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Technological contributions to environmental pollution emanating from military adventurism: A review

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ABSTRACT

Technology is the knowledge of the manipulation of nature for human purposes. This implies that all practical or technical skills are ultimately derived from alterations or manipulation of nature. Furthermore, technology is the knowledge and instruments that humans use to accomplish the purposes of life. The study was conducted to review technological contributions to environmental pollution and its associated health risk, with a view to find out environmental pollution resulting from military adventurism and its effect to man and environment. In order to achieve this, proven industrial activities that depict technology related to military adventurism were discussed.

***Keywords*:** Technology, environment, environmental pollution, military adventurism

1. INTRODUCTION

The military, war and armament industry, also known as the defense industry or the arms trade, is a global industry which manufactures and sells weapons and military technology. It consists of a commercial industry involved in research and development, engineering, production, and servicing of military material, equipment, and facilities. Arms-producing companies, also referred to as arms dealers, produce arms for the armed forces of states and for civilians. Products of the arms industry include guns, artillery, ammunition, missiles, military aircraft, military vehicles, ships, electronic systems, night vision devices, holographic weapon sights, laser rangefinders, laser sights, hand grenades, landmines.

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There has been an interrelated relationship between warfare and the physical environment. The destruction associated with modern warfare is particularly catastrophic due to the extent, magnitude and duration of contemporary wars. Conflict has been an ever present aspect of human civilization. Undeniably, throughout the 20th century military engagements has continuously plagued the world leading to more than 100 million human deaths across a number of major and minor wars (Pendersen 2002; Sarkees *et al.,* 2003). Human warfare has also been documented as having a significant influence on the environment (Dudley *et al.,* 2002; Machlis and Hanson 2008). Consequently, human conflict has a wide range of potential impacts on the environment; in reality the consequences of warfare generate a gamut of outcomes ranging from highly positive to highly detrimental. Warfare, a powerful agent of landscape change, is a unique form of landscape disturbance; this radically alter the shape of the landscape, limiting the ability of the landscape to revert back to its original state.

2. HISTORICAL PERSPECTIVE OF MILITARY, WAR AND ARMAMENT

Prehistory

Military weapons existed long before the twentieth century. In ancient days, weapons used in the military or for war were in numerous forms. Ancient weapons used for war include the spear, daggers, the atlatl with light javelin or similar projectile, the bow and arrow, the sling; pole arms such as the spear and javelin; hand to hand weapons such as swords, spears, clubs, maces, axes, and knives. Catapults, siege towers, and battering rams were used during sieges. The earliest military weapons of war dates from the period before knowledge of metal working had been acquired. The heavy reliance on human muscle was one of the weapons used in war. The stone walls of Jericho were one of the first military weapons, which date from about 8000 BC; these walls were clearly intended to protect the settlement of people and from human intruders. Then came the weapons of stone tools and the first arrowheads which date more than 60,000 years ago.

Hunting tools, the spear-thrower, the simple bow, the javelin, and the sling were weapons used in the military which had serious military potential. During the Chalcolithic Period or early Bronze Age, the first known offensive weapons was designed; the maces or rods been cast of copper. The mace was a siple rock, shaped for the hand and intended to smash bone and flesh, a handle was added to it which help to increase the velocity and force of the blow. The copper mace head, yielding higher density and greater crushing power, represents one of the earliest significant uses of metal other than for ornamental purposes.

Then, the application of horse power became a prime ingredient of victory. For mobility and for carrying important items such as rations, tents and firewood; carts, horses, mules, chariot, war elephant and donkeys were means of transportation required by the soldiers to carry all their personal equipment. By 3000 BC, then came the era of defensive weapons, called the armour. Armour was used to protect the soldier’s body. Armour include the craft helmet of copper and arsenic bronze, capable of covering the entire head, scale armour, coats of mail; made of iron, very flexible and provided good protection against cutting and piercing weapons.

The breastplate for the body and greaves to cover the shins. The shield used for effective protection; to cover any unprotected parts of the body. An armour bearer or shield bearer could also be employed to carry the soldier’s weapons and his shield.

Furthermore, a wide variety of offensive weapons appeared in antiquity, the development of the offensive weaponry of war consist of ax, halberd, crossbow, spear, javelin, sling, sword, bow, arrows, mechanical artillery; catapult and the gun powder. The ax has narrower blades, designed primarily for piercing rather than cutting. The pace and timing of these developments varied enormously from place to place, depending on the local level of technology. The spear, though early man probably employed spears of fire-hardened wood, spearheads of knapped stone were among the earliest militarily weapon.

The javelin or throwing spears, were designed for shock combat and had smaller heads; shorter and lighter than spears. The sling featured prominently in warfare in antiquity and classical times. The sling was the simplest of the missile weapons of antiquity; it consisted of two cords or thongs fastened to a pouch. A small stone was placed in the pouch, and the slinger whirled the whole affair around to build up velocity before letting go of one of the cord ends to release the projectile. The bow as one of weapons of war was made from a single piece of wood, consisted of a stave of wood slightly bent by the tension of a bowstring connecting its two ends. Another weapon of war is the arrow; arrow shafts were made of relatively inexpensive wood and reed throughout history, designed as a military cutting or piercing implement. Mechanical artillery, catapult is the general term for mechanical artillery. The Romans called their catapults onagers. The Romans used large ballistae and onagers effectively in siege operation.

Industrial Innovation, Modern Technology in Military, War and Armament Industry

Military technology is the application of technology in warfare; which cover a range of weapons, equipment, structures, and vehicles used specifically for the purpose of warfare. It includes the knowledge required to construct such technology, to employ it in combat, to repair and replenish it. At the start of the World Wars, various nations had developed sophisticated weapons that were a surprise to their adversaries. Some of these weapons include the flame throwers, first used in the First World War, then the introduction of the armored car in 1902 by the French. Then in 1918, came the first armored troop carrier. In 1911, aviation became important in World War I, this led to the development of an aircraft carrier with a decent unhindered flight deck. During World War I, chemical warfare exploded into the public consciousness, in 1915 the Germans developed a chlorine gas that was highly lethal; the Germans used gas-filled shells to moderate effect at the Second Battle of Ypres. The Gas masks were invented in matter of weeks, and poison gas proved ineffective at winning battles. Then came the invention of Radar, independently invented by the Allies and Axis powers which used radio waves to detect objects. In 1945, the atomic bomb was developed by the Manhattan Project, quickly ending World War II. During the Cold War, nuclear arms was used. By 1866 and 1870-71, the machine gun had begun entering into the militaries. Other technological advances include missiles; ballistic missiles, cruise missiles.

Mind blowing advancements in military technology means that the battlefields of today and tomorrow are filled with cyborg bugs, invisible tanks, guided bullets and more. New weapons development can dramatically alter the face of war, the cost of warfare, the preparations, and the training of soldiers and leaders (Hacker, 1994). The technology of war may be divided into five categories. Offensive arms; harm the enemy while defensive weapons ward off offensive blows. Transportation technology moves soldiers and weaponry; communications coordinate the movements of armed forces; and sensors detect forces and guide weaponry. With advancements in technology, war has been an important factor in creating states and empires throughout history; preparation for war has been based on technological arms encompassing all sorts of new weapon systems, such as nuclear and biological, as well as computerized control systems (Roland, 2010). Major advances in technology brought about the modern military which comprise of air force, navy and ground forces.

The equipment's, ammunitions used by the military industry are military aircraft; supersonic aircraft, bombs, artillery, rocket and missile system, nuclear weapon, chemical warfare, biological warfare, fortification, naval ship, and military communication. Weapons such as aerial weapons, air force weapons, army weapons, cannons, grenades, infantry weapons, machine guns, Marine Corps weapons, navy weapons poses a great risk to the environment. The environmental impact of war centers on the modernization of warfare and its increasing effects on the environment. However, modern weapons used in warfare cause far greater devastation on the environment. The progression of warfare from chemical weapons to nuclear weapons has increasingly created stress on ecosystems and the environment. Specific examples of the environmental impact of war include: World War I, World War II, the Vietnam War, the Rwandan Civil War, the Kosovo War and the Gulf War.

Modern Technology in the Armies

Rapid development in military technology had a dramatic impact on armies and navies in the industrialized world in 1840-1914. For land warfare, cavalry faded in importance, while infantry became transformed by the use of highly accurate and more rapidly loading rifles, and the use of smokeless powder. Machine guns were developed in the 1860s. Artillery became more powerful as new high explosives based on nitroglycerin arrived after 1860, and the French introduced much more accurate rapid-fire field artillery. Logistics and communications support for land warfare dramatically improved with use of railways and telegraphs. Industrialization provided a base of factories that could be converted to produce munitions, as well as uniforms, tents, wagons and essential supplies.

Modern Technology in the Naval and Aerial

Naval warfare was transformed by many innovations, most notably the coal-based steam engine, highly accurate long-range naval guns, heavy steel armour for battleships, mines, and the introduction of the torpedo, followed by the torpedo boat and the destroyer. Coal after 1900 was eventually displaced by more efficient oil, though navies with an international scope had to depend on a network of coaling stations to refuel. War colleges developed, as military theory became a specialty; cadets and senior commanders were taught the theories of Jomini, Clausewitz and Mahan, and engaged in tabletop war games. Around 1900, entirely new innovations such as submarines and airplanes appeared, and were quickly adapted to warfare by 1914. Incorporation of weapons, propulsion and armour in the navy and aerial made all other battleships antiquated.

Environmental Hazards Resulting from Military, War and Armament

Though the role of technology in military and warfare is breathtaking, but the environmental consequences of military, war and armament are deleterious. Improvements in military weapons throughout history have resulted to continual adoption of new fighting tactics to win battles and conquer armies. The release of dangerous forces resulting from attacks on dams, chemical factories, or nuclear facilities can lead to severe environmental disruption.

This is evident in the modern era where advances in robotics and targeting systems have led to smarter weapons with deadlier payloads and thus, lead to environmental pollution or degradation of the ecosystem. Military activity affects the physical environment in direct and indirect ways, the direct impact are thus:

Aerial Pollution

Sonic booms, jet afterburners, rotary pulses, etc are aircraft commonly used in military operations and these generate bursts of noise. According to Dunnet (1977) in many animals, the auditory system is more sensitive compared to that of humans and hence aerial activities pose a major source of noise pollution that is of global concern for the wellbeing of wildlife. Noise generated from military aircraft has variable impacts on wildlife; these effects include eardrum rupture, shifts in hearing abilities which can be either temporary or permanent and also unable to recognize noises from prey, predators, or mates. In addition, there are physiological effects which can lead to impediments in reproduction, foraging behavior (Francis 2011). Furthermore, other impacts consist of population declines, species extinction and habitat degradation.

The environment has been affected by means beyond noise pollution from military aircraft. For example, during World War II (WWII), aircraft was a means of transportation whereby weeds and cultivated species were brought to oceanic island (Stoddart 1968). Prior to the war, these isolated islands were home to a number of sensitive and endemic species which have naturally dispersed to another positions. However, as a result of aerial warfare events, large numbers of invasive species become established on these islands, and this may lead to competitive exclusion, predation, and extinction of endemic species (Mooney and Cleland 2001). Air to ground effects lead to wildlife mortality and destruction of natural habitat, which may contribute to a decline in a confined population. Conventional aerial weapons are generally categorized into four groups, which include: high explosive fragmentation, incendiary weapons, enhanced blast munitions, and defoliants; all of which have potential to destroy wildlife and natural habitat in different ways and with varying degrees of severity. These impacts have been illustrated in a number of species including Asian elephants and snow leopards where aerial combat maneuvers were observed to devastate entire forest ecosystems leaving behind stumps and craters, alongside contaminated and destabilized soils (Dudley *et al*., 2002).

Depleted Uranium Munitions

The use of depleted uranium in munitions has been a controversial issue because of numerous questions about potential long-term health effects (Miller and McClain, 2007). Normal functioning of the kidney, brain, liver, heart, and other systems can be affected by uranium exposure, since uranium is a toxic metal and also weakly radioactive (Elena, Aquel, Meghan, Melissa, Heather, Mohamed,2004). The aerosol produced during combustion of depleted uranium munitions can potentially contaminate wide areas around the impact sites and also can be inhaled by civilians and military personnel (Mitsakou, Eleftheriadis, Housiadas, Lazaridis, 2003). In 2003, during a three-week period of conflict in Iraq, it was estimated over 1000 tons of depleted uranium munitions were used mostly in cities.

The U.S. Department of Defense claims that no human cancer of any type has been seen as a result of exposure to either natural or depleted uranium (U.S. Office of the Secretary of Defense, 2007).

Yet, U.S. Department of Defense studies using cultured cells and laboratory rodents continue to suggest the possibility of leukemogenic, genetic, reproductive, and neurological effects from chronic exposure (Miller and McClain, 2007). In addition, the UK Pensions Appeal Tribunal Service in early 2004 attributed birth defect claims from a February 1991 Gulf War combat veteran to depleted uranium poisoning.

Terrestrial Conflict

Ground warfare often takes place in sensitive and distant places around the globe (Hart *et al,*. 1997; Kim 1997; Hanson *et al.*, 2009). Furthermore, natural landscapes and wildlife has been affected in a number of ways as a result of ground warfare. Often, soldiers were positioned for on-ground battle within critical habitats of endemic and endangered species representing a potential threat to these organisms (Hanson *et al*., 2009; Lindsell *et al.*, 2011). Armed conflict found within the terrestrial environment often promote destruction of the landscape and wildlife populations by displaced refugees of war (Dudley *et al.*, 2002; McNeely 2003; Dubey and Shreni 2008; Draulans and Van Krunkelsven 2002). In contrast, there are reports of large adaptable predators, including Bengal tigers (Panthera tigristigris) and grey wolves (Canis lupus) becoming adapted to gunfire noise on the battlefields of WWII; they were often sighted foraging on casualties in the aftermath of battleswhich may acutely benefit the species as in the case of marine predators (Orians and Pfeiffer 1970; Westing 1980; McNeely 2003).

The weapons employed by the military poses a great threat to the environment; numerous explosive techniques and tools at the disposal of army forces during ground warfare has been deleterious on landscapes by leaving large craters, shrapnel and contamination, thus devastating many ecosystems across the biosphere (Westing 1980; Hupy 2008; Certini*et al.*, 2013). In addition, landmines during ground warfare have left a lasting legacy on the environment and still remain a major threat to the environment, even decades after being deployed (Westing 1985; Berhe 2007). However, landmines may help ecosystems convalesce after heavy impact from armed conflict by creating a no man's land in a comparable manner to a game reserve or park as seen in the case of the cranes in the demilitarized zone of the Korean Peninsula (Higuchi *et al.*, 1996; Kim 1997; Dudley *et al.*, 2002). Landmines do not differentiate between soldiers and wildlife especially large mammals and therefore, many organisms have been damaged or killed directly from landmine explosions (Westing 1996; Berhe 2007). Actually, landmines have been responsible for pushing at risk species closer to extinction such as elephants in Africa, leopards in Afghanistan and deteriorating ecosystem integrity by destroying vegetation and degrading soil structure (Miller 1972; Berhe 2007).

Artillery fire also poses a risk to the environment; troops often found shelter or fought battles in forest areas resulting in heavy artillery fire on these regions, thereby devastating the local environment (Hupy 2008). Decades after WWII, craters in Verdun, France, produced by heavy artillery fire still remain devoid of vegetative growth; deep craters extending to the water table cause hydric conditions, making them unsuitable for colonization by terrestrial plant species. Thus, shelling can result in chronic legacy impacts in addition to acute influences such as instant mortality (Hupy 2006).Ground forces, in the past, have used explosives to destroy hydropower dams and dikes as a means to hinder the mobility of countering factions (Gleick 1993; Francis 2011). The sudden removal of long established dams can cause a number of ecological consequences, such as siltation, mortality of fish and produce lasting physical, chemical, and biological effects (Bednarek 2001; Stanley and Doyle 2003).

Naval Operations

Marine environment has been affected due to naval conflict between foreign nations. Naval blasts and sonar operations have the potential to impede the lives of many aquatic species. The acoustic frequency used by dolphins and whales coincides with that used by naval sonar devices, which can cause ear hemorrhage and beach stranding. In addition, conventional naval ordinance such as depth charges, torpedoes create substantial underwater blasts that can inflict overpressure and fragmentation injury to invertebrates, fish, reptiles, birds, and marine mammals in proximity of the blast radius (Westing 1980).

Naval conflicts, particularly during WWII, also led to the creation of heterogeneous habitats that would not exist otherwise. During WWII, there was a global expansion with ocean-going vessels that navigated the coastal and pelagic waters of the Atlantic and South-Pacific oceans to engage hostile countries. Although this led to devastating consequences for human life, the resulting ship wrecks created a large number of artificial reefs where aquatic life could colonize, utilize, and flourish.

Aerial and Naval Bombardment

Bombardment of the urban infrastructure, which constitutes the environment and a significant fraction of the world's human population, has always caused forced dislocation of survivors. The bombardment of cities and the destruction of forests, farms, transport systems and irrigation networks during World War II produced devastating environmental consequences and by the end of the war there were almost 50 million refugees and displaced people. In the last year of the war the land of coastal and northern France was torn up, Holland south of the Zuyder Sea was flooded with the destruction of dikes, and many ports were clogged with unexploded ordnance and sunken ships. During World War II, aerial bombardments in military became increasingly prevalent, and hundreds of thousands of people died as a result(Westing, 1986).In addition, aerial bombardment lead to destruction of home, urban and rural infrastructure, and progressive waves of dislocated or homeless people, can be seen in all wars subsequent to World War II. In the 15 years of the war in Southeast Asia, the US bombardment of Vietnam, Laos and Cambodia forced about 17 million people to become refugees (Westing, 1980).

The military use of the term bomb or more specifically aerial bomb action typically refers to air dropped, unpowered explosive weapons most commonly used by air force and naval aviation. Other military explosive weapons not classified as bombs include shells, depth charges used in water or land mines. The devastating shock wave that accompanies detonation of a high explosive (HE), results in widespread damage and loss of life. High explosives consist of an intimate mixture of oxidant and reductant, either within a single molecule, such as nitroglycerin, pentaerythritol tetranitrate (PETN), trinitrotoline (TNT), or triacetone triperoxide (TATP), or within an ionic solid, such as ammonium nitrate, when mixed with fuel oil. Mixtures of high explosives are frequently used. For example, Semtex is a blend of cyclomethylenetrinitramine and PETN.

Reductants (e.g., aluminum powder, fuel oil) may be added to solids such as ammonium nitrate, which have excess oxidizing power, in order to increase the explosive yield. When these high explosive compounds such as nitroglycerin (dynamite), cyclonite, picric acid and trinitrotoluene (TNT) explode, it releases gases such as CO, NO, NO_2, CO_2 and smoke, into the atmosphere leading to air pollution and health hazards. These gases release into the environment causes severe harm to human, plants, as well as animals.

Blast Effects

Animals caught within the blast wave can be affected in a number of ways; terrestrial species are likely to experience damage resulting from overpressure injury. Using blast pressures similar to what has been reported during nuclear explosions, rats experienced severe lung damage as well as large degrees of hemorrhaging in various regions of the body (Jaffin *et al.*, 1987). Physiological damage has also been found in a number of other vertebrate species, the extent of physiological damage depend upon the mass of the animal; larger animals are less susceptible to injury as well as the magnitude and duration of the over-pressure exposure. Obviously, there is an increase in mortality rates in exposed populations resulting from nuclear detonation. However, other intensifying effects are the large amount of debris and shrapnel carried through the air by the blast causing injury and death to animals in the surrounding area. This effect has been directly observed during a nuclear detonation on both humans and other mammalian species (Candole, 1967; Jaffin *et al.*, 1987; Mayorga, 1997; Masco, 2004; Shaeffer 1957; Liebow 1983; Kishi, 2000).

During nuclear warhead detonation, blast energy accounts for approximately 50% of the total emitted energy that moves away from the epicentre in a radial pattern (Glasstone, 1962). The large amount of kinetic energy emanating from the blast (1–3500+ kPa) is damaging to plants whereby the blast force is capable of removing plants as well as damaging branch structure and uprooting vegetation from the soil, thereby destroying a large proportion of the surrounding plant life and primary production (Shields and Wells 1962; Palumbo 1962; Shields *et al.*, 1963; Beatley 1966; Hunter 1991).

In addition, nuclear detonations in proximity to aquatic environments have been discovered to result in massive death of fish population owning to the fact that aquatic organisms are particularly sensitive to the effects of a blast thereby leading to fish mortality on a much larger scale(Govoni *et al.*, 2008; Popper and Hastings 2009; Planes *et al.*, 2005).Due to the presence of large gas filled lungs in marine mammals, they are likely to suffer high rates of mortality under a nuclear blast resulting from severe lung damage. This is as a result of the anatomical design of teleost fish having a gas-filled swim bladder that is easily ruptured upon exposure to large pressure differentials (Baxter *et al.*, 1982; Planes *et al.*, 2005; Goertner, 1982). Grippingly, under a nuclear blast, invertebrates are not apparently affected by pressure waves in aquatic systems and thus unlikely to be affected; because not all invertebrates are equal, in respect to kinetic energy disturbances. Nuclear explosions over coral reefs leads to widespread coral death apparently through mechanical disruption from the blast, highly turbid conditions generated during blasts have led to the extinction of calm water specialist coral species on some reefs (Richards *et al.*, 2008).

Greenhouse Gas Emissions and Pollution

Military activities involve high emissions of gaseous pollutants leading to environmental pollution and also a consumer of high volumes of hazardous materials (Department of National Defence Canada, 2017).However, several studies have shown a strong positive correlation between military spending and increased greenhouse gas emissions (Hamilton and Stoner, 2017; Jorgenson and Brett, 2016). Additionally, armed forces are responsible for the emission of two thirds of chlorofluorocarbons (CFCs) that were banned in the 1987 Montreal Protocol for causing damage to the ozone layer.

The world's military forces are responsible for the release of more than two thirds of CFC into the ozone layer. During the Cold War, the US and Soviet armed forces produced enormous amounts of hazardous wastes. As a result of naval accidents there are at least 50 nuclear warheads and eleven nuclear reactors littering the ocean floor. There are more nuclear reactors at sea than on land. In addition, the military also contribute to climate change through emission of greenhouse gases, especially from aircraft.

Nuclear Warfare

The development and use of nuclear missiles, in both times of peace and conflict, has indisputably left a significant scar on the Earth's surface. As of the late 1990s, more than 2000 nuclear weapons tests have been conducted around the world (Yang *et al.* 2003). The detonation of a nuclear warhead denotes a significant threat to the environment, the energy released is partitioned into three distinct categories including thermal (35%), kinetic (50%), and radioactive (15%) energies (Brode 1968). Nuclear warfare imposes both direct and indirect effects on the environment.

The physical destruction due to the blast or by the biospheric damage due to ionizing radiation or radio toxicity directly affect ecosystems within the blast radius. Also, the atmospheric or geospheric disturbances caused by the weapons can lead to weather and climate changes. The potential effects of each of these detonation such as thermal and radiation, affect the environmentandare discussed below.

Thermal impacts

Thermal emissions from nuclear blasts can have a number of impacts on the ecosystems. The enormous release of thermal energy at the detonation's epicenter results in high temperatures in excess of 3000 °C (Brode 1968; Pinaev and Shcherbakov 1996). In addition, thermal emissions pose a lethal force to any life in the vicinity of the epicentre resulting from incineration as seen in the bombings of Japan (Silberner 1981). Beyond the epicentre, an outward thermal wave (100–1000 °C) moves radially; a distance dependent on the bomb strength and is a serious risk to most life over its expansion (Brode 1968). Here, local vegetation is burnt and defoliated, often perishing through the extreme heat representing severe reductions in plant species richness and abundances.

The spatial extent to which the vegetation is defoliated is highly dependent on the status such as moisture content and composition of the vegetation present in the blast area. It is speculated that thermal emissions may indirectly impact adjacent forests and vegetative regions, through the generation and spread of wildfires that may extend the immediate population and diversity reduction outside of the blast area for both plants and animals (Noble and Slatyer 1980; Grace and Keeley 2006; Palumbo 1962; Shields and Wells 1962; Shields *et al.*, 1963; Craft 1964; Small and Bush 1985; Singer *et al.*, 1989; Moreira and Russo 2007; Lindenmayer *et al.*, 2008). Thermal wave exposure has been reported to cause severe whole body burns on unprotected skin in humans. In the bombings of Japan, fatal burns and mild non-lethal burns were observed within 1.2–2.5 km and 3–4 km from the epicentre, respectively, with the former resulting in a large proportion of the total deaths (∼30%). Additionally, thermal radiation, along with high intensity visible radiation, can also result in severe retinal burning in humans (Oyama and Sasaki 1946; Rose *et al.*, 1956).

This invariably will have similar consequences among terrestrial wildlife, especially mammals. Experimental tests of simulated and actual nuclear weapons produced thermal energy exposure in rats (Alpen and Sheline 1954), dogs (Brooks *et al.*, 1952), rabbits (Byrnes *et al.* 1955; DuPont Guerry *et al.* 1956; Ham *et al.*, 1957), and swine (Baxter *et al.*, 1953; Hinshaw 1968) have generated analogous effects as seen in humans suggesting that wild mammals may have a similar burn response during a nuclear detonation. Severe burns were also reported in teleost fish that were in close proximity to the detonation of the warhead in Bikini Atoll (Donaldson *et al.*, 1997). Not surprisingly, in simulated experiments, severe burns increased the rates of mammalian mortality, resulting from general physiological disturbances and secondary infection occurring 0–2 weeks post blast.

This effect was also amplified under a combined thermal and radiation exposure resulting in a severely immune compromised, physiologically disturbed individual similar to what is believed to occur in humans (Brooks *et al.*, 1952; Baxter *et al.*, 1953; Alpen and Sheline 1954; Valeriote and Baker 1964). Scaling these effects up, it would be highly likely that thermal emission exposure would result in a large die-off event in the local animal life thereby reducing local populations and potentially reducing local species richness over an acute timeframe (0–2 weeks).

Radiation impacts

Nuclear weapons emit energy as ionizing, radioactive emissions either as electromagnetic radiation such as gamma and X-rays or through radionuclides of various elements which are accumulated primarily through direct exposure(Aarkrog 1988; Robison and Noshkin1999; Whicker and Pinder 2002; Donaldson *et al.*, 1997; Entry and Watrud 1998). However, the effects of radioactivity on life and on the environment differs; radiation exposure in humans can result in blood cell and tissue destruction, high level of developing a chronic disease, such as neoplasia and mortality in excess doses, which bring about increase in mortality rate in the bombings of Japan (Prosser *et al.*, 1947; Ohkita 1975).

Radioactive exposure also has more chronic effects on animal populations. According to Mole (1958), assuming this effect occurred in a similar manner as in humans, it is likely to reduce life expectancies and survival in wild animals. Chronic radiation effects may also result in the development of chromosomal and genetic abnormalities, in addition to altered genetic structure of populations in wild animals (Bickham *et al.*, 1988; Lamb*et al.*, 1991; Sugg *et al.*, 1995; Theodorakis and Shugart 1997, 1998).Similar effects have been observed to occur in terrestrial mammals in both laboratory experiments and bomb exposed animals resulting in mortality (Eldred and Trowbridge 1954; Brown *et al.*, 1961; Zallinger and Tempel 1998; Tullis *et al*., 1955).

Acute radiation exposure in plants, results in tissue degradation and death under sufficiently high radioactivity levels; the extent of tissue damage in plants varies with development state (Sparrow and Woodwell 1962; Shields *et al*., 1963; Rhoads and Platt 1971). However, depending on the strength and type of the effect, the overall impacts are quite uncertain and probably have variable consequences on a given population. It is pertinent to say that these affected areas are devoid of human activity as a result of hazard caused by radiation and risk associated with nuclear weapons test and production sites and thus serve as important refuge sites for a variety of plant and animal species (Gray and Rickard 1989; Whicker *et al.*, 2004; Davis 2007; Richards *et al.*, 2008; Houk and Musburger, 2013).

Land Use

People are displaced when the military take over land and water bodies that the local residents need to live or feed from; land use as bases, target ranges, weapons stores, training grounds etc. A few of the many examples are Thule in Greenland where indigenous Inuit were displaced for the US base, and the US bases in Okinawa (Japan), Guantanamo (Cuba), and Diego Garcia. Military activities often involve the use of fuels, explosives, solvents and other toxic substances. When improperly handled or stored, they can seep into the environment and affect nearby communities. Military exercises often damage farmland and other property, as heavy military vehicles travel over small roads and bridges. In Canada, noise pollution from low-flying military aircraft has proved a serious menace, including the rearing of animals. This has prompted the development of a vigorous citizens' campaign (International Peace Bureau, 2002).

Maintenance and Operations of Military Equipment

The environmental impacts associated with the upkeep of military infrastructure and equipment have been a growing concern. Military infrastructure and equipment is subject to rigorous use, often under extreme conditions, creating the need for constant maintenance and upkeep. This maintenance leads to the generation of large quantities of hazardous wastes including heavy metals, solvents, corrosives, paints, fuel, and oils (Brady 1992). When these hazardous wastes are improperly disposed, it can cause serious water contamination and habitat degradation issues, which can directly affect the environment (Edwards 2002; Osuji and Nwoye 2007). There have been documented reports of military sites that dump hazardous wastes into open holding ponds, evaporation ponds, mines, and wells which have begun to leak, causing environmental pollution (Brady, 1992).

Training Activities; Live Fire

The impact of live fire training on the environment include the alteration of the local landscape and vegetation destruction, chemical and heavy metal contamination and the incidental killing or maiming of wildlife (Owens 1990). Training facilities are faced with the challenge of repeated use of live fire training shooting ranges, which leads to consistent site degradation and contamination. The most common and extensive life-fire training occurs on small arms ranges which are associated with extensive heavy metal contamination, with lead (Pb) being the most notable contaminant. The weathering and oxidation of lead (Pb) bullets leads to the contamination of soils, groundwater, and surface water sources. It has been noted that high lead (Pb) concentration in soils can reduce vegetation growth and species richness (Cao *et al.,* 2003a, 2003b; Hardison *et al.*, 2004).

Other forms of live fire training involve the use of advanced high power weaponry such as artillery and mortars, multiple launch rocket systems, hand grenades, and anti-tank weapons. In addition, these high-powered weapons require special training areas to safely contain the blast radius and noise from civilian areas. This type of weapon training can create significant habitat damage by cratering the terrain and altering the species composition within the area. Specifically, these highly disturbed landscapes can suffer from degraded soil structure and quality, and are reduced to disturbance-tolerant flora and fauna species (Smith *et al.,* 2002; Pekins 2006; Warren *et al.,* 2007; Rideout and Walsh 1990; Doxford and Judd 2002).

Chemical contamination is also prevalent in these training areas in the form of heavy metals, radiation and unused propellants, all of which can directly impact community composition (Doxford and Judd 2002; Edwards 2002; Garten *et al.*, 2003).

Furthermore, armoured vehicles signify all tracked and wheeled military vehicles used for combat and transport and are essential in most conflict situations because of their long-range firing capacity, protective armour (Doxford and Judd 2002; Johnson 1982). These vehicles are generally outfitted with heavy armour and weaponry, making them extremely heavy, with some vehicles weighing upwards of 60 metric tons. Because of the heavy weight of these vehicles, terrain compaction is a significant issue that can have detrimental impacts on the soil and vegetation communities.

The conditions for which armoured manoeuvre training occurs can also influence the severity of the impact on the landscape; operations during wet spring conditions can cause enlarged track ruts and high rates of vegetation removal (Johnson 1982; Watts 1998; Dickson *et al.*, 2008; Foster *et al.*, 2006). In frequently used landscapes, tracked vehicles have been noted to reduce total plant and woody vegetation cover, and increase soil erosion rates. Armoured manoeuvre training can also lead to changes in soil structure and chemistry with frequently used sites having lower carbon to nitrogen ratios, as well as reduced soil carbon content (Johnson 1982; Wilson 1988; Garten *et al.*, 2003; Doxford and Judd 2002). Armoured manoeuvre training is seen as being particularly damaging and persistent especially in fragile environments, such as the Mojave Desert. Armoured vehicle operations have also been linked to incidentally hitting and killing wildlife during training exercises (Zakrajsek and Bissonette 2005; Telesco and Van Manen 2006).

Apart from terrestrial armoured vehicle training, military training areas are intensively used for fighter jet and helicopter training exercises (Harrington and Veitch 1991; Conomy *et al.*, 1998). The largest environmental impact associated with aviation exercises is hitting and killing birds during flight manoeuvres (Richardson and West 2000; Zakrajsek and Bissonette 2005). Bird aircraft collisions are particularly serious as they can often cause a loss of human life and damage or destruction of aircraft. From 1985–1998, the United States Air Force (USAF) recorded an average of 2700 aviation related bird strikes each year, accumulating in excess of 35 000 bird aircraft collisions over the 13 year period; an average cost of $35 million US dollars annually in aircraft repair and replacement to the USAF (Zakrajsek and Bissonette 2005). The most vulnerable bird species to aircraft collisions noted by the USAF included raptors, waterfowl, and passerines (Lovell and Dolbeer 1999; Zakrajsek and Bissonette 2005). For all bird aircraft collisions, it has been estimated that roughly 69% take place below 305 m of altitude, which makes birds especially vulnerable to low-flight training exercises (Lovell and Dolbeer 1999; Zakrajsek and Bissonette 2005; Dukiya and Gahlot 2013). Because of the high risk of bird aircraft collisions, special measures have been taken at airstrips to reduce bird strike hazards. These precautionary measures include reducing attractive installations near airfields such as landfills or new water environments, altering flight training routes, and using falconry to deter birds from the airfield vicinity (Lovell and Dolbeer 1999).

Naval military training exercises can have negative impacts on marine life. Unlike the issues associated with over-pressure injuries from explosive detonations and live-fire operations, the main impacts of naval training exercises are caused from the generation of excessive noise pollution (Dolman *et al.*, 2009). Noise pollution can be generated from a variety of sources which includes mechanical and propeller noise, gun discharges, explosives detonations, and the use of sonar technologies (Parsons *et al.*, 2000; Scott 2007; Dolman *et al.*, 2009). Active sonar systems range from low frequency levels, 1 Hz – 1 kHz, to mid-frequency levels, 1–10 kHz; both low and mid-frequency systems emit high intensity sound into the ocean and listen for echoes that provide a sonic image of the ocean environment (Dolman *et al.*, 2009). This type of imaging technology is highly useful for military operations, but it can affect the behaviour and survival of large marine mammals (Balcomb and Claridge 2001; Madsen 2005). Marine mammals rely on echolocation for most biological aspects of their lives, and the use of sonar technologies has been linked to disrupting their signaling abilities. This can interfere with foraging, reproduction, communication, and their predator detection abilities (Rendell and Gordon 1999; Miller *et al.*, 2000; Dolman *et al.*, 2009).

3. CONCLUSION

From the pool of existing literature, it is evident that the impact of military, war and armament on environment are overwhelmingly lethal. Military activities affect the environment in the following direct ways; pollution of the air, land, and water. The impacts of conflict, nuclear weapons testing and production and training operations all contribute to both reductions in the populations of local flora and fauna as well as reducing species diversity in the affected ecosystems thereby leading to environmental pollution. The application of weapons, the destruction of structures and oil fields, fires, military transport movements and chemical spraying are all examples of the destroying impact war may have on the environment. Air, water and soil are polluted, man and animal are killed, and numerous health affects occur among those still living. With humanity continually engaging in war and with technological advancements in military, the environment is likely to be in jeopardy.

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