another study of value would be the combustion profile and related health effects of AN8 jet fuel in these conditions. This will change depending on airframe and climate, but since this is an expected routine exposure it would be extremely valuable to the ESOH professionals

supporting ECW missions. This paper found several chemicals in the exhaust, but is still only the start of understanding the real-world impact on aircrew health using this fuel.

One of the key takeaways from my interviews of everyone, including conversations with civilians, is the absolute remoteness of ECW. At any given time, there is one supply line keeping the regions functioning. All resources arrive via plane or ship, with no major support from a local economy. This makes it an extremely costly proposition to move cargo and increases the threshold for “necessary” equipment. In a nation like Kuwait, there were commercial contractors who could be paid to bring materials, but from a logistics perspective there is no economy in this region to support an airfield. This makes sense for many things, since all cargo is thought of as “is it worth the fuel” to get it where it needs to go. When you consider that ergonomic aides or creature comforts would take an amount of space on an LC-130, which could be used for something required to keep the station functioning, then it begins to make sense how life in ECW takes shape. It will be fraught with high-risk environments and large expenditures to make them functional in the long-term.

There is certainly no shortage of research potential in ECW environments, it changes almost every aspect of life. The more you speak with those in ECW the more limitations are uncovered, and some issues cannot be paid away. Creating new technologies to embrace the region is essential for operations, sharing many similarities with space exploration. Minimizing size/weight of items and increasing efficiency will be paramount, as well as adjusting operations.

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LIST OF SYMBOLS, ABBREVIATIONS AND ACRONYMS

ANG	Air National Guard
BQL	Below Quantifiable Limit
ECW	Extreme cold weather
°C	degrees Centigrade
°F	degrees Fahrenheit
DoD	Department of Defense
DOEHRS	Defense Occupational and Environmental Health Readiness System
DRI	direct reading instruments
ESOH	Environmental, Safety and Occupational Health
GC/MS	Gas Chromatograph/Mass Spectroscopy
m	meter
mL	milliliters
min	minute
m/z	mass-to-charge ratio
ND	not detectable
OEHSA	Occupational, Environmental, Health Site Assessment
PPE	personal protective equipment
ppb	parts per billion
ppm	parts per million
TD	Thermal Desorption
VOC	volatile organic chemical