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Analysis of sodium tripolyphosphate production processes with a cumulative calculation method

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Sodium tripolyphosphate – one of the condensed phosphates is an important ingredient in various types of cleaning substances and a food additive. The paper presents a comparison of different variants of STPP production with the application of the cumulative calculation method. The material balances of the processes were taken as the basis of the analysis. The method of the process analysis as shown in the cumulative calculation determines the influence of the emissions of dust and gas pollutions originating from a particular production process, as well as wastewater and solid wastes resulting from it, upon the natural environment. It was proved that the solution of the production STPP with the dry one-step method has the lowest impact on the environment among the three assessed solutions.

Keywords: sodium tripolyphosphate, cumulative calculation, ecological analysis.

INTRODUCTION

Chemical production, including the production of condensed phosphates, constitutes a significant burden upon the natural environment. One of the condensed phosphates is sodium tripolyphosphate – an important ingredient in various types of cleaning substances and a food additive[1]. In order to determine which of the technological solutions of the STPP manufacturing is the most ecologically beneficial, they have been compared with the application of the cumulative calculation method.

Sodium tripolyphosphate, commonly used in cleaning substances, performs the function of an active builder, and exerts a considerable influence on the processes of washing and cleaning.

The row material for the STPP production is a solution of sodium orthophosphates with the Na_2O/P_2O_5 molar ratio 1.67. It is normally obtained by phosphoric acid neutralisation with sodium carbonate.

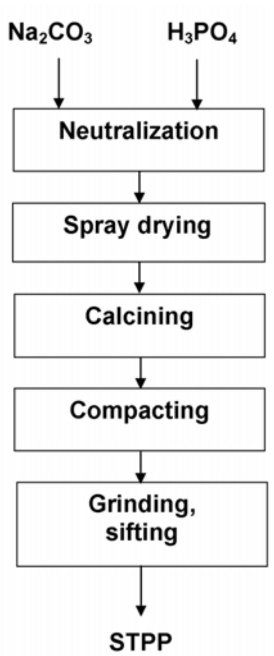

Figure 1. Schematic diagram of obtaining heavy STPP with the classical spray drying method

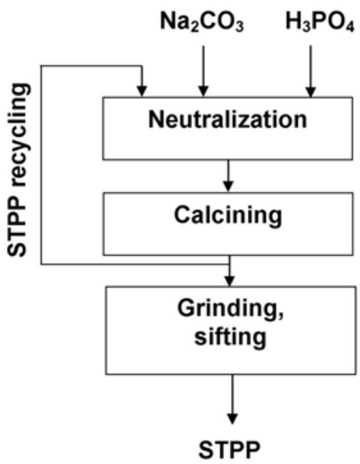

Figure 2. Schematic diagram of obtaining sodium tripolyphosphate with the dry one-step method

At the commercial scale STPP is produced from sodium orthophosphate solutions with one ore two-step method. At the first variant drying and calcining is carried out in one apparatus, the rotary kiln with the product recirculation most commonly (Fig. 1). Such technology is applied by Progil, Piesteritz and Saint Gobain. At the two-step option drying takes place in a spry drier while the calcining in the rotary kiln (Fig. 2). This method, also called spry-kiln or a classic method is used at Alwernia S.A. Chemical Company, Knapsack and FMC[2].

A new way of STPP manufacturing has recently been developed as well. It is calcining the mixture of crystallized $NaH_2PO_4{\cdot}2H_2O$ and $Na_2HPO_4{\cdot}7H_2O$, illustrated in figure 3, also called wet method[3].

The products obtained with those three methods have comparable qualities. The main difference is connected with bulk density which has the lowest value for the STPP produced by two-step variant.

EXPERIMENTAL PART

This work presents a comparison of the production processes of STPP by the one-step method, with the use of the rotary kiln, the two-step method and the wet method.

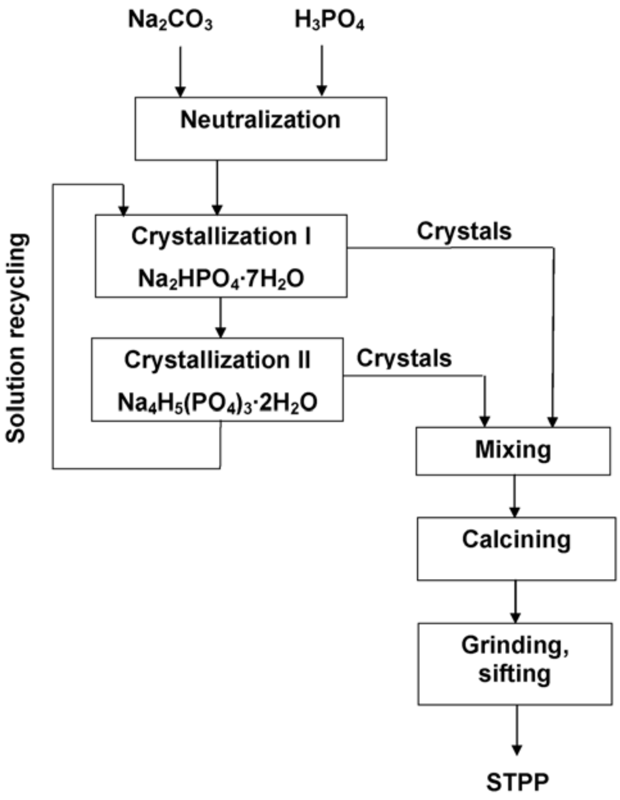

Figure 3. Schematic diagram of obtaining $Na_5P_3O_{10}$ with the wet method

The comparison was carried out with the application of the cumulative calculation method, with the assumption of the material balances of the processes as basis. The method of the process analysis as shown in the cumulative calculation determines the influence of the emissions of dust and gas pollutions originating from a particular production process as well as wastewater and solid wastes resulting from it upon the natural environment[4 – 5].

The analyzed industrial variants of STPP production are technologies which generate no sewage or waste, hence only the emissions of dusts and gases were evaluated.

The evaluation methodology introduces the following concepts[4 – 5]:

– cumulative threat (ZS), as the sum of emissions (E) or sewage and waste dumping (O) of one type of substance during the process phases (where: number of phases f = 1, …, n):

$$ZS_E = \sum_{f=1}^{n} E \tag{1}$$

– index of a cumulative threat (WS), as the quotient of the cumulative threat (ZS) and production quantity (P):

$$WS = \frac{ZS}{P} \tag{2}$$

– index of cumulative threat taking into account toxicity coefficient (K):

$$WSk = WS \times K \tag{3}$$

The toxicity coefficient represents a numerical distinguishing mark of toxicity characterizing a particular substance. For the dusts and gases emission, K is defined as a quotient of charges for the emission into the atmosphere of 1 Mg of a specified substance and 1 Mg of sulfur dioxide. Under the Polish conditions it is additionally multiplied by the conversion factor (in PLN) of USD to PLN[5].

– global index of cumulative threats (GWS), as the sum of indexes for all the phases of the process:

$$GWS = \sum_{f=1}^{n} WSk \tag{4}$$

– relative index of threat to the natural environment (WZZ) comparing global indexes of cumulative threats for the initial process (GWSP) and the modernized one (GWSN):

$$WZZ = \frac{\sum GWS^P - \sum GWS^N}{\sum GWS^P} \cdot 100\% \tag{5}$$

The WZZ value lower than 100% shows the relative environmental advantage of a modernized process compared to the initial one.

DISCUSSION OVER RESULTS

Tables 1 – 3 present the calculation results of global indexes of cumulative threats for the manufacturing of STPP with the application of particular production variants. The indexes were determined for 1 Mg of STPP with the content of P_2O_5 57.9% mass. The theoretical emission

Table 1. Global index of cumulative threats for the classical spray drying method with compacting a product[6]

Process phases	Emission of dusts and gases [kg]						
	Soda	H_3PO_4	Phosphate dusts	STPP dusts	SO_2	NO_X	CO_2
Unloading soda	6	0	0	0	0	0	0
Transport and feeding soda	6	0	0	0	0	0	16 550
Neutralization	0	12	30	0	0	0	0
Spray drying, de-dusting and absorption units	0	0	24	0	2.6	3	14 400
Calcining	0	0	18	0	1.8	3	9 600
Hydrating and compacting	0	0	0	3	0	0	0
Grinding	0	0	0	2	0	0	0
Sifting and transport	0	0	0	3	0	0	0
Transportation, packaging, shipment	0	0	0	3	0	0	0
Cumulative threat (ZS)	12	12	72	11	4.4	6	40 550
Index of cumulative threats (WS)	0.0003	0.0003	0.0018	0.0003	0.0001	0.0002	1.0138
Toxicity index (K)	9.200	9.220	9.220	9.220	3.900	3.900	0.002
Index of cumulative threat (WSk)	0.0028	0.0028	0.0166	0.0025	0.0004	0.0006	0.0020
Global index of cumulative threats (GWS)	0.0277						

Table 2. Global index of cumulative threats for the wet method[6]

Process phases	Emission of dusts and gases [kg]						
	Soda	H_3PO_4	Phosphate dusts	STPP dusts	SO_2	NO_X	CO_2
Unloading soda	6	0	0	0	0	0	0
Transport and feeding soda	6	0	0	0	0	0	16 000
Neutralization	0	12	30	0	0	0	0
Crystallization and centrifugation	0	0	0	0	0	0	0
Calcining, de-dusting, absorption	0	0	6	0	1.8	3	9 600
Grinding	0	0	0	2	0	0	0
Sifting and transport	0	0	0	3	0	0	0
Transportation, packaging, shipment	0	0	0	3	0	0	0
Cumulative threat (ZS)	12	12	36	8	1.8	3	25 600
Index of cumulative threats (WS)	0.0003	0.0003	0.0009	0.0002	$5*10^{-5}$	0.0001	0.6400
Toxicity coefficient (K)	9.200	9.220	9.220	9.220	3.900	3.900	0.002
Index of cumulative threat (WSk)	0.0028	0.0028	0.0083	0.0018	0.0002	0.0003	0.0013
Global index of cumulative threats (GWS)	0.0174						
Relative index of threat to the natural environment (WZZ) - in relation to the classical method	37.1%						

Table 3. Global index of cumulative threats for the dry method[6]

Process phases	Emission of dusts and gases [kg]						
	Soda	H_3PO_4	Phosphate dusts	STPP dusts	SO_2	NO_X	CO_2
Unloading soda	6	0	0	0	0	0	0
Transport and feeding soda	6	0	0	0	0	0	16 000
Neutralization	0	6	15	0	0	0	0
Calcining, de-dusting, absorption	0	0	6	0	2.2	3.6	12 000
Grinding	0	0	0	2	0	0	0
Sifting and transportation	0	0	0	3	0	0	0
Transportation, packaging, shipment	0	0	0	3	0	0	0
Cumulative threat (ZS)	12	6	21	8	2.2	3.6	28 000
Index of cumulative threats (WS)	0.0003	0.0002	0.0005	0.0002	0.0001	0.0001	0.7000
Toxicity coefficient (K)	9.200	9.220	9.220	9.220	3.900	3.900	0.002
Index of cumulative threat WSk	0.0028	0.0014	0.0048	0.0018	0.0002	0.0004	0.0014
Global index of cumulative threats (GWS)	0.0128						
Relative index of threat to the natural environment (WZZ) - in relation to the classical method	53.8%						

indexes were estimated on the basis of technological assumptions[6].

Dusts and gasses emission are closely connected with individual steps of STPP production: soda ash is emitted during row material preparation while phosphoric acid fumes during neutralization. From that step as well as the following one (calcining, de-dusting and absorption) the phosphate dust is released whereas the finished product dusts form at the last stages of each analyzed variants of STPP manufacturing. SO_2, NO_x and CO_2 emission is related with the thermal treatment of the product. Relatively large phosphate dusts and CO_2 emissions are observed for che lassic method during spry drying. As an effect the indexes of cumulative treats are also much higher. It should be pointed out that the emissions from the neutralization stage in the wet variant are half the size than for the other technological options.

A low value of global index of the cumulative threats GWS is typical of the classical variant. GWS indexes for the remaining production methods of STPP are even smaller, which results from a relatively low level of dust and gas emissions into the atmosphere.

A significant relative decrease in the cumulative threat for both the wet method and the dry one-step method in relation to the classical one was identified.

CONCLUSION

The impact of the discussed technological variants of sodium tripolyphosphate manufacturing upon the environment is relatively small. From the ecological point of view, the production of STPP with the dry one-step method is the most beneficial.

Moreover, there is a potential for a further reduction of the influence of sodium tripolyphosphate production upon the natural environment. This may be achieved through the application of new technological design and apparatus solutions, i.e. basic elements of the proposed activities in the methodology of cleaner productions[7–8].

LITERATURE CITED

1. Wzorek, Z. (2002). Operational properties of sodium tripoliphosphate. Czasopismo Techniczne, Chemia Z. 3-Ch, 67 – 73 (in Polish).

2. Makara, A. & Wzorek, Z. (2009) Preparation of sodium tripolyphosphate from concentrated phosphoric acid by one-stage method. Przem. Chem, 88, 4, 375 – 379 (in Polish).

3. Banach, M., Kowalski, Z., Wzorek, Z., & Gorazda, K. (2009). A chemical method of the production of "heavy" sodium tripolyphosphate with the high content of Form I or Form II, Pol. J. Chem. Tech., 11(2), 13 – 20. DOI: 10.2478/v10026-009-0018-x.

4. Gollinger-Tarajko, M. (2002). Ecological and economic assessment methods of technological processes modernization on the example of chromium and phosphorus compounds production. Kraków, Poland,: Wydawnictwo Akademii Ekonomicznej (in Polish).

5. Gollinger-Tarajko, M., & Kowalski, Z. (2000). Calculation of toxicity coefficient for the method of process analysis with the use of cumulative calculus. Czasopismo Techniczne, Chemia Z. 3Ch, 53 – 69 (in Polish).

6. Kijowska, R., Kowalski, Z., Gorazda, K., Wzorek, Z., Pawłowska-Kozińska, D., Banach, M., & Marjankowska, A. (2008). Report from realization of research project No 3T09/B07328, The new technological solutions of sodium tripoliphosphate and sodium pyrophosphate production processes. Task V and VI. Unpublished, Kraków, Poland (in Polish).

7. Kowalski, Z., & Kulczycka, J. (2004). Cleaner production as a basic element for the sustainable development strategy. Pol. J. Chem. Tech. 6(4), 35 – 40.

8. Nowak, Z. (ed.). (2000). System of Environment Management by Cleaner Production and its preparing for certification among ISO 14001. Basis and practical advices. Polish Centre of Cleaner Production, Katowice, Poland (in Polish).