Military Chaff
Is it of concern?

Summary
A literature survey was conducted to assess the health and environmental effects of the use of military chaff. Based on what has been written, the results are that:

- most of the work on the health and environmental effects of chaff was not published in peer-reviewed publications, but rather prepared by the military in-house or by contract with universities,
- most of the work was done in the 1990's with a key report in 1997,
- it is not supported that chaff is a risk to health or the environment,
- recent military environmental assessments (including the one for Alpena) concerning chaff rely on the work published in 1997 to conclude findings of "No Significant Impacts,"
- the use of chaff in Michigan started in 2002, and
- there has been very little work related to the impact on fish health and behavior.

This report also 1) points out that humans, wildlife, and the environment are naturally exposed to aluminum and silicon, the two elements comprising chaff and 2) questions the use of chaff over the Au Sable River watershed which portions of the rivers are classified as either a National Scenic River or a Michigan Natural River.

Introduction
Military chaff is material released in the atmosphere by military aircraft, for example, to confuse enemy radars. It is used in electromagnetic warfare (more commonly called electronic warfare) which is defined by the Department of Defense as "any military action involving the use of electromagnetic and directed energy to control the electromagnetic spectrum or to attack the enemy."

The most common modern chaff is a rod made of amorphous (no crystalline structure, i.e., glass) silica (SiO_2) coated with aluminum. It has a typical diameter of 0.0099 inches (0.025 mm) and a typical length of 0.3 inches (7.6 mm) to over 2 inches (51 mm). Newer "superfine" chaff has a typical diameter of 0.007 inches (0.018 mm) (Wiki, 2023). The rod, termed a dipole, is cut to a length that interferes with the target radar's wavelength.

The chaff eventually settles out of the atmosphere, raining down on the environment. Increases in electronic warfare training at Camp Grayling and in the number of sorties across the Au Sable River watershed from Camp Grayling to Lake Huron have been proposed. These increases raise concerns about the risks from chaff in terms of health (human and ecosystem) and environmental contamination. The question is how real are these concerns?

To answer this question, a literature review on military chaff was conducted. Web of Science and PubMed (via the MSU Library), Google Scholar, and just Google were used as the search engines. Example search terms were "military, chaff, health;" "military, chaff, health issues;" "military, chaff, environment;" "chaff, countermeasure, health;" radiofrequency, chaff, health, environment." The result of a literature review is a list of published works related to the subject.

Results

Although there is much written on the use and composition of chaff, there is less written on the effects of chaff on health and the environment. Most of the health and environmental studies were done in the 1990s. A few were done in the early 2000's and the most recent in 2010. Most of the studies were done by military researchers or by researchers from universities reporting to the military. In many instances the works were not published in peer reviewed journals.

Two of the most recent publications are mainly literature reviews (Arfsten et al., 2002; Farrell and Siciliano, 2004). The former published in a peer reviewed journal; the latter is a report submitted to Canadian Forces Base Goose Bay. Farrrell and Siliciano (2004) do provide a disclaimer that states their opinions are strictly theirs and not reflecting the views of the Canadian Department of National Defense. Both publications cite similar references, some of which are no longer available. However, one report (USAF, 1997) referenced by both sets of authors as well as other researchers (e.g., Marr and Velasco, 2005) contains the most detailed research on the environmental and health effects of chaff. Thus, this work is the basis of many of the conclusions drawn by Arfsten et al. (2002) and Farrell and Siciliano (2004) on the health and environmental effects of chaff. The conclusions from the 2000s literature review are that health issues associated with the inhalation or ingestion of chaff fibers are negligible, toxicological effects associated with ingestion by wildlife are not of concern, and chaff has not contaminated soils and water resources (Arfsten et al., 2002; Farrell and Siciliano, 2004).

Health and environmental concerns

The size of airborne particulate matter is directly related to its potential to adversely affect health (EPA, 2003). Particles less than 10 micrometers (0.00039 inches) (PM10) in diameter can get deep into the lungs and some may even get into the bloodstream. Particles less than 2.5 micrometers ($9.8x10^{-5}$ inches) in diameter (PM2.5), pose the greatest risk to health. Particles larger than 10 micrometers are of less concern, but they can irritate eyes, nose, and throat. The size of chaff material is too large to get into the lungs.

Ingestion is another pathway for chaff exposure. Marr and Velasco (2005) examined the health risk of exposure to chaff on Sonoran pronghorn on the Barry M. Goldwater Range, Arizona. The population of the Sonoran pronghorn has decreased, and efforts were underway to better understand the cause of the decrease and identify and reduce any further risks. At the time this paper was written, the Sonoran pronghorn had been exposed to chaff used during military training for over 50 years. This was considered a risk to the Sonoran pronghorn that needed to be studied. Sediment, soil, and water samples were collected for chemical analyses. Chaff was identified in the sediment and soil samples via microscopy and chemically analyzed. An

ecological risk assessment was conducted, and it was concluded that would be impossible for the Sonoran pronghorn to ingest enough chaff to cause health concerns.

Silicon and aluminum are the second and third most abundant elements in the earth's crust, i.e., oxygen (47%), silicon (28%), aluminum (8%), iron (5%), and magnesium (4%). Thus, soils and sediments contain silicon and aluminum. The forms are silica typically as quartz (SiO_4) for silicon and alumino-silicates such as clays and feldspars for both aluminum and silicon. A typical clay in Michigan is kaolinite ($Al_2O_3\ 2SiO_2{\cdot}2H_2O$) and a typical feldspar is ($KAlSi_3O_8$). An environmental contaminant is a substance whose concentrations have been elevated in media (e.g., soil, water) over background concentrations. An environmental pollutant is a substance whose concentrations cause adverse effects (e.g., health). Studies reveal that chaff does not elevate aluminum concentrations above background values in soils or sediments, even in areas of high chaff usage. For example, Marr and Velasco (2005) found that aluminum concentrations in soils and sediments were similar or lower than background concentrations in Arizona. Wilson et al. (2002) measured aluminum concentrations in sediment in the U.S. Navy training area on Chesapeake Bay. They estimated that over 25 years several hundred thousand pounds of chaff were released over the bay. Their results suggested that the chaff released did not elevate aluminum concentrations in the bay sediments.

Concentrations of silicon and aluminum in water are a function of the pH, temperature, and other dissolved solutes in the water. Silicon concentrations are closely related to the solubility of quartz. At pH's below ten, concentrations in water average around 10 mg/L (Hem, 1985). The solubility of aluminum is lowest in the pH range of 5.5 to 8 and increases at higher and lower pHs (Long et al., 2008). Chaff appears to be slow to weather (break down/dissolve) in the environment (USAF, 1997). Michigan groundwater and rivers have pH's typically between 6.5 and 8. Silicon concentrations average around 10 mg/L. The chemistry of the solubility of aluminum is more complex than that for silicon in that it involves different forms of aluminum and interactions with other dissolved ions such as fluoride. However, in this pH range aluminum concentrations are low (Hem, 1985). The dissolution of chaff is not expected to contaminate water resources.

Effects on wildlife

Few studies on the effects of exposure to chaff on wildlife were reported in 1997 (USAF, 1997). This remains the case today. USAF (1997) concluded that effects on wildlife would be negligible. However, it was pointed out that it is a site-specific issue and would be of concern in areas where large quantities of chaff are dispersed over aquatic habitat used by waterfowl. It was also pointed out that wilderness areas or wild and scenic rivers, citizens and land managers are more likely to perceive chaff debris as undesirable since it conflicts with expectations of primeval character and management objectives to preserve naturalness or the environment.

From the USAF (1977) report: "Wild and Scenic Rivers Act of 1968 defines wild, scenic, and recreational rivers, designates a river classification, and establishes limits to development on shoreline areas." Similar to highly valued Wilderness Areas, selected rivers and their immediate

environments which "possess outstandingly scenic, recreational, geologic, fish and wildlife, historic, cultural, or other similar values, shall be preserved in free-flowing condition, and they and their immediate environments shall be protected for the benefit and enjoyment of present and future generations. Accumulations of chaff fibers or chaff debris which affect any of these attributes along designated rivers could result in land use impacts to sensitive resources."

In a study prepared for the Naval Research Laboratory by Systems Consultants, Inc (1977), the effects of direct exposure of six marine organisms from Chesapeake Bay to chaff fibers were examined. Blue crab, menhaden, and killfish were force fed whole and broken fibers at concentrations up to 1000-times greater than those reported in the Bay. The experiment lasted for several weeks. No adverse effects were observed. Similarly, oyster larvae showed no adverse effects when exposed to 10- and 100-times environmental concentrations. At 1000-times environmental exposure the size of 10-day-old larvae showed a small decrease. Polychaete worms exposed to chaff at 10-times normal the environmental exposure showed no effects.

Choi et al., (2010) report that Pacific Swift Apus pacificus harvest airborne chaff and use as nesting material.

Policy

Arfsten et al., (2002) summarized current policy <u>at the time their article was created.</u> The summary was based on two documents (CJCSM, 1998; USGAO, 1998). In brief:

- The DOD, in an attempt to balance the chaff training needs of the Armed Services with public concerns for the negative impacts of chaff, has severely restricted the use of chaff in training to reduce environmental contamination and to protect civilian airspace.
- As a result of a 1998 Joint Chiefs of Staff directive on chaff use policies for each of the Armed Forces, the number of chaff training sites was reduced to approximately 50 selected ranges and MOAs in and around the United States. *The State of Michigan was not one of the areas listed for chaff training at that time.*
- Flight rules stipulate that chaff should not be released below certain altitudes to ensure that chaff plumes are widely dispersed, and dipole (single chaff strand) ground level concentrations are very low (e.g., one to two dipoles per acre).
- Current DOD policy for chaff operations requires that every effort be made to conduct chaff releases away from major air routes and air route hubs, to avoid frequent dispersal over the same ground points.
- For planned chaff releases -
    - FAA must grant approval and the releases must not violate any EPA restrictions placed on the training area. Planned release points are mostly within controlled airspace such as MOAs, flight-restricted areas, and flight-warning areas.
    - Chaff release plans must incorporate geographic features of importance, wind speeds and direction, the intended release altitude, the rate of fall of chaff, and allowances for error in these estimates.

    - The authority to authorize chaff releases resides with local environmental agencies.
- There are several initiatives between the DOD and Department of Interior (DOI) agencies that are aimed at minimizing the impact of chaff on public lands. The DOD has agreements with both the Fish and Wildlife Service and Bureau of Land Management which place limits on chaff release over wildlife refuges, Native American reservations, and public lands.
- The U.S. Navy has agreements with DOI agencies to restrict chaff use over wildlife refuges and public lands in the interest of protecting sensitive species.
- The DOD and the Bureau of Land Management have formed a committee to periodically evaluate the chaff deployment policies of each of the Armed Services for training conducted over public lands.

Summary and applications to the Au Sable River

There are few studies on the effects of chaff on human and ecosystem health. Most studies are military reports, and few are in peer-reviewed journals. There is a dearth of recent studies other than a few review papers. This might imply that the studies done in the 1990s were definitive, with the conclusion that there is no risk to human health and the environment. For example, the Texas Air National Guard proposed to increase the number of sorties and chaff releases at the Joint Base San Antonio-Lackland, Kelly Field Annex training area (USAF, 2019). An Environmental Assessment was done with a finding of "No Significant Impact." The assessment regarding the environmental effects of chaff was based on the studies that were done in the 1990s (e.g., USAF, 1997). Similarly, the proposed modification of the airspace associated with the Alpena Airspace Complex (ARN-Alpena, 2022) used the same documents to conclude a finding of "No Significant Impact."

Although we might consider deploying chaff over residents, recreationers, and the Au Sable watershed appalling, objections to the use of chaff watershed based on human and ecosystem health and environmental contamination may not get much traction. *However, there is a lack of studies on the effects of chaff on the health and behavior of fish,* which is a valid concern for this watershed. As mentioned, the Joint Chiefs of Staff directive (CJCSM, 1998) identified 50 areas in the U.S. where chaff is used in training. Michigan was not one of the designated areas at that time. However, in 2002 this changed with Michigan being included as an area for chaff training (NGB, 2002). *What changed that allowed chaff to be used in Michigan?* Also questionable is the use of chaff in Michigan over the Au Sable River watershed. The 23-mile portion of the Au Sable River that stretches from Mio to Alcona Pond is classified as a National Scenic River. Upstream it is classified as a Michigan Natural River. These are two examples of Pure Michigan. *With such classifications, one would assume that chaff training would not be used in this area (consider the USAF 1977 report).*

References

Arfsten, D. P., Burton, D. T., Fisher, D. J., Callahan, J., Wilson, C. L., Still, K. R., & Spargo, B. J. (2004) Assessment of the aquatic and terrestrial toxicity of five biodegradable polymers. Environ Research 94: 198–210.

Arfsten, D. P., Wilson, C. L. & Spargo, B. J. (2002) Radio frequency chaff: The effects of its use in training on the environment. Ecol. Environ. Safety 53: 1–11.

ARN-Alpena (2022) Environmental Assessment for Modification and Addition of Airspace at the Alpena Special Use Airspace Complex. Michigan Air National Guard Alpena Combat Readiness Training Center Alpena, Michigan. Draft. https://www.alpenacrtc.ang.af.mil/Portals/12/documents/AirSpace%20Documents/Draft%20EA_Alpena%20SUA%20Complex_MainBody_November%202022.pdf?ver=Ey56o_w9iSiyQBSEw-O16w%3D%3D.

Choi, C-Y, Nam, H-Y., and Park, J-G (2010) Radio-frequency chaff in a nest of Pacific Swift Apus pacificus. Forktail 26: 136-137.

CJCSM (1998). Chairman of the Joint Chiefs of Staff Manual Performing Electronic Attack in the United States and Canada forests, raining, and Exercises. CJCSM 3212.02. 1 October 1998. https://info.publicintelligence.net/CJCS-US-EA.pdf.

EPA (2003) Particle Pollution and Your Health. http://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1001EX6.txt.

Farrell, R. and Siciliano, S. (2004). Environmental Effects of Radio Frequency (RF) Chaff Released during Military Training Exercises: A Review of the Literature.

Hem, J.D. (1985) Study and Interpretation of the Chemical Characteristics of Natural Water. Third Edition. U.S Geological Survey Water-Supply. Paper 2254 272 pages.

Long, D.T., Lyons, W.B., and Hines, M.E. (2008) Influence of hydrogeology, microbiology, and landscape history on the Geochemistry of acid hypersaline waters, Southern Australia. Applied Geochemistry. 24: 285-296.

Marr, C.H., and Velasco, A. (2005) Effects of Military Aircraft Chaff on Water Sources Available to Sonoran Pronghorn. U.S. Fish and Wildlife Service, Arizona Ecological Services Office. https://www.researchgate.net/publication/357970094_Effects_of_Military_Aircraft_Chaff_on_Water_Sources_Available_to_Sonoran_Pronghorn.

Marr, Carrie H., Effects of Military Aircraft Chaff on Water Sources Available to Sonoran Pronghorn. Arizona Memory Project, accessed 19/03/2023, https://azmemory.azlibrary.gov/nodes/view/208448.

NGB (2002) Final Environmental Assessment for Deployment of Chaff and Flares in Military Operations Areas (Phase 1). Andrews Air Force Base, Maryland: Prepared for the Air National Guard by National Guard Bureau Environmental Division. https://www.142wg.ang.af.mil/Portals/38/documents/EIS/EA_for_Deployment_of_Chaff_and_Flares_in_Military_Training_Airspace_(Phase_1)r.pdf?ver=ChSWZX6jjRu-KMUIWH_ang%3D%3D.

Systems Consultants, Inc (1977) Effects of aluminized fiberglass on representative Chesapeake Bay Marine Organisms. https://apps.dtic.mil/sti/pdfs/ADA059313.pdf.

USAF (1997) U.S. Air Force. Environmental Effects of Self-Protection Chaff and Flares. Final report, U.S. Air Force Combat Command, Langley Air Force Base, VA. https://www.globalsecurity.org/military/library/report/enviro/1997-08-01385.pdf.

USAF (2019) Final Environmental Assessment Combat Air Forces Adversary Air Joint Base San Antonio-Lackland, Kelly Field Annex, Texas.

https://www.jbsa.mil/Portals/102/Documents/Environmental%20PA/Kelly%20Final%20EA%20signed%20FONSI%20(April%202019).pdf.
USGAO (1998) Management Issues Related to Chaff. United States General Accounting Office. GAO/NSIAD-98-219. https://www.gao.gov/assets/nsiad-98-219.pdf.
Wiki (2023) Chaff (countermeasure) https://en.wikipedia.org/wiki/Chaff_(countermeasure) Accessed 10Mar2023.
Wilson, C. L., Arfsten, D. P., Carpenter, R. L., Alexander, W. K. & Still, K. R. (2002) Effect of navy chaff release on aluminum levels in an area of the Chesapeake Bay. Ecol. Environ. Safety 52: 137– 142.

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