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Research Article

Influence of TNT Melting Methods from Waste Munition on the Quality of Pink Wastewater

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Abstract

This research examined the efficiency of two methods of melting trinitrotoluene (TNT), direct (MDH) and indirect (MIH) heating with water vapor and examined their impact on the environment through the production of pink wastewater. The MIH compared to the MDH for the 60 mm projectile has: an increased capacity of working and melting TNT in one cycle by 55.6%; increased charging, melting, cooling and discharging time of one cycle by 37.6%; reduced water condensate by 63.2%; reduced TNT drying time by 100%; equal time of projectile preparation, crystallization and packing of TNT. The time of effective work, calculated according to one 60 mm projectile, was reduced by 28.7%. Wastewater produced from 60 mm projectiles MIH compared to MDH has reduced content of energetic materials by 100%. MIH does not produce pink wastewater.

Keywords: TNT; Autoclave; Pink wastewater; Explosive; TNT melting; Efficiency

General Information

The term demilitarization refers to a complete set of processes that render weapons, ammunition and explosives unfit for their original purpose [1]. Demilitarization is a necessary step for military items before their release to a non-military environment and is carried out in a safe, inexpensive, practical and environmentally responsible manner [2]. Actions taken in demilitarization processes should make the item unidentifiable as ammunition after demilitarization [3]. The explosives in many conventional munitions are cast, so these munitions can be demilitarized by heating the explosive charge sufficiently to melt it and flow out of the munition. Explosives that melt at relatively low temperatures are, for example, Composition B (80°C) and TNT (80°C). Melting can be done by direct heat: steam, autoclave [4] or hot bath. The applied heat liquefies the explosive that pours out of the projectile. Hazardous substances, i.e. ammunition, rockets, shells, etc., should be handled with special care to avoid creating safety and health hazards and environmental contamination [5]. Molten TNT flows into the granulator, which is a metal vessel filled with water and a stirrer. TNT is insoluble in water, so the jet of liquid explosive turns into pellets [6] when it comes into contact with water.

The TNT present in wastewater is photochemically active, and when exposed to sunlight, gives off a pink hue. That's how pink water got the name pink water. TNT is poorly degradable and can be found in low concentrations in soil, surface and groundwater. Unfortunately, not only TNT is harmful, but also its degradation products. Explosive compounds have a negative effect on various types of soil, water, plants, animals, and on humans. The degree of impact of explosive contamination is not the same on all living beings. The use of explosives leads to contamination in several ways; however, the largest input of explosives into the environment comes from military activities (testing and training, demilitarization, open ignition/open detonation and associated industries (manufacturing, packaging, storage, loading). In order to develop a resource recovery and reuse plan (R3) for explosive waste, some basic features are needed [3,7]:

1. ensure the safety of all personnel involved in the planned processes,
2. processes should recover valuable energy materials for reuse and/or produce high-value by-products,
3. processes should be environmentally safe, i.e. that they do not release toxic substances into the environment - land, water or air.
4. processes should be cost effective and efficient for mass processing.

There are two main alternative approaches in the recycling of energy materials. The first and simplest involves the preparation of energy ingredients and their use for other purposes with little or no modification, i.e. processing, separation and preparation of energy material for re-production of new explosive products [8]. Another alternative is the transformation of recovered energetic materials into new products, but with chemical modifications that eliminate the explosive characteristics of the material [5].

Materials and Methods

For the purposes of testing, 60 mm caliber projectiles were prepared with the T mark on them, with which the manufacturer shared the information that the projectiles were filled with an explosive charge of TNT. Information about the projectiles used during the experiment is presented in Table 1 (Table 1).

Table 1: Projectile of 60 mm caliber used in experimental research.

Type	Caliber	Model	Explosive Charge	Production Year
Mina	60 mm	M73	TNT	1982

The number of projectiles used in one autoclave operation cycle for both methods was determined based on the capacity of the autoclave itself, i.e. based on the available working space inside the autoclave of the direct heating method (autoclave 1, MDH) and the working space inside the autoclave of the indirect heating method with water vapor (autoclave 2, MIH). An examination of the influence of melting methods (MDZ, MIZ) of two different autoclaves on the efficiency of the process of melting TNT-based explosive charge from the body of a 60 mm projectile was performed. Sampling and testing of pink wastewater for specific parameters (content of energy materials) at the end of the melting process (MDZ, MIZ) was performed. Examination of the influence of the melting method on the efficiency of the melting process of the TNT-based explosive charge from the projectile.

The processes of melting TNT by methods of melting explosive charges based on TNT by direct and indirect heating with water vapor consist of operations [9]:

1. Receipt and preparation of ammunition,
2. Preparation of the autoclave system for melting (turning on the steam generator and the provided connections),
3. Melting explosives with water vapor from ammunition projectiles (one of the methods),
4. Final control (cooling) of extracted or melted explosives,
5. Disposal of disassembled elements.

Figure 1 shows the schedule of activities in the plant for melting explosives (Figure 1).

Figure 2 shows a comparison of two autoclaves, MDZ and MIZ, in the stages of operation that are the subject of the test. The efficiency of two melting processes of two different autoclaves was performed according to the parameters listed in Table 2. 60 mm projectiles were used to test the efficiency of one melting process (Table 2). In one work cycle, autoclave 1 was loaded with 64 projectiles of 60 mm caliber, and autoclave 2 was loaded with 144 projectiles of 60 mm caliber, which represents a difference of 55.6%. Correspondingly, in this experiment 13.4 kg of TNT is present in autoclave 1 and 30.24 kg of TNT is present in autoclave 2.

The process of melting TNT-based explosive charge by MDH was carried out in all experiments with autoclave 1, and by MIH in all experiments with autoclave 2 (Table 2, Figure 2).

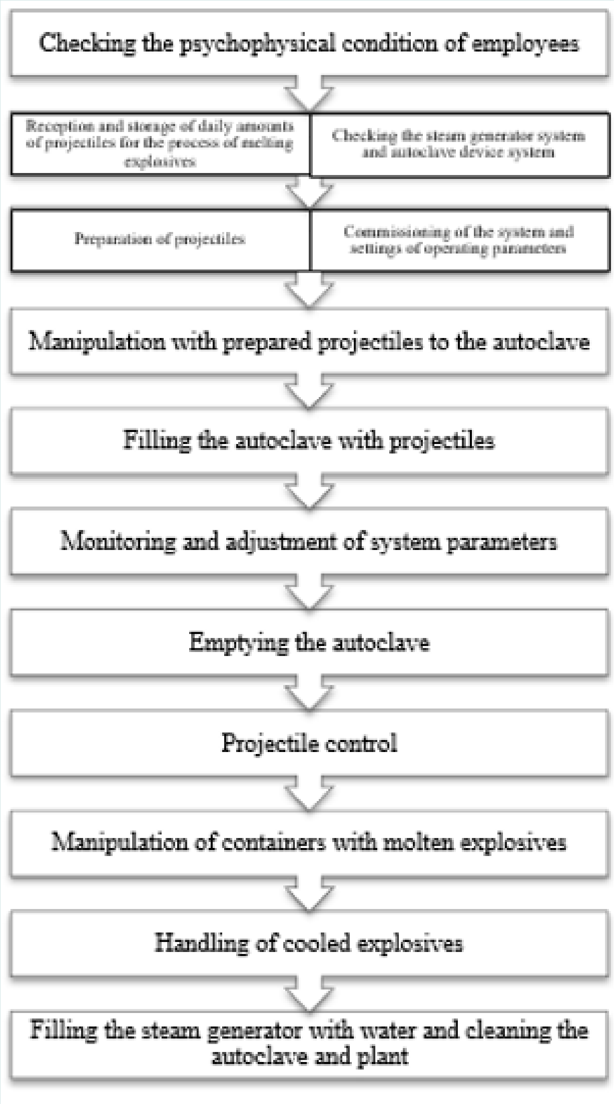

Figure 1: Schedule of daily activities in the plant for melting explosives.

Table 2: Results of testing the influence of melting methods on the effectiveness of the process of melting TNT-based explosive charge from the projectile body.

Parameter	[M. unit]	A1	A2	Δ [%]
Caliber	mm	60	60	-
Number of projectiles	com	64	144	55,6
Melting method	-	DH	IH	-
Explosive charge of the projectile	kg	13,4	30,24	55,6
Water condensate of one work cycle	liter	8,0	6,1	23,8
Ammunition that can be subject to melting (caliber)	mm	60-155	60-155	
Disassembly	min	160	360	-
Preparation of ammunition	min	10	10	0
Switching on the equipment and adjusting the system parameters (summer)	min	45-60	45-60	-
Switching on equipment and adjusting system parameters (winter)	min	60-75	60-75	-

The time of filling the projectile body into the autoclave chamber	min	3	5	40,0
Melting of the explosive from the projectile	min	18	31,5	42,9
Cooling the projectile body with the autoclave lid open	min	5	5	0
Emptying the autoclave	min	3	5	40,0
Crystallization of molten explosives	h	24	24	0
Drying of crystallized explosives	h	24	0	100
Packaging of dried explosives	min	5	5	0
TOTAL (filling, melting, cooling, discharging)	min	29	46,5	37,6
TOTAL (filling, melting, cooling, discharging/1 projectile)	min	0,45	0,32	28,74

A (1, 2) – Autoclave; DH-direct heating; IH-indirect heating; Δ - difference

Examination of the concentration of TNT and its decomposition products in wastewater

The subject of the experiment is the wastewater of two autoclaves:

1. the wastewater of the method of melting explosive charges based on TNT by direct heating of TNT in a 60 mm projectile at the outlet of the precipitator and
2. waste water of the TNT-based explosive charge melting method by indirect heating of TNT over the 60 mm projectile body at the exit from the autoclave.

Analysis of wastewater samples includes parameters [10,11]:

1. RDX,
2. 1,3-dinitrobenzene,
3. TNT,
4. 2,6-dinitrotoluene,
5. 2,4-dinitrotoluene,
6. 4-amino-2,6-dinitrotoluene,
7. 2-amino-4,6-dinitrotoluene.

All samples taken are liquid and prepared for HPLC analysis by centrifugation for 2 min and filtering with a 0.2 μm pore filter. A ZORBAX column was used. The mobile phase is a mixture of acetonitrile: methanol: water in the ratio 10:40:50. Stationary phase is Bonus RP, Gradient. The column temperature is 25°C. The detector is DAD, and the wavelength is 230 nm. The applied flow rate was 1.0 ml/min. The results of this analysis provide information on the quality of wastewater, whether the wastewater is in the category of pink wastewater or whether it is industrial wastewater. Condensed water vapor at the outlet of the precipitator (after autoclave 1) constitutes Sample 5. Condensed water vapor at the outlet of autoclave 2 constitutes Sample 5.1. The mentioned samples of two autoclaves represent wastewater that is discharged into the environment without further treatment.

Results and Discussion

Examination of the influence of the melting method on the efficiency of the melting process of the TNT-based explosive charge from the projectile

The efficiency test parameters of two plants for melting TNT-based explosive charges using direct and indirect heating methods (in accordance with the steps in Figure 1) were examined and presented in Table 2. The process of melting TNT-based explosive charges from projectiles (artillery and mortars) is organized through several working points (parameters in Table 2):

Receipt and preparation of projectiles (Figure 2-a)

The projectiles, which are previously intended for the process of melting the TNT-based explosive charge, are disassembled and transported from the ammunition delaboration plant to the temporary storage. The time of delaboration or disassembly of the 60 mm projectile is about 2.5 minutes per piece. To disassemble:

1. 64 pieces of 60 mm projectiles take 160 minutes (2.7 hours),
2. 144 pieces of 60 mm projectiles take 360 minutes (6 hours).

Projectiles intended for the TNT-based explosive charge melting process are separated on a daily basis from the operator according to the prescribed daily quantities. Data on the type (designation of the projectile series and designation of the type of explosive charge) and quantity, the correctness of the packaging and the release of the initial means are checked. The mentioned process of preparing ammunition for autoclaves 1 and 2 required the same time, which is 10 minutes. The reason for the identical time consumption is due to the fact that at the beginning of the work, the total delivered daily amount of ammunition that is the subject of the work is checked and the specified time consumption occurs once a day before the start of the melting process.

Preparation of the autoclave system for melting (Figure 2-b1, c1)

Before the first melting cycle, it is necessary to carry out preparatory actions, which represent the inclusion of the steam generator and the provided connections to the autoclaves. The pre-treatment includes the actions of turning on the light switch in the building and the main switch of the steam generator. When the steam generator starts working, without a warning signal, it takes 45-60 minutes in the summer period and 60-75 minutes in the winter period to reach the required operating temperature (water vapor heat). During the operation of the steam generator, the entire system of the plant is monitored, and when it is established that the plant is ready for operation, the switch for the hot steam from the steam generator to autoclave 1 or to the distributor where steam is sent to autoclave 2 is opened.

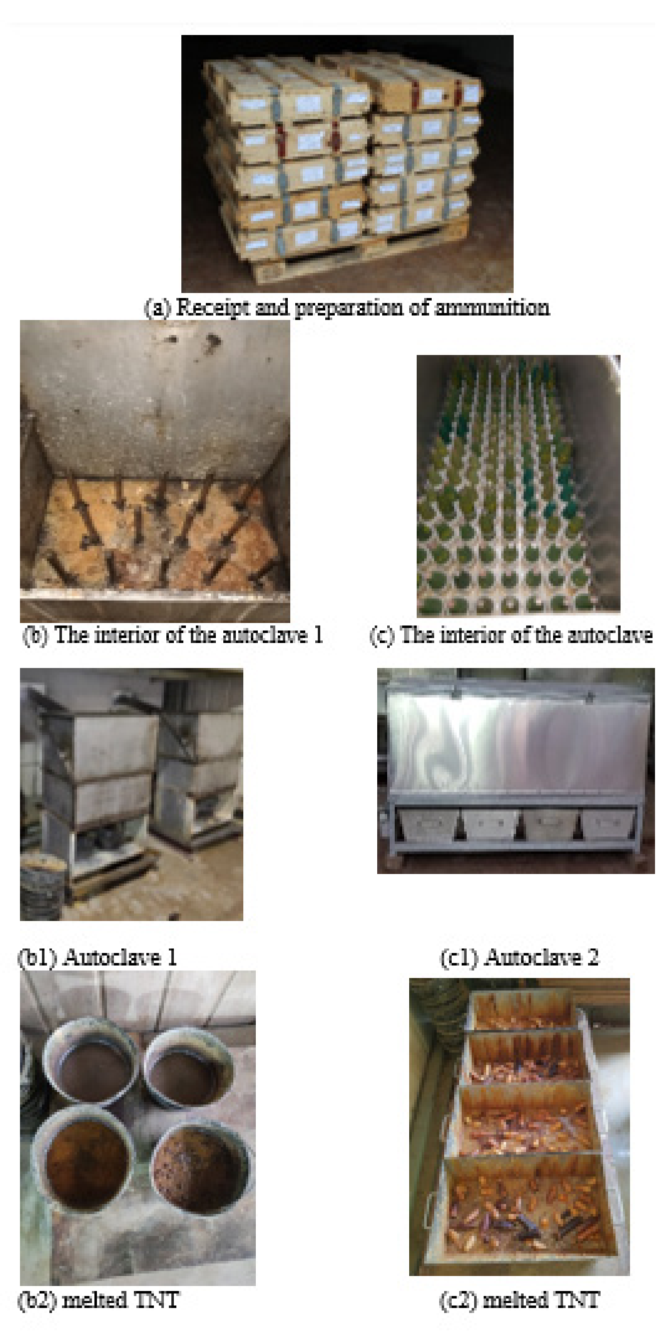

Figure 2: Melting process of TNT-based explosive charge MDH (b1-autoclave 1) and MIH (c1-autoclave 2).

Filling the autoclave with projectiles (Figure 2-b, c)

Both autoclaves are opened via the lid. Autoclave 1 (A1) is made of stainless steel. A1 has available 12 places in one chamber, vertical pipes from which water vapor flows, to accommodate 12 projectiles (Figure 2-b). Below this there is a working chamber for placing containers for receiving molten TNT and it is open on one side (Figure 2-b1). During the experiment, a modification was noticed in the application of autoclave 1, where a metal mesh was additionally installed above the steam discharge pipe. Projectiles are densely lined up on the metal mesh (Figure 3). In this way, for 60 mm projectiles, the number of pieces in one charge in A1 was increased from 12 to 64 (in some cases, 128 pieces of 60 mm projectiles). A1, in a modified charging mode, releases a stream of water vapor under the projectile, where water vapor and TNT come into direct contact from inside the 60 mm projectile body, while a smaller part of the water does not enter the projectile, but heats the projectile body from the outside and goes into the atmosphere. Autoclave 2 (A2) has two chambers, the lower one containing container for receiving explosives and the upper one containing thermoplastic inlets, which are positioned in a stainless-steel plate at the bottom of the upper chamber of the autoclave (Figure 3).

Figure 3: Modification of autoclave 1.

Filling the autoclave represents the stacking of the projectile body in the autoclave, and this action lasted (Table 2):

1. 3 minutes for 64 projectiles of 60 mm caliber in A1,
2. 5 minutes for 144 projectiles of 60 mm caliber in A2.

The difference in charging times of A1 and A2 was 40% or 2 minutes. This difference is expected considering the fact that the capacity of A1 (64 projectiles of 60 mm caliber) and A2 (144 projectiles of 60 mm caliber) are not the same.

Melting explosives with water vapor from ammunition projectiles (Figure 2-b1, c1)

The A1 can melt TNT-based explosive charges from 60-100 mm caliber ammunition (there is another autoclave for 100-155 mm calibers). The A2 can melt TNT-based explosive charges from 60-155 mm caliber ammunition with the adjustment of the thermoplastic opening. When using larger calibers, it is necessary to close the unused openings with a thermoplastic plug. After the autoclaves are filled with projectiles, the chambers are closed and secured via the fuses on the lids of both autoclaves. A2 additionally has a sealing system made of rubber, which prevents water vapor and TNT vapor from mixing.

After closing the autoclaves (A1, A2), according to the technological procedure, hot steam is introduced into the autoclaves. This is the moment when the explosive from the body of the ammunition projectile begins to melt. In the TNT melting phase in A1, the melting process is monitored by periodically taking a sample from the tap (Figure 4) where the melted TNT is poured into containers for receiving and crystallization. The method of melting an explosive charge based on TNT by direct heating with hot water vapor produces melted TNT and, to a lesser extent, dissolved TNT in water (the formation of pink wastewater). Completion of TNT melting in A1 is checked visually. This is the moment when liquid TNT cannot be seen in the sample (Figure 4).

It was observed that the taps at the bottom of chamber A1 are not fully functional and that a constant dripping of TNT and pink wastewater is noticeable. This causes the crystallization of TNT, i.e. the formation of waste TNT on the stand on which there are plastic containers for receiving the melted TNT. The occurrence of waste TNT in this phase of the A1 operation is planned. Below A1, a shallow tub is placed, as an integral part of A1, whose role is to receive liquid TNT leaking from the autoclave (Figure 5) and pink wastewater. This waste is piped to the precipitator (Figure 5).

Figure 4: Liquid TNT (left) and pink wastewater (right).

Figure 5: Leakage of waste TNT and pink wastewater from autoclave 1.

A larger amount of crystallized waste TNT was observed in the pipes. Due to non-flow or very slow flow of pink wastewater, there is a noticeable clogging of the pipe (>30% of the inside of the pipe), which retains the waste and favors further crystallization of TNT and vaporization of pink wastewater. During the transfer of containers, contamination of the bottom of the container from the outside with solid or liquid TNT occurs, which causes the scattering of TNT, its transfer to work tables and workshop floors. It was noticed that in a radius of 1-2 m from A1, the contamination with waste TNT is more pronounced. In operation A2, there is no tap at the bottom of the upper chamber, but TNT from the projectile is directly poured over the containers and poured into the containers for receiving and crystallization of the molten TNT. Aggravating circumstances were observed in this phase of operation of A2:

1. It is not possible to direct the pouring of molten TNT, which results in the impossibility of controlling splashing and contamination of the edges of containers for receiving molten TNT.

2. It is not possible to stop the molten TNT pouring process, which results in too heavy blocks of TNT.

3. The technological procedure of work A2 does not envisage changing the containers during the melting process, but it is also imposed as a necessity to reduce the size of the TNT blocks due to the difficulty of handling them, which weigh around 20 kg. In order to improve work with TNT A2 blocks, it is necessary to modify the autoclave by adding a tub in the form of a funnel with a tap under the TNT melting chamber or add partitions inside the existing metal containers for receiving melted TNT, which would make the obtained blocks smaller.

4. It is difficult to control the end of the TNT melting process, and it could be improved by adding a visual checker.

Melting of TNT lasted (Table 2):

1. 18 minutes from 64 projectiles of 60 mm caliber in A1,

2. 31.5 minutes from 144 projectiles of 60 mm caliber in A2.

Melting of TNT, looking at 60 mm projectiles, in A1 was done 42.9% before A2. We conclude that the difference in the melting times of A1 and A2 is about 40%. The number of projectiles used in the melting process affects the length of the melting time through the amount of TNT in the individual projectile. After the expiration of the time period required for one melting cycle provided for one caliber of projectiles, it is necessary to stop the supply of steam to the autoclaves and wait for the required cooling time of the projectiles in the autoclaves. After cooling, the autoclaves are opened. Above A1 there is a hood for draining hot water vapor and it has been recorded that when A1 is opened, a significant portion of water vapor is released from A1. The reason for this phenomenon is insufficient cooling time due to which water vapor does not condense inside A1. This phenomenon was recorded in 2 out of 3 tested work cycles of A1. After opening A2, there is a visible appearance of water vapor, but unlike A1, in this case water vapor did not have direct contact with TNT and it is not in the role of environmental pollutant.

The cooling of projectiles lasted (Table 2):

1. 5 minutes for the bodies of 64 projectiles of caliber 60 mm in A1,

2. 5 minutes for the bodies of 144 projectiles of caliber 60 mm in A2.

We conclude that the difference in the cooling times of the projectile bodies in A1 and A2 is 0%, which is defined according to valid technological procedures. Cooling of the projectile bodies has the role of bringing them into a state of safe handling, which results in safe manipulation of the projectiles using protective gloves without the risk of burns on the employee's hands. During the emptying of the autoclaves, which represents the removal of the projectiles from the chamber of both autoclaves, the degree of melting of the TNT is checked. In the event that TNT is not melted from one or more projectiles, it needs to be additionally treated with a new melting cycle.

The emptying of A1 and A2 represent the removal of the projectile bodies from the autoclaves, and this action lasted:

1. 3 minutes for 64 projectile bodies of caliber 60 mm from A1,

2. 5 minutes for 144 projectile bodies of caliber 60 mm from A2.

The emptying of A1 was completed in 40% of the time before A2. This difference is expected considering the fact that the capacity of A1 (64 projectiles of caliber 60 mm) and A2 (144 projectiles of caliber 60 mm) are not the same.

Final control (cooling) of extracted or melted explosives (Figure 2-b2, c2)

Crystallization of melted TNT from A1, regardless of the caliber of the projectile, takes 24 hours according to the current technological procedure. Crystallization takes place in plastic containers with a volume of 12 litres. After crystallization, pink wastewater is drained from the plastic container into the drain towards the precipitator, then solid TNT is removed from the vessel and left to dry for at least the next 24 hours. Crystallization of melted TNT from A2, regardless of the caliber of the projectile, takes about 5 hours (one shift). However, according to the technological procedure, TNT is left for 24 hours before packing. Crystallization takes place in metal containers with a volume of 20 Liters. After crystallization, solid TNT is removed from the container and there is no need for drying. Drying of the crystallized TNT from A2 is not necessary, which represents a 100%-time reduction (24 h less) compared to A1. The packing of crystallized TNT from A2 and dried TNT from A1 takes the same time, about 5 minutes, and no significant time difference was observed in this step. It was noticed that the container for receiving the melted TNT from A2, as a product of crystallization, give heavy and large block of TNT. Due to the difficult manipulation, it is necessary to redesign the container in order to obtain smaller block of TNT.

The total working time of the autoclave using 60 mm projectiles, which includes the time of filling, melting, cooling and emptying, is 29 minutes for A1 and 46.5 minutes for A2, which represents a difference of 37.6%.

In order to correctly assess the efficiency of the TNT-based explosive charge melting methods by direct and indirect heating, we calculated the total operating times of both autoclaves according to one projectile.

The total working time of the autoclave using 60 mm projectiles per projectile, under which the time of filling, melting, cooling and discharging is added, for A1 is 0.45 min/projectile and for A2 is 0.32 min/projectile, which is the difference of 28.75 %. The calculated difference of the two total operating times is in favor of A2 because it is a reduction of operating times per one projectile, on the basis of which we conclude that the TNT-based explosive charge melting method by indirect heating using A2 is more efficient than the indirect heating melting method using A1.

Wastewater from the melting process of TNT-based explosive charges

The water condensate collected from the operation of A1 and A2 represents wastewater. In his work, A1 uses the method of melting an explosive charge based on TNT by direct heating, and in this case water vapor is directly mixed with TNT, resulting in a mixture of melted TNT and water in which TNT is dissolved. Dissolved TNT in water makes pink wastewater, and confirmation of this claim will be given by the results of testing the content of energetic materials in this wastewater. Water condensate from A2 represents wastewater that should be without the presence of energetic materials and, accordingly, does not carry the epithet pink wastewater, and confirmation of this statement will be provided by the results of the examination of the content of energetic materials in this wastewater.

One work cycle produces (Table 2):

1. 8.0 l of wastewater by melting TNT from the 64 projectiles of 60 mm caliber from A1,

2. 6.1 l of wastewater by melting TNT from the 144 projectiles of 60 mm caliber from A2.

We conclude that there was a reduction in the generation of wastewater in one operation cycle when comparing A1 and A2 using 60 mm projectiles. A2 compared to A1 produces 23.8% less wastewater in a experiment in which 60 mm projectiles were used.

Examination of the influence of the melting method on the efficiency of the melting process of the TNT-based explosive charge from the projectile

Table 3 summarizes the experiment results of the taken liquid wastewater samples on concentration of energetic substances. The first four parameters represent the A1 and A2 settings, which specify: the caliber of the used projectiles, the number of used projectiles in the operation of one A1 and A2 cycle, the used melting method (MDH, MIH) and the weight of the TNT-based explosive charge in one melting cycle within A1 (13.4 kg in 64 projectiles of 60 mm caliber) and A2 (30.24 kg in 144 projectiles of 60 mm caliber). The results are ordered in such a way that A2 follows A1, and then the difference in the obtained results is calculated, where the reduction is always calculated in relation to the higher result. After that, the obtained experiment values were calculated for one projectile of 60 mm calibre (Table 3).

Table 3: Experiment results of the concentration of TNT and its decomposition products in the wastewater of two autoclaves.

Parameter	[U]	A1	A2	Δ [%]
Caliber	mm	60	60	-
Number of projectiles	Ko m	64	144	55,6
Melting method	*	DH	IH	-
Explosive charge of the projectile	kg	13,4	30,24	55,6
Sample**	-	5	5.1	-
TNT		20,939	0	100
RDX		4,366	0	100
1,3- dinitrobenzene		0	0	-
2,6- dinitrotoluene		0	0	-
2,4- dinitrotoluene		0	0	-
4-amino-2,6-dinitrotoluene		0,352	0	100
2-amino-4,6-dinitrotoluene	mg/l	0,703	0	100

A(1,2)–Autoclave; DH-direct heating; IH-indirect heating; Δ-difference; U–Measuring unit

Based on the results for Sample 5 and Sample 5.1, we conclude:

1. Using the method of melting TNT-based explosive charge by direct heating of 64 projectiles of 60 mm caliber with water vapor in A1, pink wastewater was created.

In Sample 5, energetic materials are determined:

a. TNT in the amount of 20.9394 mg/l or 0.3272 mg/l per 60 mm caliber projectile,

b. RDX in the amount of 4.3657 mg/l or 0.0682 mg/l per 60 mm projectile,

c. 1,3-DNB in the amount of 0 mg/l.

d. 2,6-DNT in the amount of 0 mg/l.

e. 2,4-DNT in the amount of 0 mg/l.

f. 4-amino-2,6-DNT in the amount of 0.3516 mg/l or 0.0055 mg/l per 60 mm projectile,

g. 2-amino-4,6-DNT in the amount of 0.7032 mg/l or 0.0110 mg/l per 60 mm projectile.

2. Using the method of melting the TNT-based explosive charge by indirectly heating of 144 projectiles of 60 mm caliber with water vapor in A2, pink wastewater was not created at the exit from A2. Sample 5.1 has no traces of energetic substances.

3. A 100% reduction in wastewater pollution with energetic materials at the exit from A2 was achieved compared to A1.

Conclusion

The ambient temperature affects the time it takes for the steam generator to reach the required temperature of hot water vapor (45-60 minutes in summer and 60-75 minutes in winter). In autoclave 2, it is not possible to direct the pouring of molten TNT, which results in the impossibility of controlling splashing and contamination of the edges of containers for receiving molten TNT. The total working time of the autoclave using 60 mm projectiles, which includes the time of filling, melting, cooling and emptying, is 29 minutes for autoclave 1 and 46.5 minutes for autoclave 2, which represents a difference of 37.6%. The total working time of the autoclave using 60 mm projectiles per projectile, under which the time of filling, melting, cooling and discharging is added, for autoclave 1 is 0.45 min/projectile and for autoclave 2 is 0.32 min/projectile, which is the difference of 28.75 %. The TNT-based explosive charge melting method by indirect heating using autoclave 2 is more efficient than the indirect heating method using autoclave 1. By using the TNT-based explosive charge melting method with indirect heating compared to the direct heating method, a 100% reduction in the pollution of wastewater with energetic materials was achieved. Using the method of melting the TNT-based explosive charge by indirectly heating of 144 projectiles of 60 mm caliber with water vapor in autoclave 2, pink wastewater was not created at the exit from autoclave 2.

Acknowledgement

None.

Conflict of Interest

No conflict of interest.

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