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8-Jan-26

Our Reference: ACPRES_01

REPORT ON ENERGETIC MATERIAL LIFECYCLE CHEMISTRY

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1. Presentation setup

The presentation was made to the lecturer and cohort on the 28th of November 2025 by the team. The team consisted of Owen Miller (2221022), Libbie Bush (2223155), Charles Hadley (2207149) & Dan Garton (2219350). Libbie Bush was unable to present due to sickness. The full presentation of the students contribution is available at Annex A.

At project start a Microsoft Teams Page was setup to allow for communication and collaborative work on the presentation.

Prior to the presentation the group rehearsed and provided constructive feedback to the members tweaking slides and delivery in collective support of success.

2. The Question

The question explored in the presentation was titled "Energetic Material Lifecycle Chemistry – From Synthesis to Demilitarisation". This was further expanded to "Critically evaluate how chemical principles govern the entire lifecycle of key energetic materials, from synthesis and energy release to degradation and environmentally compliant disposal"

3. Life cycle stages

The standard acronym that the UK Ministry of Defence uses to describe the lifecycle stages of a product is CADMID. This stands for "Concept, Assessment, Demonstration, Manufacture, In-Service and Disposal" [1]. To Further simplify and split these stages amongst the four team members 'concepts, assessment and demonstration' can be defined as 'design' simplifying the sections in to Design, Manufacture, In-Service and Disposal. The student was randomly allocated the Disposal portion of the lifecycle stage.

4. The Munition

To allow for easier explanation of the question a munition was introduced to structure and provide energetic and engineering examples through life. The munition chosen was a UK 81mm Mortar.

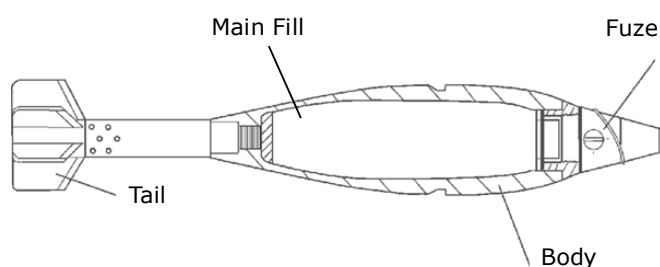


Figure 1 - 81mm Mortar

In this example of the 81mm mortar the main fill consists of ~750g of TNT and the point detonating fuze consists of a stab initiator and tetryl booster.

5. Disposal

5.1. Simplified Question

to further simplify the question in relation to the disposal stage it was reframed to "How do chemical principles govern decisions during munition disposal".

6. Explosive Waste Stages

Explosives waste is primarily generated at two of the 4 lifecycle stages these are at manufacture and end of life. Whilst there is some waste generated throughout the

in-service stage through aspects such as In-Service Surveillance (ISS), Breakdown Test and Criticality Analysis (BTCA), Testing, Trials, Use and Damage for the purpose of this presentation these form part of consumption in the end of life / disposal stage.

7. Manufacture

Within the manufacture stage there are 2 main stages that explosives waste is generated, during synthesis and during processing of the raw explosive in to products. In the case of the mortar this correlates to the TNT synthesis stage and the main body filling stage. These are further detailed below.

7.1. Energetic Synthesis

TNT synthesis is the start of life for many explosives it's where the raw materials of Acid and Toluene are reacted together, most commonly in a Flow Reactor.

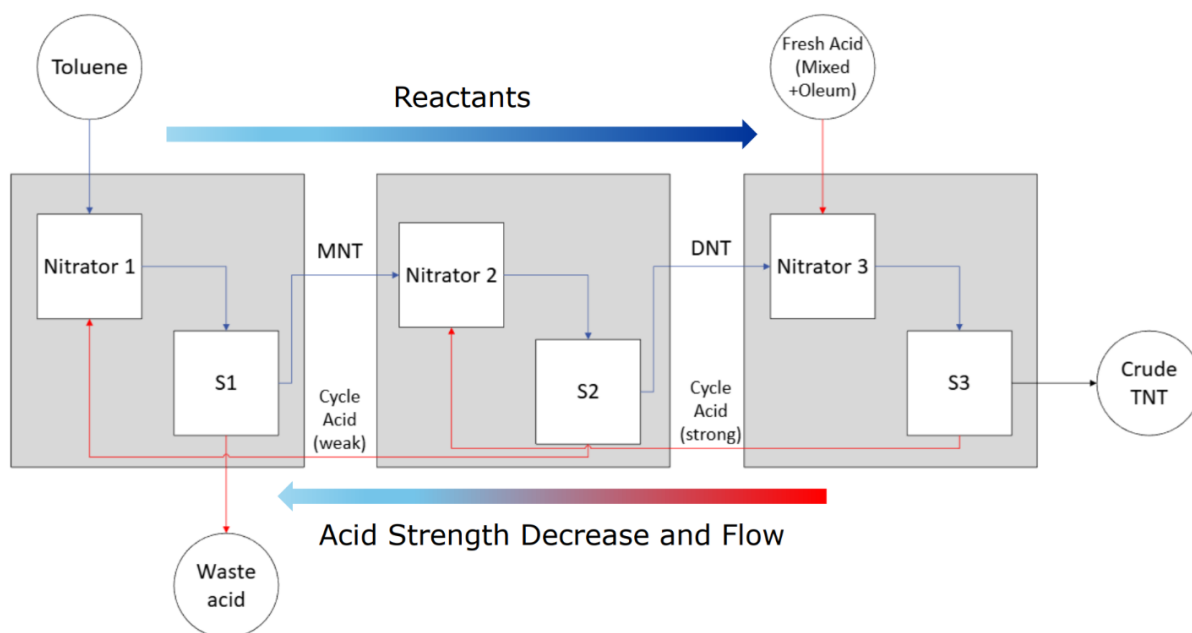


Figure 2 - Flow Reactor Diagram [2]

At each stage of the flow reactor the previous product is nitrated to form the next stage. Starting with Toluene, Progressing through Mononitrotoluene (MNT) and Dinitrotoluene (DNT) to form Trinitrotoluene (TNT).

From these reactions Crude TNT and Waste acid contaminated with unreacted Toluene, MNT, DNT and TNT is produced. To further purify the crude product a process of Sodium Sulfite (Sellite) purification is used. This results in a Aqueous solution of dinitrotoluene sulfonate compounds. This is referred to as 'Red Water' due to its intense red colour. [3]

Additionally during the processing and handling of crude TNT equipment becomes contaminated and must be cleaned and 'washed out'. As TNT is slightly soluble in water this creates contaminated waters that have a light red or pink hue. Pink water is also present in the disposal stage as aqueous products from photodecomposition of TNT yield a similarly coloured water due to the similar contents. [4]

7.2.Processing

Once synthesized TNT wax is a malleable, meltable and formable material ideal for filling in to munitions or other products. In the case of the mortar example the TNT is melted and simply poured into the cases.

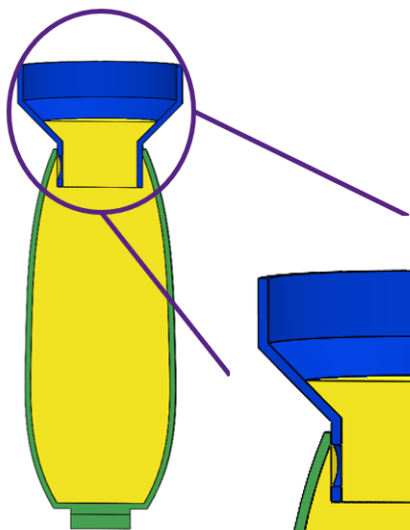


Figure 3 - Mortar Header



Figure 4 - Drip Tray

During the Filling process a small funnel is used to fill the cases, this remains filled with a small amount of TNT that hardens and is recycled into the next batch. At the end of the run one 'set' of unusable headers exist. Throughout the filling machines there are stages where pored TNT may drip these are captured by trays and solidify for recycling or disposal.

8. End Of Life

How a munition or explosive article reaches its end of life matters little as all items will eventually reach the end. It is critical at this stage to safely manage the processing and disposal of these items to ensure that not only are people protected from them but the environment is too.

8.1.Consumption

The safest and most reliable method to consume explosive articles is to use them in the way they were designed. In the example of the mortar the easiest and most efficient method of disposal would simply be to fire it. This detonation would release the most energy and least amount of byproducts. Though this is the best option for an ideal scenario, it is not always an option. [5] [6] [7]

The next method to initiate the mortar would be in testing where we can 'hijack' the explosive train and use an external trigger to initiate the munition. This method is less reliable and starts to produce unknown byproducts in the detonation and a complete initiation may not be achieved.

Lastly the remaining method to initiate the mortar would be through Explosive Ordnance Disposal (EOD) methods. This commonly involves the addition of a second larger charge that will initiate a sympathetic detonation. This is the least reliable method that yields the greatest production of byproducts. [8]

Risk		
Use	Functioning (Testing)	Detonation (EOD)
Full Explosive Chain / First order Detonation	Partial explosive chain	No Explosive Chain, initiation via takeover
Reliable Results	Less reliable Results	Least Reliable
Detonation and secondary burn products		
$H_2O + CO + C + H_2 + CO_2 + N_2$	$H_2O + CO + C + H_2 + CO_2$ + $N_2 + CH_4 + C_NH_M$	$H_2O + CO + C + H_2 + CO_2 +$ $N_2 + CH_4 + C_NH_M + GHGs +$ $NO_x + SO_x + VOCs$

Figure 5 - Consumption Risk

8.2.Demilitarisation

Where consumption/ detonation is not possible demilitarisation through deflagration is the most common method chosen for the release of energetic material energy. Burning and deflagration is a cost effective and reliable method that will render safe most munitions.

8.2.1.1. Open Burning

Open burning is the most basic method of disposal it involves the use of a starter agent such as diesel to initiate a burn of the energetic material. It can be use on whole items, contaminated waste or bulk explosive and is commonplace across the UK. Due to the nature of the burn most combustion products are aerosolised and released in to the atmosphere. This would be against the clean air regulations but explosives are specifically exempt. The products from this process vary by item being disposed but can include " $H_2O + CO + C + H_2 + CO_2 + N_2 + CH_4 + C_NH_M + GHGs + NO_x + SO_x + VOCs + PbO$ " which are mostly hazardous to the environment. [9]

8.2.1.2. Incineration

Where available a preferred method of disposal is incineration as it allows for the full rection of gaseous byproducts and recycling of solid by-products. Unfortunately it can only be used with whole items, bulk explosive and regularly sized items due to the mechanisms. Fewer by products such as " $H_2O + CO_2 + N_2 + GHGs + NO_x + SO_x + VOCs + PbO$ " are released from the incineration process.



Figure 6 - Rotary Incineration Kiln [10]

9. Explosives In the Environment

Due to its extensive history, TNTs progression through the environment is well understood and, in most countries, well managed. Despite this TNT photodecomposition products released in to the environment can end up in the food supply and becoming ingested by humans or animals alike. These byproducts can have severe impacts on the health of humans that includes but is not limited to, Anaemia and Neurological conditions.

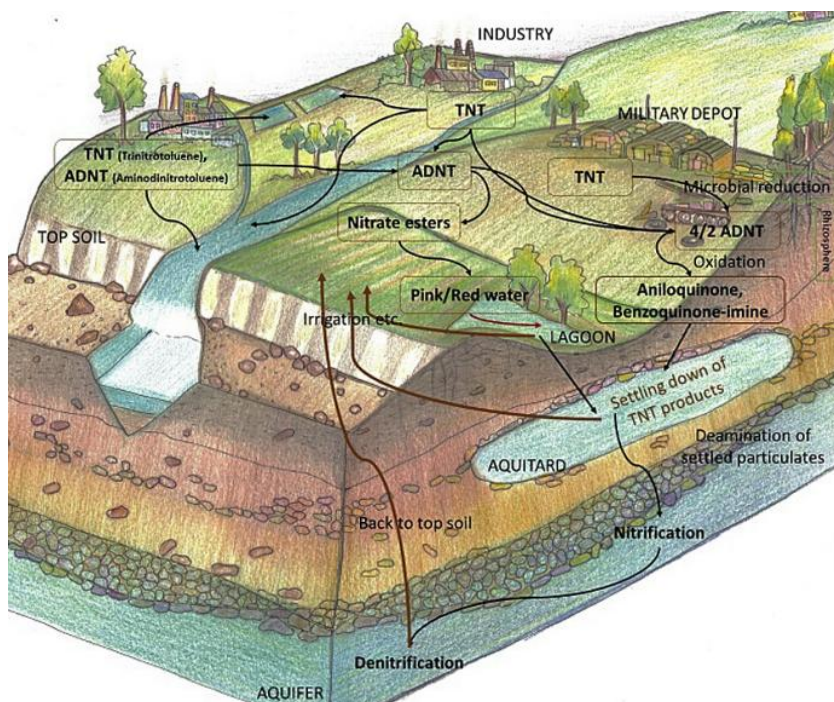


Figure 7 - TNT in the Environment [11]

9.1.1. Off Gass Treatment [12]

To best protect the environment from the incineration, process a series of processing steps are applied to the Off Gass to reduce, filter, react and clean the gas being released. This is outlined in Figure 8.

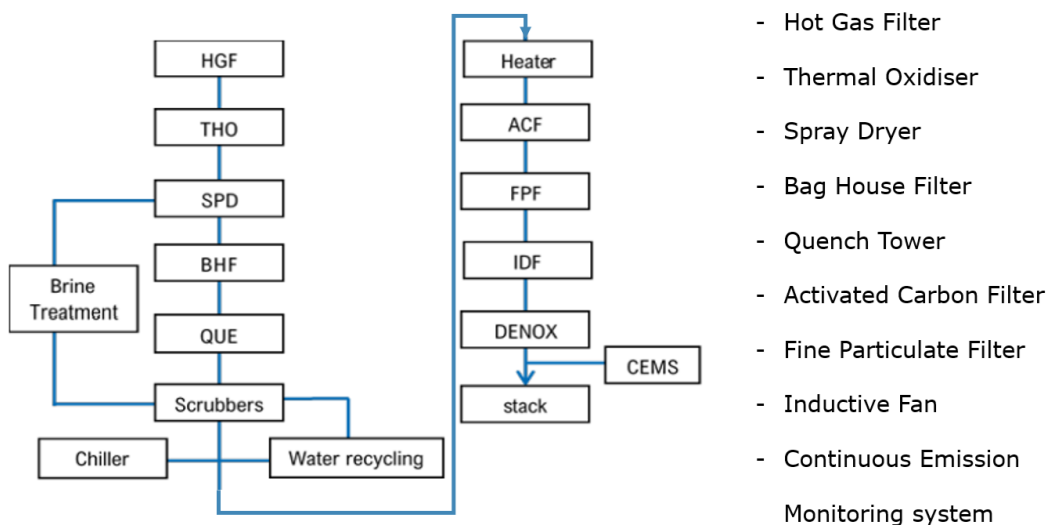


Figure 8 - OGT Process [12]

10. Conclusions

Disposal is a critical stage in the lifecycle of energetic materials as it assures the long-term safety of both people and the environment. From synthesis to incineration an effective and assessed disposal plan can be the difference between an ecological disaster and a silent process. The method chosen for disposal can be heavily dependent on scenario but with sufficient planning and understanding of the chemical byproducts and reactions an appropriate solution can be achieved.

11. References

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12. Annex A – Final Presentation Slides CTH



Energetic Material Lifecycle Chemistry

Presented By:

Owen Miller (2221022), Libbie Bush (2223155),
Charles Hadley (2207149) & Dan Garton (2219350)

For Group Presentation in Advanced Chemistry of OME (ACDA6020)

BAE SYSTEMS



The Question

1. Energetic Material Lifecycle Chemistry – From Synthesis to Demilitarisation (4 people)

Critically evaluate how chemical principles govern the entire lifecycle of key energetic materials, from synthesis and energy release to degradation and environmentally compliant disposal.

Munition Life Cycle

**Owen
Miller**



Design

**Dan
Garton**



Manufacture

Libbie Bush



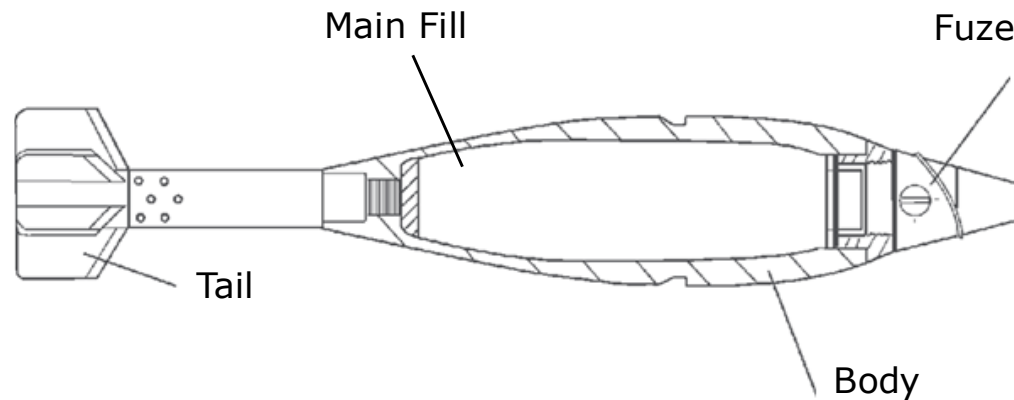
In Service

**Charles
Hadley**

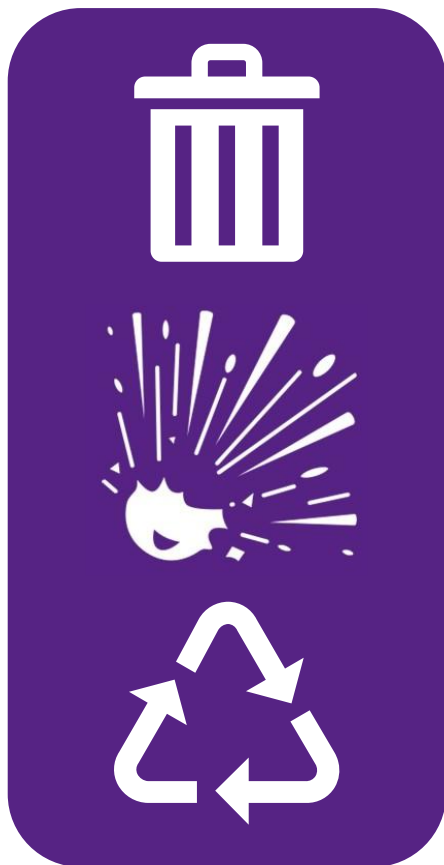


Disposal

The Munition: 81mm Mortar



A typical 81mm Mortar will be used as the example throughout this lifecycle presentation.



Disposal

Charles Hadley (2207149)

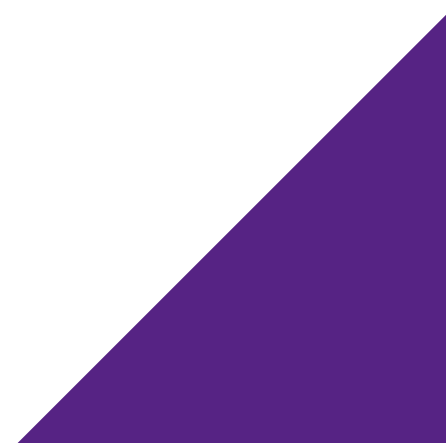
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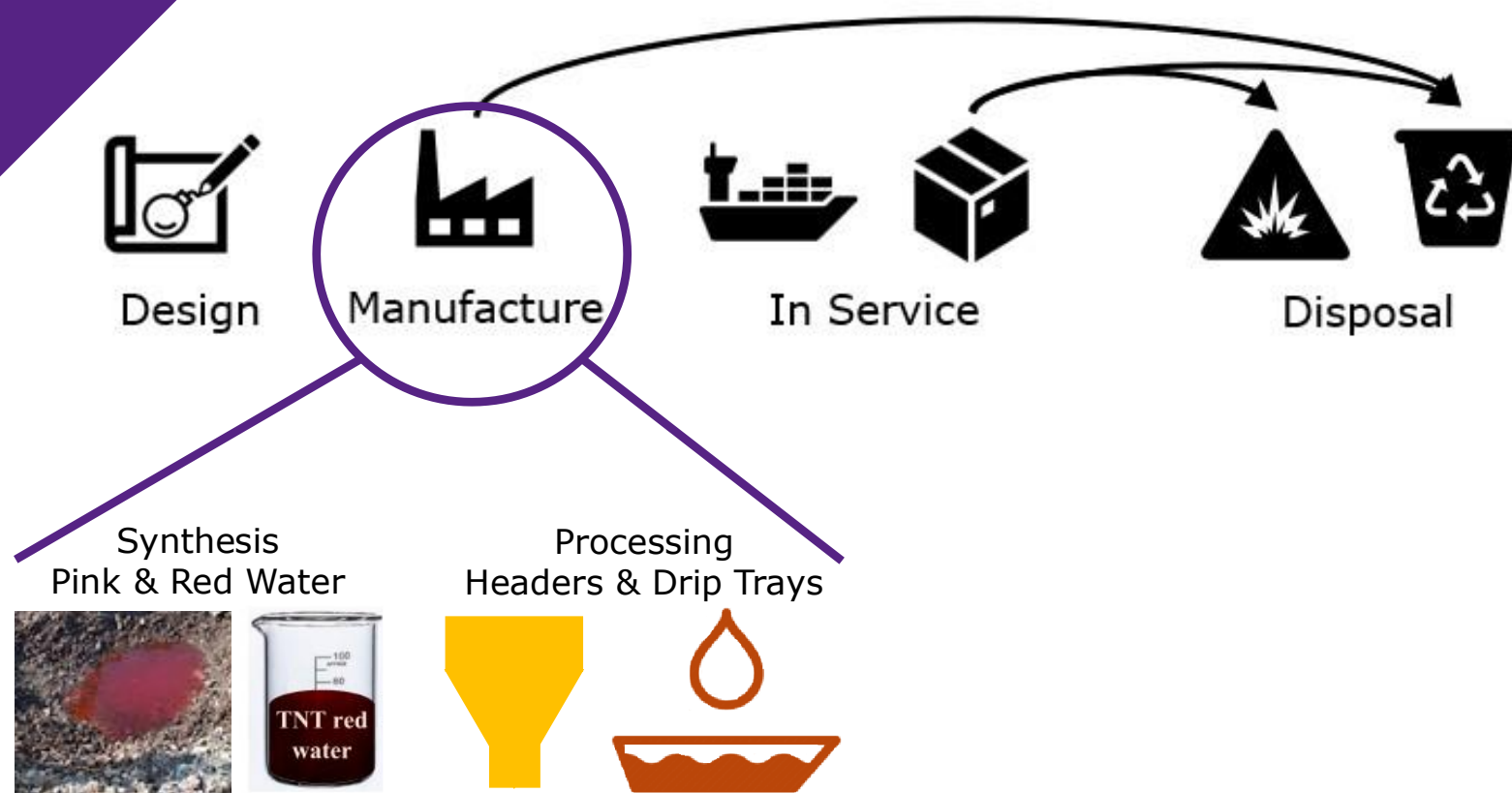
Question Simplified

How do chemical principles
govern decisions during Munition
Disposal?



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Explosive Waste Stages



Ref:[3][4]

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Pink and Red Water

- Red Water – Waste liquid from sodium sulfite solution (Sellite) Purification
- Pink Water – Wastewater runoff from Equipment Washing, high concentrations of TNT ($\sim 150\text{ppm}$)

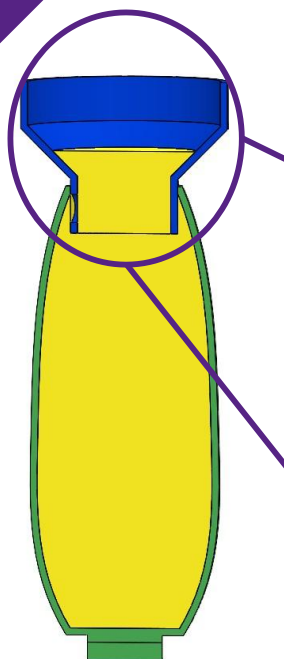


Ref:[3][4][5]

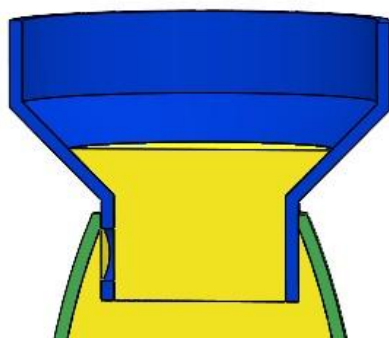
Charles Hadley

Headers and Drip Trays

- Headers - Small funnel shaped segments of explosive filling remain after pouring



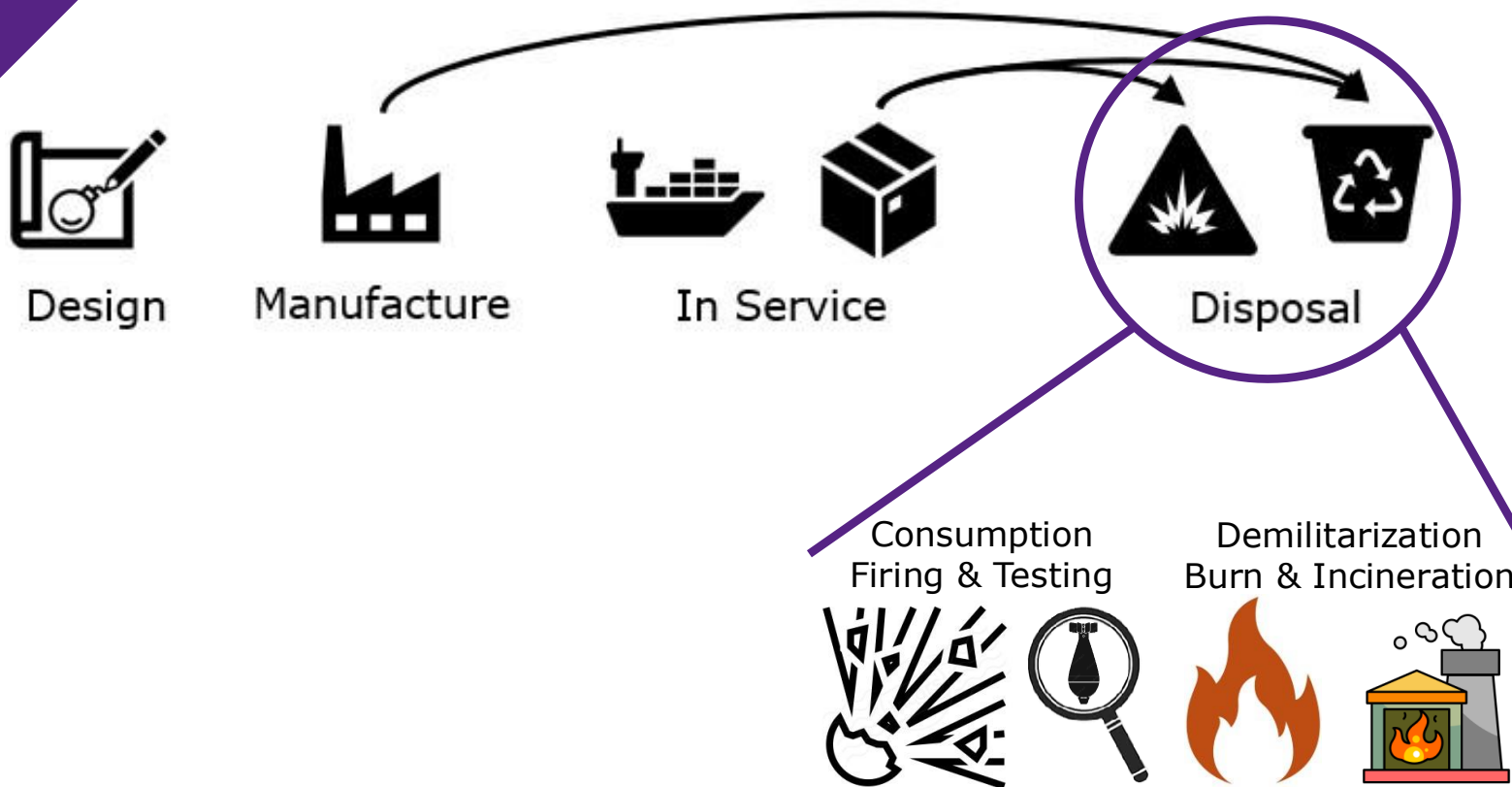
- Drip Trays – Metal trays used to catch explosive drips from pouring and melting.



- Bulk Explosive waste that then moves to disposal

Ref:[6]

Explosive Waste Stages



Ref:[1][2][7]

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Consumption

Risk



Use	Functioning (Testing)	Detonation (EOD)
Full Explosive Chain / First order Detonation	Partial explosive chain	No Explosive Chain, initiation via takeover
Reliable Results	Less reliable Results	Least Reliable
Detonation and secondary burn products		
$H_2O + CO + C + H_2 + CO_2 + N_2$	$H_2O + CO + C + H_2 + CO_2$ $+ N_2 + CH_4 + C_N H_M$	$H_2O + CO + C + H_2 + CO_2 +$ $N_2 + CH_4 + C_N H_M + GHGs +$ $NO_x + SO_x + VOCs$

Ref:[1][2][8][9]

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Open Burning

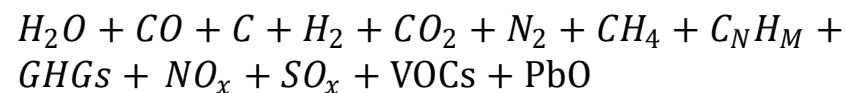


Majority of products released into the atmosphere. Black Smoke Exemption

Solids and liquids not aerosolized remain in container for Hazardous waste disposal

Used for Whole items, Contaminated waste, Bulk explosive etc.

Products:



Ref:[1][2][8][9][10]

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Incineration



Gaseous Products Recovered through Off Gas Treatment. This intense heat fully reacts all possible materials

Solid remnants recovered are often suitable for recycling, Lead, Steel, Brass etc.

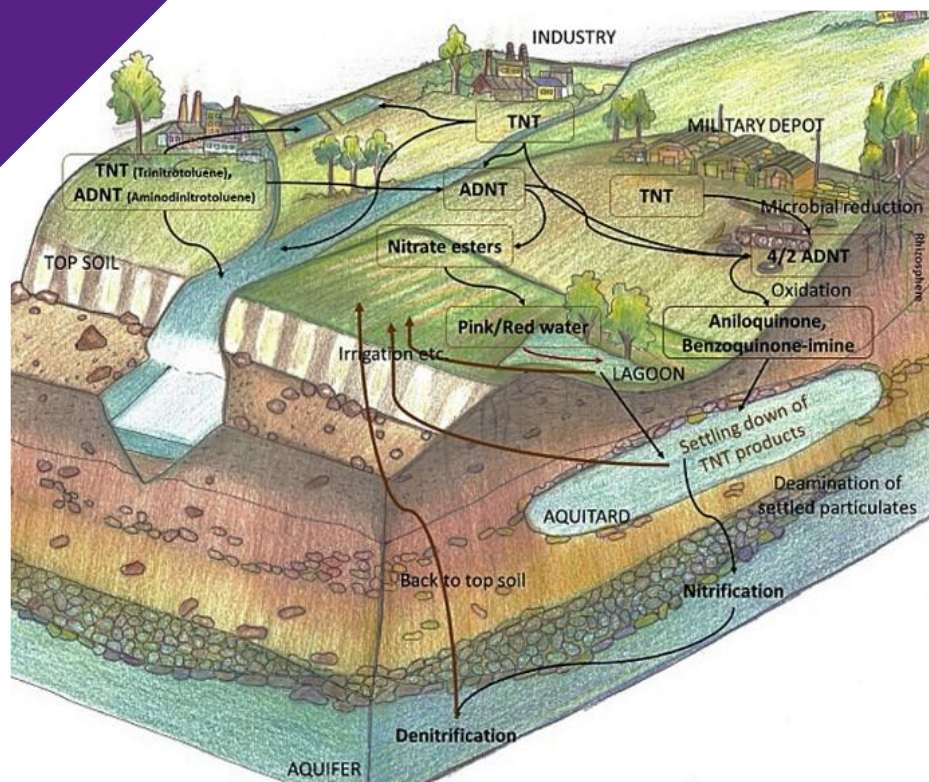
Used for Whole items and Bulk explosive, items that won't disrupt the system

Products: $H_2O + CO_2 + N_2 + GHGs + NO_x + SO_x + VOCs + PbO$

Ref:[9][10][11]

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Explosive pollutants in the Environment



Pollutant	Effect In Humans
<i>CO</i>	Prevents <i>O</i> being released from Hemoglobin.

2,4 – *DNT* Poisoning like *CO*

2,4 – <i>ADNT</i> 2,6 – <i>ADNT</i>	Anemia, Neurological
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Pollutant	Environmental Effects
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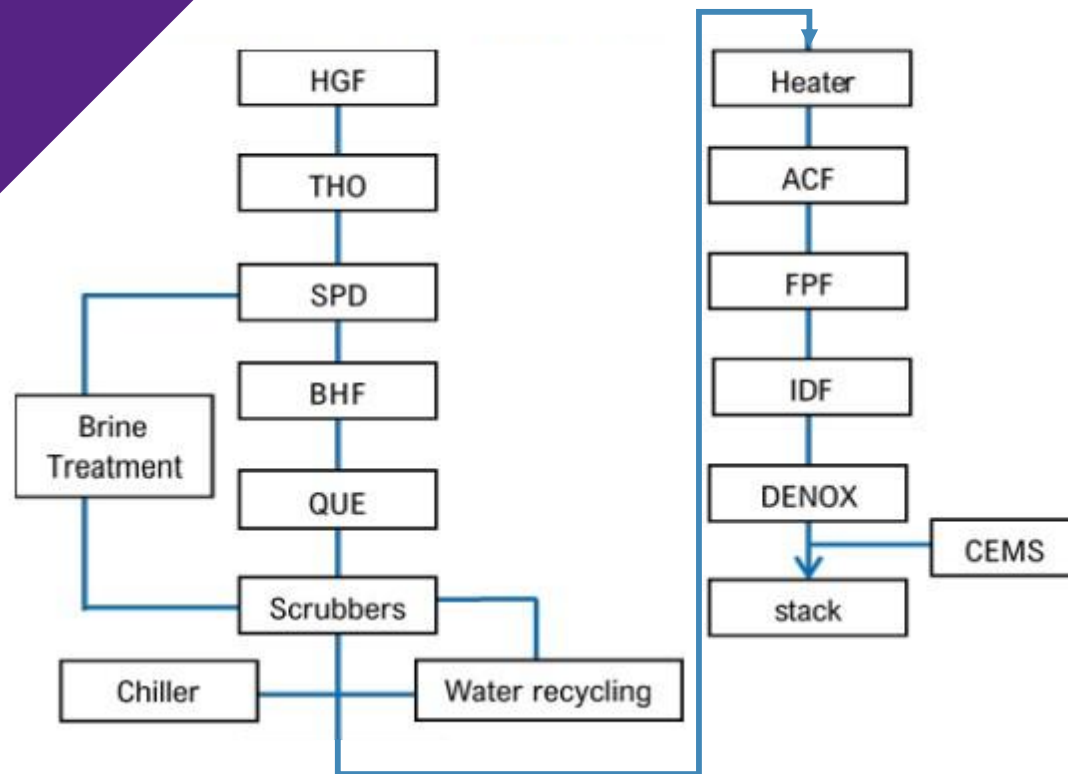
GHGs
*CO*₂ Green House Gas Effect

VOCs
*NO*_{*x*}
*SO*_{*x*} Acid Rain, Ozone Creation

Ref:[13][14]

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Off Gas Treatment (OGT)

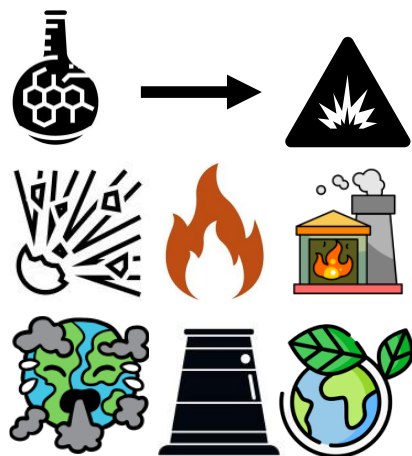


- Hot Gas Filter
- Thermal Oxidiser
- Spray Dryer
- Bag House Filter
- Quench Tower
- Activated Carbon Filter
- Fine Particulate Filter
- Inductive Fan
- Continuous Emission Monitoring system

Ref:[12]

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Summary



- Where explosive waste occurs from chemical synthesis to energetic breakdown.
- How these compounds breakdown during disposal
- The varied methods of disposal
- The impact of chemicals in the environment
- How off gasses can be treated to minimise environmental impact.

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