Watson Institute for International & Public Affairs
BROWN UNIVERSITY

COSTS OF WAR

Lessons from Fallujah: War Returnees Face Long-Term Health Risks from Heavy Metal Exposure

Kali Rubaii, Mark Griffiths, Ellen Wells, Aaron Specht, Ian Lindsay, Samira Alani, and Abdulqader Alrawi[1]

March 24, 2025

Summary

Based on interdisciplinary biological, environmental, and anthropological research in Fallujah, Iraq, this study finds that people who return to bombarded homes and neighborhoods may face increased risk of negative health impacts from heavy metal exposure, both for themselves and for future generations. Our findings support prior research which has demonstrated that those who are first at the scenes of war-damaged areas may be at a higher risk of reproductive health harms, and that Fallujah's population faced a 17-fold increase in birth anomalies and myriad other health problems linked with the 2003 U.S. invasion of Iraq.[2] Our study demonstrates that exposure to remnants of war, amplified by vitamin deficiencies, may play a role in these health outcomes.

Fallujah is exemplary of the negative long-term health impacts of wide-ranging heavy metals use in military bombardment in the post-9/11 wars.[3] Our team's environmental sampling of Fallujah detected higher levels of heavy metals in the soil of more heavily bombarded neighborhoods, indicating the enduring distribution of heavy metals linked with military activity.[4]

---

[1] At Purdue University, Dr. Kali Rubaii is the PI of a health research team that includes Dr. Ellen Wells (epidemiology), Dr. Aaron Specht (health physics), Dr. Ian Lindsay (GIS), and several research assistants, spearheaded by medical doctors Samira Alani (pediatrics) and Abdulqader Alrawi (genetics) in Fallujah. Funded by Purdue University, this research was conducted under Purdue's IRB protocols with oversight from Fallujah Women and Children's Hospital and the Anbar Ministry of Health and Environment. The team is joined by Mark Griffiths (geography) at Newcastle University, a partnership is made possible by the *War and Geos* project, funded by UKRI.

[2] See footnote 16 and Gottesdiener, L. (2020, November 9). The Children of Fallujah: The Medical Mystery at the Heart of the Iraq War. *The Nation.* https://www.thenation.com/article/world/fallujah-iraq-birth-defects/

[3] Griffiths, M. & Rubaii, K. (2024, October 18). Late modern war and the *geos:* the ecological 'beforemaths' of advanced military technologies. *Security Dialogue, 56*(1):38-57.

[4] Specht, A., Lindsay, I., Wells, E., Rubaii, K. (2024, May 11). Spatial Distribution of Heavy Metal Contamination in Soils of Fallujah, Iraq, *Exposure and Health, 17,* 31-39.

This report highlights a previously unpublished finding of our ongoing study: our team's bone sampling detected uranium in the bones of 29% of study participants in Fallujah and lead was detected in 100% of participants' bone samples. Researchers have never before detected uranium in bones in vivo: in vivo bone XRF sampling is groundbreaking in identifying uranium exposure among living populations. The amount of lead detected in participants' bones was 600% higher than averages from similarly aged populations in the U.S.[5]

Additionally, our ethnographic research found that in the process of people in bombarded areas being displaced, returning, and re-establishing households, nutritional gaps can compound health risks, even for the next generation.

These retroactive insights 10 and 20 years after heavy bombardment campaigns in Fallujah may support prevention in other places. Returnees to bombarded cities in places such as Gaza, Ukraine, Syria, and Lebanon likely face negative long-term health impacts from heavy metal exposure, both for themselves and for future generations.

Returnees can limit exposure by wearing personal protective equipment and prioritizing certain nutritional practices. Vitamin protocols can help limit the negative health impacts of heavy metal exposure. (See Appendix B for a list of our recommendations in Arabic and Ukrainian.)

Introduction

In the two decades since two U.S.-led battles in Fallujah, Iraq in 2004, and nearly a decade since ISIS occupation of the city, the enduring environmental health impacts of war are still evident. In 2004, an estimated 60-70 percent of the city was levelled, and thousands were killed. Public infrastructure including hospitals, the electrical grid, and water supply were shelled and destroyed.[6] Similar violence took place again when ISIS occupied the city in 2014 and when the Iraqi government, supported with U.S. military equipment, bombed Fallujah to recapture the city in 2016. In both cases, siege warfare combined with widespread reports of summary executions. Many witnessed the violent death of family members and the decay of corpses on the street.[7]

Fallujah today, among other bombarded cities in Iraq, reports a high rate of cancers, including a 12-fold increase in childhood cancer since 2004, exceeding the rates in post-

[5] Uranium has long been a marker of military violence, given its documented use in tanks and missiles and its general absence from non-military industries, but it should not be interpreted as exceptional in its environmental health effects: rather, it should be understood as one of many heavy metals deployed in warfare.
[6] Caputi, R., Hil, R., & Mulhearn, D. (2019). *The Sacking of Fallujah: A People's History.* University of Massachusetts Press.
[7] Iraq Family Health Survey Study Group. (2008, January 31). Violence-Related Mortality in Iraq from 2002 to 2006. *The New England Journal of Medicine, 358*(5).

bombing Hiroshima.[8] There are also reports of an increase in negative birth outcomes, including a 17-fold increase in anomalous births.[9] These high rates of cancer and birth anomalies may be attributed to exposure to the remnants of war, as are manifold other similar spikes in, for example, early onset cancers[10] and respiratory diseases.[11] Prior research makes clear that the type, range, and quantity of illness in Fallujah reflect population-level stress as the direct and indirect results of these wars. Through interdisciplinary methods that address families' lived experiences, our research identifies post-war return as one possible route to high-level exposure.

There was a mass exodus from Fallujah in 2004 and again in 2014. Each time, after military battles ceased, large numbers of people returned to what remained of their homes –in some cases, partially demolished buildings, with the charred remains of ash-covered walls; in other cases, houses with chemical spills and bullet holes; and in other cases, craters where their homes or offices once were. Returnees to Fallujah faced urgent priorities, among them avoiding unexploded ordinance, gaining access to water and food, and establishing safe shelter. Compounded by depleted healthcare services,[12] elevated levels of overall pollution,[13] and a high prevalence of psychological trauma,[14] handling war debris posed additional long-term and intergenerational health risks.

This report outlines some early findings of our interdisciplinary research (2021-2025) in Fallujah on the effects of war on intergenerational and reproductive health. This research is pioneering in its breadth and depth, utilizing multiple layers of data, including biological, environmental, and ethnographic data, and multiple forms of data analysis. Our research team consists of an anthropologist, a pediatrician, a genetics MD, an epidemiologist, a medical physicist, a geographer, and a GIS expert. This comprehensive approach helps us understand the full range of military exposures and social practices that shape health outcomes. See Appendix A for a fuller description of our research methods.

---

[8] Busby, C., Hamdan, M., & Ariabi, E. (2010, July). Cancer, Infant Mortality and Birth Sex-Ratio in Fallujah, Iraq 2005–2009. *International Journal of Environmental Research and Public Health, 7*(7): 2828-2837.

[9] Alaani, S., Tafash, M., Busby, C., Hamdan, M., & Blaurock-Busch, E. (2011, September 2). Uranium and other contaminants in hair from the parents of children with congenital anomalies in Fallujah, Iraq. *Conflict and Health*. *5*(15).

[10] Chalabi, M. (2023, April 3). Iraq war leukemia rates worse than after Hiroshima bombing. *The Guardian.* https://www.theguardian.com/news/datablog/2023/apr/02/iraq-war-hiroshima-bombing-leukemia-rates

[11] Vidal, J. (2016, August 22). Iraqi children pay high health cost of war-induced air pollution, study finds. *The Guardian.* https://www.theguardian.com/global-development/2016/aug/22/iraq-children-health-cost-war-induced-air-pollution-study-toxic-waste-birth-defects

[12] Al Hilfi, T. K., Lafta, R., & Burnham, G. (2013, March 16). Health Services in Iraq. *The Lancet, 381*(9870), 939-948.

[13] Al-Shammari, A. M. (2016, June 1). Environmental pollutions associated to conflicts in Iraq and related health problems, *Reviews on Environmental Health, 31*(2): 245-250.

[14] Crawford, N, (2013, March). Civilian Death and Injury in the Iraq War: 2003-2013. *Cost of War, Watson Institute, Brown University.* *https://watson.brown.edu/costsofwar/files/cow/imce/papers/2013/Civilian%20Death%20and%20Injury%20in%20the%20Iraq%20War%2C%202003-2013.pdf*

Heavy Metals Found in Human Bodies and Soil

We found that the environmental impact of warfighting and the presence of heavy metals are long-lasting and widespread in both human bodies and soil. Our findings support prior research which has demonstrated that those who are first at the scenes of war-damaged areas may be at a higher risk of reproductive health harms.[15]

In Fallujah's soil, we have published findings that some areas of the city that saw heavy bombardment and firefighting in 2004 and again in the 2010s have higher levels of heavy metals in the soil than less bombarded areas.[16] Multiple heavy metals were detected at concerning levels, including uranium, thorium, lead, and arsenic. These findings may be related to past military activities in areas in and surrounding the communities, as previous studies have demonstrated the impact of military activity on heavy metal contamination[17] and the deployment of a military arsenal containing a high quantity of heavy metals. For example, between March 19 and April 18, 2003 alone, a total of 19,040 precision-guided bombs, 8885 unguided unitary munitions, and 1276 cluster bombs were dropped in Iraq.[18] Agronomists in Mosul have examined how heavy metal deposits, like depleted uranium, carve new pollution pathways that "may have serious impacts on the regions' food chains and subsequently on human health across Iraq: largely through plant uptake and edible food crops."[19]

---

[15] Studies on reproductive outcomes among women pregnant at the time of the World Trade Center disaster, and exposed to similar conditions as post-war returnees, identified adverse effects that "suggest an impact of pollutants and/or stress." Female military personnel risk "exposure to environmental toxins during early pregnancy is associated with adverse birth outcomes. While pregnancy often prevents deployment, some women veterans discover their pregnancy status post-deployment and are at heightened risk to toxic exposures," according to the US Department of Veteran Affairs.. An association between infertility and environmental exposures to chemical and hazardous materials among male and female veterans during military service has been established. Meanwhile, studies on war and post-war contexts argue that "It is well established that women's sexual and reproductive health is negatively affected by war," but while negative reproductive health outcomes are widely known, some underlying causes may be more closely linked to social and infrastructural conditions that limit women's control over reproductive choices.
See: Lederman, S. A., et al. (2004, September 8). The Effects of the World Trade Center Event on Birth Outcomes among Term Deliveries at Three Lower Manhattan Hospitals. *Environmental Health Perspectives, 112*(17): 1772-1778.; U.S. Department of Veteran Affairs. *War Related Illness and Injury Study Center: Reproductive Health.* https://www.warrelatedillness.va.gov/WARRELATEDILLNESS/WRIISC-WOMEN/ww-repro.asp; Mancuso, A., et al. (2022, November). Lifetime infertility and environmental, chemical, and hazardous exposures among female and male U.S. veterans. *American Journal of Obstetrics and Gynecology, 227*(5); Hedström, J., & Herder, T. (2023, March 17). Women's sexual and reproductive health in war and conflict: are we seeing the full picture? *Global Health Action, 16*(1).

[16] Specht, A.J., Lindsay, I.C., Wells, E.M., & Rubaii, K. (2024, May). Spatial Distribution of Heavy Metal Contamination in Soils of Fallujah, Iraq. *Exposure and Health, 17*, 31–39.

[17] Skalny, A.; et al. (2021, October). Environmental and health hazards of military metal pollution. *Environmental Research*, *201*:111568.

[18] Human Rights Watch. (2003). *Off target the conduct of the War and Civilian Casualties in Iraq.* https://www.hrw.org/reports/2003/usa1203/usa1203.pdf

[19] Fathi, R, A., Matti, L. Y., Al-Salih, H. S., & Godbold, D. (2013). Environmental pollution by depleted uranium in Iraq with special reference to Mosul and possible effects on cancer and birth defect rates. *Medicine, Conflict and Survival, 29*(1), 7–25. P. 7.

Our team's XRF bone sampling detected uranium in the bones of 29% of study participants, all of child bearing age, in Fallujah. Researchers have never before detected uranium in bones in vivo: in vivo bone XRF sampling is groundbreaking in identifying uranium exposure among living populations. In comparison to Fallujah, The Trace Metals Analysis Lab at Purdue University has tested for uranium in U.S. populations and found no detectable levels. Furthermore, lead was detected in 100% of participants' bone samples. The amount of lead detected in participants' bones was 600% higher than averages from similarly aged populations in the U.S.

Uranium has long been a marker of military violence, given its documented use on tanks and missiles and its general absence in non-military industries, but it should not be interpreted as exceptional in its environmental health effects. Rather, it should be understood as one of many heavy metals deployed in warfare. We are currently analyzing other heavy metals readings in these samples (eg. those known for widespread use in military bombardment like arsenic, cadmium, thorium, tantalum, etc.). The presence of uranium in residents' bone sampling may be consistent with the well-documented widespread use of depleted uranium weapons in the 1990s during the U.S.-led Gulf War on Iraq, and in the 2000s: investigations have found that 116,000kg of depleted uranium were used by U.S. and allied forces during the initial invasion of Iraq in 2003.[20] To date, there is not current evidence of depleted uranium's deployment in Iraqi or U.S. military battles with ISIS from 2014-2017.

These rates provide evidence of such high exposure to heavy metals that the likeliest cause is exposure to remnants of war rather than other factors. We are also analyzing confounding factors, as lead vectors may include previous historical use of leaded petroleum and manufactured products with lead, in addition to military bombardment. Naturally occurring elements are not likely to account for the levels detected, but it is difficult to attribute our results to a single or certain cause.[21] For example, war-damaged water filtration systems, wartime and postwar underregulated industrial production, and military bombardment may have a synergistic impact on public health. These multiple factors can also limit the ability of scientists to document how exactly each of these compounding burdens impact people's lived environments.[22]

---

[20] Zwijnenburg, W. & Weir, D. (2016, October 5). *Targets of Opportunity: Analysis of the use of depleted uranium by A-10s in the 2003 Iraq War*. Conflict and Environment Observatory, PAX, International Coalition to Ban Uranium Weapons. https://ceobs.org/wp-content/uploads/2018/03/pax_icbuw_targets_of_opportunity.pdf

[21] Logan D. (2018). Toxic violence: the politics of militarized toxicity in Iraq and Afghanistan. *Cultural Dynamics, 30*(4):253–283; Skalny, A.V., et al. (2021, October). Environmental and health hazards of military metal pollution. *Environmental Research, 201*:111568.

[22] Zhang, P., et al. (2023, September). Water quality degradation due to heavy metal contamination: health impacts and eco-friendly approaches for heavy metal remediation. *Toxics, 11*(10):828; Bith-Melander, P., et al. (2022, February 4). Slow burns: a qualitative study of burn pit and toxic exposures among military veterans serving in Afghanistan, Iraq and throughout the Middle East. *Annals of Psychiatry and Clinical Neuroscience, 4*(1):1042; Reis, A.P., et al. (2015, August). Investigating relationships between biomarkers of exposure and environmental copper and manganese levels in house dusts from a Portuguese industrial city. *Environmental Geochemistry and Health, 37*(4), 725–744.

The presence of heavy metals in human bone reflects cumulative exposure over a person's lifetime. This presence is not necessarily a predictor of inevitable health problems, but as one ages, and during pregnancy, bones release metals back into the body, which can have negative health effects, including cancer.[23] As noted in our prior publication, heavy metal exposure has known impacts on nearly all organ systems in the body.[24] Lead has drastic impacts on childhood neurodevelopment,[25] but can also impact adults' cardiovascular and neurological health, as well as birth outcomes.[26] Additionally, arsenic and mercury have known impacts on birth outcomes and neurologic health.[27] Finally, uranium has known impacts on neurological function but is the least studied of the metals identified here for birth outcomes.[28]

As described below, vitamin protocols can help limit these negative health impacts of heavy metal exposure.

Nutritional Gaps Compound the Impact of Heavy Metals Exposure

We found that poor reproductive outcomes linked with heavy metal exposure may be amplified by vitamin deficiencies amongst returnees to bombarded areas.

During interviews and exposure histories, many study participants described the financial incentive to return ahead of other displaced families and participate in

---

[23] Khoshakhlagh, A.H., Mohammadzadeh, M., & Gruszecka-Kosowska, A. (2024, August 1). The preventive and carcinogenic effect of metals on cancer: a systematic review. *BMC Public Health, 24*, 2079.
[24] Surdyk S., et al. (2021, February 21). Weaponised uranium and adverse health outcomes in Iraq: a systematic review. *BMJ Global Health, 6*(2); Dickerson, A.S., et al. (2019, April). Population-based study of amyotrophic lateral sclerosis and occupational lead exposure in Denmark. *Occupational and Environmental Medicine, 76*(4), 208–214; Lin, Y., et al. (2019, April 1). Blood lead, bone lead and child attention-deficit-hyperactivity-disorder-like behavior. *Science of the Total Environment, 659*, 161–167; Mordukhovich, I., et al. (2012, January). Associations of toenail arsenic, cadmium, mercury, manganese, and lead with blood pressure in the normative aging study. *Environmental Health Perspectives, 120*(1), 98–104; Weisskopf, M.G., et al. (2004, December 15). Cumulative lead exposure and prospective change in cognition among elderly men: the VA normative aging study. *American Journal of Epidemiology, 160*(12), 1184–1193.
[25] Lanphear, B.P., et al. (2005, March 18). Low-level environmental lead exposure and children's intellectual function: an international pooled analysis, *Environmental Health Perspectives, 113*(7), 894–899.
[26] Weisskopf, M.G., et al. (2004, December 15). Cumulative lead exposure and prospective change in cognition among elderly men: the VA normative aging study. *American Journal of Epidemiology, 160*(12), 1184–1193; Navas-Acien, A., Guallar, E., Silbergeld, E.K., & Rothenberg, S.J. (2007, March). Lead exposure and cardiovascular disease—a systematic review. *Environmental Health Perspectives, 115*(3), 472–482; Johnson, K.M., et al. (2021, February 10). Lead exposure and association with angiogenic factors and hypertensive disorders of pregnancy. *Pregnancy Hypertensions, 22*, 93–98.
[27] Suhl, J., et al. (2022, November). Prepregnancy exposure to dietary arsenic and congenital heart defects. *Birth Defects Research, 115*(1), 79–87; Cariccio, V.L., Samà, A., Bramanti, P., & Mazzon, E. (2019, February). Mercury involvement in neuronal damage and in neurodegenerative diseases. *Biological Trace Elements Research, 187*(2), 341–356; Lee, M.S., et al. (2021, May). Umbilical cord blood metal mixtures and birth size in Bangladeshi children. *Environmental Health Perspectives, 129*(5), 57006.
[28] Dinocourt, C., Legrand, M., Dublineau, I., & Lestaevel, P. (2015, November 4). The neurotoxicology of uranium. *Toxicology, 337*, 58–71; Vellingiri, B. (2023, September). A deeper understanding about the role of uranium toxicity in neurodegeneration. *Environmental Research, 233*:116430.

reconstruction activities. Thus, poorer families and construction workers were often the first to return and rebuild the city after bombardment. During our exposure histories, these participants – the first to return – described living in recently bombarded homes, repairing their own homes, clearing rubble, and rebuilding other houses in Fallujah's neighborhoods, usually without masks or gloves. First returnees are like other first-responders in that they face higher exposure to carcinogens and toxins[29], higher incidence of cancer[30], and negative birth outcomes[31]. This is likely the result of their exposure through inhalation to toxins from detonated munitions, incinerated materials, dioxins, and other forms of dust at a much higher rate than those who returned after buildings were restored. What are often nutritionally-depleted people are brought into contact with harmful materials in the process of people returning to clean and rebuild.

Based on ethnographic observation, dwelling histories, and interviews, we found that in the process of being displaced, returning, and re-establishing households, nutritional gaps can compound health risks of heavy metal exposure, even for the next generation. People engaged in post-war clean-up often do so when they are under-nourished, and without using personal protective equipment. Iraqis have faced periods of malnutrition from sanctions[32] and sieges,[33] though malnutrition rates[34] have decreased over time. During the 2004 and 2014 occupations of Fallujah, sieges limited regular food access. For example, a Comprehensive Food Security and Vulnerability Analysis in 2016,[35] during the 2014-2016 ISIS occupation of Fallujah, showed that malnutrition symptoms, like wasting, were in the medium severity range, with 7.5% for residents of Iraq and 5.5% for internally displaced people.[36] This study was conducted roughly a year before many first returnees arrived in Fallujah to clean up and rebuild after a period of heavy bombardment. Malnutrition can have negative reproductive outcomes, including low birth weights. In Iraq, nationwide rates of low birth weight increased from 13.4% in 2011 to 25.2% in 2018.

---

[29] Landrigan, P., et al. (2004, May). Health and environmental consequences of the world trade center disaster. *Environmental Health Perspectives, 112*(6), 731-739.
[30] Solan, S., et al. (2013, June). Cancer Incidence in World Trade Center Rescue and Recovery Workers, 2001–2008, *Environmental Health Perspectives, 121*(6): 699-704.
[31] Lederman, S. A., et al. (2004, September 8). The Effects of the World Trade Center Event on Birth Outcomes among Term Deliveries at Three Lower Manhattan Hospitals. *Environmental Health Perspectives, 112*(17), 1772-1778.
[32] OCHA Relief Web. (2004, June 8). *Iraq: Briefing paper on food security.* https://reliefweb.int/report/iraq/iraq-briefing-paper-food-security-0
[33] Human Rights Watch. (2016, April 27). *Iraq: Fallujah Siege Starving Population, Government Forces Block Aid; ISIS Bars Civilian Flight.* https://www.hrw.org/news/2016/04/07/iraq-fallujah-siege-starving-population
[34] Sabeeh, H. K., Saadulddin, H. A., & Al-Jawalde, A. (2022, February 6). Iraq Is Moving Forward to Achieve Global Targets in Nutrition. *Children, 9*(2), 215.
[35] Sabeeh, H. K., Saadulddin, H. A., & Al-Jawalde, A. (2022, February 6).
[36] During ethnographic fieldwork among displaced Anbari families, Rubaii observed a high number of children from Fallujah showed signs of Kwashiorkor. Kwashiorkor is a malnutrition disease, with symptoms including changes in skin pigment, decreased muscle mass, diarrhea, changes in hair color and texture, and increased severity of infections due to a damaged immune system.

Maternal nutrition plays a role in intergenerational health,[37] including offspring's risk of heart disease, type 2 diabetes, cancer, and chronic obstructive pulmonary diseases (COPD).

Our ethnographic research has found additional ways that war-related malnutrition can intensify reproductive health risks. For example, pregnant women's lack of access to proper nutrition during battles, during displacement, and upon returning to levelled cities (where grocery markets are not fully re-established) can mean they have limited access to folic acid or folate rich foods that are essential for fetal development. Thanks to the Iraqi government's federal policies to enrich bread-flour most years, and to health education efforts by doctors, most returnees to Fallujah have had semi-regular access to folic acid, but our preliminary research findings do show that case participants were less likely to have taken folic acid supplements in the first trimester of pregnancy than have control returnees. Especially during the first trimester of pregnancy, insufficient folate intake can lead to neural tube defects like spina bifida.[38] This risk is compounded when handling war debris, as certain heavy metals can disrupt folate pathways, intensifying poor birth outcomes.

Beyond reproductive impacts, nutritional deprivation can compound the general health effects of post-war heavy metal exposure.[39] High enough levels of calcium, vitamin C, and vitamin D in food or supplements can limit both the uptake (metals getting into the body) and release (metals leaving bone tissue and impacting health as one ages) of heavy metals. Without these essential vitamins, the potential health effects of contact with heavy metals increases.

Recommendations for Returnees to Bombarded Areas

People returning to bombarded hometowns like Fallujah – whether in South Lebanon, Syria, Gaza or Ukraine – work hard to rebuild their homes, clearing debris and doing rapid construction. In the process, they are forced to expose themselves to harmful materials. In spite of limited control over these environments, and more acute risks like contact with undetonated munitions, there are some measures that can be taken to mitigate long-term health costs. Alongside measures to prevent bombardment in the first place, there is strong value in public health education among future and current returnees,

---

[37] Pullar, J., et al. (2019, September 5). The impact of maternal nutrition on offspring's risk of non-communicable diseases in adulthood: a systematic review. *Journal of Global Health, 9*(2):020405.
[38] Blencowe, H., et al. (2010, April). Folic acid to reduce neonatal mortality from neural tube disorders. *International Journal of Epidemiology, 39*(1): i110–i121.
[39] Not only can certain heavy metals impair vitamin metabolization, vitamin depletion can facilitate the circulation of heavy metals in the body. Thus, vitamin supplementation can limit the negative health impacts of heavy metals. See: Shuping**,** Z**.,** et al. (2020, August 4). Adverse Impact of Heavy Metals on Bone Cells and Bone Metabolism Dependently and Independently through Anemia**.** *Advanced Science 2020*(7); Rodríguez, J. & Mandalunis, P.M. (2018, December 23). A Review of Metal Exposure and Its Effects on Bone. *Journal of Toxicology 2018*(1); Huiwen, G., et al. (2024, November 15). Vitamin D deficiency may exacerbate the role of metal exposure in depression: A cross-sectional analysis of NHANES data from 2007 to 2018. *Journal of Affective Disorders, 365*, 265-275; Zhai, Q., Narbad, A., & Chen, W. (2014, January 14). Dietary strategies for the treatment of cadmium and lead toxicity. *Nutrients, 7*(1), 552-71.

refugee serving institutions, and local health and educational institutions like clinics, schools, and community centers.

Some ad-hoc ways in which returnees can limit exposure include wearing personal protective equipment and prioritizing certain nutritional practices. Our team's recommendations to returnees are:

- When it comes to contact with war detritus, wearing a mask or scarf to limit inhaling fine particles during the movement of rubble, cleaning activities, and reconstruction activities can drastically reduce long-term risks.

- Burying rather than burning trash, including plastics, building materials, tires, and munitions casings can reduce widespread exposure to carcinogenic and teratogenic toxins.

- When pregnant women can avoid participating in dust-producing cleanup and rebuilding activities, they should.

- When it comes to nutrition, calcium, vitamin C, and vitamin D in food or supplements can limit both the uptake (metals getting into the body) and release (metals leaving bone tissue and impacting health as one ages) of heavy metals from bone.

- Women in the first trimester of pregnancy —or seeking to conceive— should have priority in their consumption of folate rich foods when they can be found (like spinach, broccoli, fortified rice, and enriched wheat) or folic acid supplements.

Though it might seem trivial for people who have survived warfare and displacement to think of masks, vitamins, and folic acid, informed returnees do have some, albeit limited, capacity to shape the health of themselves and future generations.

Appendix B translates these recommendations into Arabic and Ukrainian.

Conclusion

There is a distinct prospect of Fallujah's patterns in public health replicating in other heavily bombarded cities. Returnees bear the double burden of military violence: not only do they suffer widespread death, dismemberment, displacement, and dispossession, but they are also likely to experience illness and harm across generations. Their exposures to heavy metals are higher, and their infrastructural, nutritional, and medical support often lower, than other members of the population. Policymakers should take these long-term health impacts into consideration when understanding and attempting to help mitigate the full scope of war's environmental and population level destruction.

The most effective way to limit heavy metal toxicity from war is by not bombing cities. The detonation of bombs and missiles is devastating not only in its initial destruction, but with lasting impacts on generations born post-war via the widespread dispersal of heavy metals. Although other forms of political pressure, including sanctions, can severely harm population health, the detonation and widespread use of heavy metals should be avoided at all costs. Damage to the quality of air, soil, and water is long lasting, and while local practices of remediation (including phytoremediation) may help with reducing heavy metal contamination, the most effective way to limit heavy metal toxicity is by withholding weapons deployment altogether. Financial disinvestment from weapons arsenals, and reallocation of funding to more effective, sophisticated forms of international relations will also reduce the prevalence of war-induced heavy metal exposures to populations.

Policies and practices that deprive populations of food and adequate nutrition during wartime not only violate international law; they compound the health effects of toxic exposure and impact multiple generations. Rapid and widespread distribution of vitamin rich nutrition to displaced and bombarded communities should be a priority to limit the delayed negative health impacts of war that can include cancer, poor birth outcomes, and permanent congenital disabilities.

Supporting and facilitating the right of displaced people to return home benefits everyone by accelerating post-war recovery. Returnees play a central but under-supported role in rebuilding their communities in the wake of war. Their work constitutes a vital public service that should supplemented with state-led financial compensation for this essential and unpaid labor, clinical support that prioritizes pregnant and conceiving women to limit negative birth outcomes, and prioritization of public infrastructure including water and electricity.

Finally, international NGOs, health institutions, local clinics, and regional radio outlets can equip returnees by rapidly disseminating information about direct measures they can take to protect their own health. Such information should include: the health cost of unprotected post-war cleanup activities on unborn children, the value of masks and scarves to limit inhalation of heavy metal particles, best practices for avoiding inhalation of burned war detritus, and the effectiveness of vitamin supplements in supporting fetal development and long-term adult health.

Appendix A: Data Collection and Analysis

We conducted a multi-level study on the effects of war on reproductive health in Fallujah in three parts: a case-control study on birth outcomes, environmental sampling, and long-term ethnographic observation among returnee households. Together, these allow us to see a cross section of ways exposure to heavy metals impact lived environmental conditions, individual health, and reproductive health over the long-term.

Our case-control study of biological samples compares parents in Fallujah who did and did not experience birth anomalies, with a primary focus on anencephaly and hydrocephaly. Our sample includes 446 pregnancies from 36 families who experienced at least one birth anomaly and 81 families who did not experience any birth anomalies. This study began in 2021 and is ongoing. Data collection includes extensive environmental and occupational exposure histories, full medical histories, and reproductive health histories in patient surveys. 70 participants also provided biological samples of blood spots, hair, toenail clippings, and XRF bone readings for heavy metal assessment. We also mapped GPS coordinates of each participant's dwelling location over their lifetime, in order to assess their proximity to known, fixed, continuous polluters (like military burn pits and factories), and participants' location during periods of heavy military bombardment. Bone samples were taken with a non-invasive, portable X-ray fluorescence (XRF) reading. XRF instrumentation was calibrated using standard phantoms and NIST standards to accepted protocols in the scientific literature. Biological samples (hair, nails, and blood spots) are being analyzed at The Trace Metals Analysis Lab at Purdue University using X-ray fluorescence (XRF). Survey results are being analyzed using logistic regression models which account for the potential influence of confounding variables.[40]

Our environmental assessment included grid sampling of soil and mapping the distribution of heavy metals across Fallujah. 117 surface soil samples were collected between December 2022 and February 2023. 100 of them were collected in a grid pattern, at approximately 200m increments across the city, while the other 17 were used to supplement and verify potential hot spots identified during analysis. In 2024, we installed three air quality monitors in Fallujah and Ramadi for ongoing environmental sampling. XRF analysis at The Trace Metals Analysis Lab at Purdue University was used to quantify the levels of 13 elements (U.S. EPA O 2015a, b[41]), while exploratory factor analysis (EFA) identified contaminant groupings. Both dwelling histories and grid soil sampling were mapped using Geographic Information Systems (GIS) mapping to visualize the spatial distribution of metals.[42] Ongoing spatial analysis is also being used to determine possible correlations between dwelling locations and health outcomes.

---

[40] Additional analysis will use models such as multilevel regression.

[41] U.S. Environmental Protection Agency. (2015a) *Ecological soil screening level metal contaminants.* https://www.epa.gov/chemical-research/ecological-soil-screening-level-metal-contaminants; U.S. Environmental Protection Agency. (2015b) *SW-846 Test method 6200 field portable X-ray fluorescence spectrometry for the determination of elemental concentrations in soil and sediment.* https://www.epa.gov/hw-sw846/sw-846-test-method-6200-field-portable-x-ray-fluorescence-spectrometry-determination

[42] Specht, A., Lindsay, I., Wells, E., & Rubaii, K. (2024, May 11). Spatial Distribution of Heavy Metal Contamination in Soils of Fallujah, Iraq, *Exposure and Health, 17,* 31-39.

Long-term and short-term ethnographic research included participant observation (living with and shadowing) families in their dwellings and workplaces to learn about their living environments and practices between 2014-2015, and periodically from 2021-2024. Ethnographic interviews were also conducted among women making reproductive choices during and after displacement. Interviews and observations were coded for patterns of perception, practices, and decisions around contamination and reproductive health, as well as categorization of military exposure types.

Appendix B: Recommendations for Returnees to Bombarded Areas, in Arabic and Ukrainian

تجربة الفلوجة: إرشادات منزلية لحماية صحة العائدين من المواد السامة

د. كالي روبي وآخرو

نحن مجموعة باحثين من تخصصات مختلفة[43] ندرس تأثيرات الحرب على البيئة وصحة الإنجاب. في ظل عودة الأهالي إلى منازلهم في غزة وجنوب لبنان،نرى أهمية مشاركة ما توصلنا إليه خلال أربع سنوات من البحث في الفلوجة حول الآثار البيئية وصحة الإنجاب، بعد عشرين عاماً من الغزو الأمريكي وعشر سنوات من داش.

نُدرك أن أولويات العائدين الملحة تشمل الحاجة للمأوى والماء والطعام والأمان، مع ضرورة تجنب مخاطر القنابل التي لم تنفجر. علاوة على ذلك، فإن التعرض لمخلفات الحرب قد يسبب مشاكل صحية مستدامة لمن يتعامل معها. تؤثر بعض الخطوات البسيطة تأثيراً مستمراً في حماية الصحة الإنجابية وسلامة المواليد مستقبلاً.

قمنا بدراسة شاملة عن تأثير الحرب على الصحة الإنجابية من خلال مسح التعرض للمواد الضارة والتاريخ الصحي وتحليل عينات من البيئة والسكان. رغم أن البحث مستمر، لدينا نتائج مهمة تفيد مستقبل صحة العائدين ومواليدهم.

أظهرت دراستنا أن أشد مخاطر التسمم تحدث حين يعود الناس لمنازلهم بعد تعرضها للقصف.

للحفاظ على صحة الأجيال القادمة، على العائدين اتباع هذه الخطوات:

تجنب مخاطر المعادن الثقيلة: المناطق في الفلوجة (مثل الجولان) التي تعرضت لقصف شديد قبل 20 سنة ما زالت تحتوي على نسبة عالية من المعادن السامة في التربة مقارنة بالمناطق الأقل تضرراً. أثر الحرب على البيئة يستمر لفترة طويلة وهذه المعادن السامة منتشرة بشكل واسع. يمكن أن تدخل للجسم عن طريق الطعام والشراب والتنفس.وجدنا في عظام سكان الفلوجة آثاراً اليورانيوم والرصاص, وهذا قد يضر بصحتهم كلما تقدموا في السن.

للحماية، اتبع ما يلي:

[43] يقود البحث أطباء من الفلوجة: د. سميرة العاني (أخصائية أطفال) ود. عبد القادر الراوي (أخصائي وراثة)، مع فريق من الباحثين يشمل د. كالي روبي (علم الصحة الاجتماعي)، د. إلين ويلز (علم الأوبئة)، د. آرون سبيخت (الفيزياء الطبية)، د. إيان لينديسي (علم الآثار) من جامعة بوردو، ود. مارك غريفيث (الجغرافيا) من جامعة نيوكاسل.

1) وجود المعادن السامة في العظام لا يسبب السرطان بحد ذاته.يمكن الحد من امتصاص المعادن الثقيلة وإطلاقها من خلال تناول الكالسيوم وفيتامين د وج (الامتصاص يعني دخولها للجسم، والإطلاق يعني خروجها من العظام وتأثيرها على الصحة مع الكِبَر)

2) عند التخلص من بقايا القذائف أو أي قطع من الأسلحة، يجب لبس قفازات وكمامة (أو لف الوجه بالكوفية).

3) يجب تحذير الأطفال من اللعب بأي قطع معدنية أو لمسها أو وضعها في الفم. فالرصاص يضعف القدرات العقلية ويسبب مشاكل صحية أخرى.

الحماية أثناء التنظيف وإعادة البناء: في الفلوجة، الرجال والنساء الذين عادوا أولاً إلى المناطق المقصوفة وشاركوا في تنظيفها، تزداد عندهم نسبة مشاكل الحمل وتشوهات المواليد مقارنة بغيرهم ممن لم يشاركوا في إعادة الإعمار. ذلك لتعرضهم الشديد للسموم المنبعثة من المتفجرات والمواد المحترقة والديوكسين والغبار. تتفق هذه النتائج مع أبحاث عن المسعفين الأوائل في حالات مشابهة. حرق مخلفات الحرب يزيد من خطر استنشاق السموم: إذا شممت رائحة الدخان، فأنت تتنفس مواد سامة.

للحماية، اتبع ما يلي:

1) لبس كمامة أو لف الوجه بقماش لتقليل استنشاق الغبار أثناء تحريك الأنقاض والتنظيف وإعادة البناء يقلل المخاطر بشكل كبير. رغم أن هذا متعب في الجو الحار، لكنه ضروري لحماية صحة الأجيال القادمة.

2) يجب على الحوامل تجنب المشاركة في أعمال التنظيف وإعادة البناء التي تسبب الغبار قدر الإمكان.

3) لا تحرق بقايا القذائف أو قطع الأسلحة. حاول تجنب حرق النفايات، خاصة البلاستيك ومواد البناء والإطارات وغيرها.

4) إذا اضطررت لحرق النفايات بدل دفنها، تجنب الدخان بتغطية الفم والأنف والوقوف في عكس اتجاه الريح.

التركيز على حمض الفوليك: كثير من العائدين يعانون من سوء التغذية، الذي يؤثر على الصحة بطرق كثيرة. نقص التغذية عند النساء يقلل فرص الحصول على حمض الفوليك والأطعمة الغنية به، مما قد يؤثر على نمو الجنين. خصوصاً في الأشهر الثلاثة الأولى من الحمل، قد يؤدي نقص الفوليك إلى تشوهات في الجهاز العصبي عند الجنين. ويزداد هذا الخطر مع التعرض لمخلفات الحرب التي تؤثر على امتصاص الفوليك.

للحماية، اتبع ما يلي:

1) بعض أنواع الطحين مدعمة بحمض الفوليك وقد تجدها في الخبز. ابحث عن الطحين المدعم ("***enriched***") إن أمكن.

2) تناول حبوب حمض الفوليك في الأشهر الثلاثة الأولى من الحمل يقلل من احتمال مشاكل الجهاز العصبي والعمود الفقري عند الجنين.

3) إذا توفرت هذه الأطعمة، يجب إعطاء الأولوية للنساء الحوامل - أو اللاتي يخططن للحمل - في تناول حبوب حمض الفوليك والأطعمة الغنية به مثل السبانخ والبروكلي والحمضيات والبيض والأرز المدعم و القمح المدعم.

САНІТАРНА ПАМ'ЯТКА ДЛЯ РОЗПОВСЮДЖЕННЯ
Урок з Фаллуджі: побутові заходи щодо обмеження токсичної шкоди для здоров'я репатріантів
Калі Рубаї та ін.

Ми є міждисциплінарною командою дослідників[44], які документують довгострокові наслідки війни для навколишнього середовища та репродуктивного здоров'я. Оскільки люди повертаються до своїх домівок у Південному Лівані, Сирії та секторі Газа, ми вважаємо за необхідне поділитися зведеним підсумком чотирьох років досліджень впливу на довкілля та репродуктивне здоров'я у Фаллуджі, проведених через 20 років після вторгнення США та майже через 10 років після ІДІЛ.

Ми визнаємо, що є багато нагальних пріоритетів для репатріантів: доступ до житла, води, їжі, загальна безпека та уникнення боєприпасів, що не розірвалися. Крім того, поводження з військовими уламками може становити довгострокові ризики для здоров'я. **Деякі прості заходи можуть мати тривалий вплив на захист репродуктивного здоров'я та здатність народжувати здорових дітей для наступного покоління.**

Ми провели багаторівневе дослідження впливу війни на репродуктивне здоров'я, включаючи опитування щодо впливу, історію репродуктивного здоров'я, історію проживання, відбір проб навколишнього середовища та біологічних проб. Наш аналіз не завершений, але ми знаємо достатньо, щоб поділитися деякими початковими висновками, які можуть інформувати про довгострокове здоров'я репатріантів та їх здатність народжувати здорових дітей.

Те, що ми виявили, свідчить про те, що одна з найнебезпечніших форм впливу токсинів відбувається, коли люди повертаються до своїх домівок після бомбардувань.

У певних межах поінформовані репатріанти можуть формувати здоров'я майбутніх поколінь:

Обмеження впливу важких металів: райони Фаллуджі (наприклад, Джолан), які зазнали потужного бомбардування 20 років тому, все ще мають вищу щільність важких металів у ґрунті, ніж райони, які зазнали меншого бомбардування. Наслідки бойових дій для навколишнього середовища є тривалими, а наявність важких металів повсюдна. Переносники включають їжу, питну воду та вдихуване повітря в короткостроковій та довгостроковій перспективі. Ми також знайшли уран і свинець у кістках людей у Фаллуджі, що може вплинути на їх здоров'я з віком.

[44] Наша міждисциплінарна дослідницька команда, очолювана лікарями з Фаллуджі, доктором Самірою Алані (педіатрія) і доктором Абдулкадером Алраві (генетика), складається з доктора Калі Рубаї (антропологія здоров'я), доктора Еллен Уеллс (епідеміологія), доктора Аарона Шпехта (фізика здоров'я) та доктора Яна Ліндсі (археологія) з Університету Пердью, і доктора Марка Гріффітса (географія) з Університету Ньюкасла.

Прийміть такі запобіжні заходи:

1) Наявність важких металів у кістковій тканині сама по собі не є причиною раку. Однак прийом кальцію, вітаміну D і вітаміну C може обмежити як поглинання (попадання металів в організм), так і вивільнення (метали залишають кісткову тканину та впливають на здоров'я з віком) важких металів з кісток.
2) Викидаючи гільзи або будь-яку частину зброї, надягайте рукавички та маску (або куфію).
3) Попередьте дітей, щоб вони не гралися з будь-якими металевими предметами, не торкалися їх і не облизували їх. Свинець може знижувати когнітивні функції та викликати інші проблеми зі здоров'ям, особливо у дітей.

Обмеження ризиків під час прибирання та відбудови: У Фаллуджі чоловіки та жінки, які першими повернулися в зони бомбардування та брали участь у прибиранні післявоєнного сміття, можуть мати вищий рівень певних вроджених аномалій (вад розвитку) і гірші результати пологів (викидні, аномалії народження, мертвонародження), ніж ті, хто повернувся пізніше або не брав безпосередньої участі в прибиранні/відбудові. Ймовірно, це пов'язано з тим, що вплив на них токсинів від детонованих боєприпасів, спалених матеріалів, діоксинів та інших форм пилу був набагато вищим. Це також узгоджується з даними, отриманими у інших дослідженнях за участю рятувальників. Палаючий бойовий детрит також може прискорити вдихання: якщо ви відчуваєте запах диму, ви вдихаєте токсини.

Прийміть такі запобіжні заходи:

1) Одягайте маску або шарф, щоб обмежити вдихання дрібних часток під час переміщення уламків, прибирання та відбудови, що може значно зменшити ризики. Незважаючи на те, що внаслідок цього буде жарко й незручно, чоловіки та жінки можуть захистити здоров'я майбутніх поколінь, просто закривши ніс і рот.
2) Вагітним жінкам слід якомога більше уникати участі в роботах з прибирання та відбудови, що утворюють пил.
3) Не спалюйте гільзи та осколки зброї. Якщо можливо, уникайте спалювання сміття, включаючи пластик, будівельні матеріали, шини тощо.
4) Якщо сміття спалюється, а не закопується, уникайте диму від пожежі, закриваючи рот і ніс і рухаючись проти вітру, щоб уникнути вдихання.

Надавайте пріоритет фолієвій кислоті: багато репатріантів страждають від недоїдання, що, звичайно, впливає на здоров'я на різних рівнях. Відсутність у жінок доступу до належного харчування, особливо протягом першого триместру вагітності, може обмежити розвиток плода, що призведе до дефектів нервової трубки та розщеплення хребта. Відсутність у жінок доступу до правильного харчування означає обмежений доступ до фолієвої кислоти або продуктів, багатих на фолієву кислоту, необхідних для розвитку плода. Особливо протягом першого триместру вагітності недостатнє споживання фолієвої кислоти може призвести до дефектів нервової трубки, таких як розщеплення хребта. Це (на додаток до обробки військових уламків, деякі з яких також можуть порушувати шляхи вироблення фолієвої кислоти) може посилити погані наслідки на можливість народження здорових дітей.

Прийміть такі запобіжні заходи:

1) Деяке пшеничне борошно збагачене фолієвою кислотою і може міститися в хлібі. Якщо є можливість, вживайте збагачене борошно.
2) Прийом добавки фолієвої кислоти протягом першого триместру вагітності може зменшити ймовірність дефектів нервової трубки або розщелини хребта.
3) Якщо ці продукти доступні, жінкам у першому триместрі вагітності — або жінкам, які планують завагітніти — слід надавати пріоритет у споживанні добавок фолієвої кислоти та продуктів, багатих на фолієву кислоту, таких як шпинат, брокколі, цитрусові, яйця, збагачений рис і збагачена пшениця.