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Reduction of the impact of peak emissions of pollutants from multipurpose batch chemical and biochemical plants

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The study presents a system-oriented approach for reduction of the impact of peak emissions of pollutants from batch chemical or biochemical plants through appropriate managing of the manufacturing starting times of the respective products. It deals with the problem by proposing novel assessments of the environmental impact of the peaks that account only for these instantaneous values of the pollutant emission strengths that exceed a given limit level and allow the pollutants to be unified by the medium of their emission. Using these assessments an optimization criterion and optimization problem are formulated. As a result, the most appropriate shifting of the starting times of manufacturing for one or more of the products within the time horizon is determined. The efficiency of the approach is illustrated on a case study of dairy industry.

Keywords: Batch plants, environmental impact peaks reduction, peaks assessments, shifting of production starting times, dairy industry

INTRODUCTION

Reduction of the impact of peak emissions from batch chemical or biochemical plants is crucial not only for the environment but also for the associated waste treatment facilities. This requires an identification of the waste emissions inventories that have peak impacts on the environment and quantification of these impacts via proper metrics for air and water pollution evaluation. The latter motivates the development of various systematic approaches which direct the research from the end-of-pipe treatment to waste minimization at the source. This is actual in the context of the constantly rising costs of waste processing, raw materials and energy needed for the batch processes. Many of these approaches manage to eliminate or reduce these pollutions by substituting raw materials, recipes, solvents and by replacing or modifying process equipment. For this purpose, Hall and Camm [1] have developed a structured approach for identification of emissions of volatile organic pollutants produced in batch processes which have peak environmental impacts, by their minimization through direct replacement of raw materials, solvents and equipment used for the processes. The research is based on analysis of the profile of each one of the generated pollutants associated with the production processes.

In many cases the peak environmental impacts are caused by overloaded utility systems, as energy, steam, solvent recovering, etc., associated with the main processes. There are many approaches which manage to reduce the overloaded utility system peaks through appropriate planning or scheduling of the production systems. In most cases this leads to the formulation of multipurpose optimization problems that should satisfy environmental along with production and economical criteria and this requires the application of specific methods and techniques for their solution.

For example, Lee and Malone [2] have created an approach for planning of a batch distillation system together with the solvent recovery system. It results in formulation of a multipurpose optimization problem aiming at maximizing the overall productivity of the system by simultaneously minimizing the costs of disposed solvent, solvent distillation and recovery. The problem is solved by simulated annealing optimization technique coupled with discrete event simulation. As a result, installation of intermediate storage units for solvent deposit and increasing the distillation system capacity are proposed as feasible solutions.

When the load of utility systems associated to the main processes varies within a broad range and considerably exceeds the average demands in short time intervals, an approach developing optimal

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production system schedules should be applied. Moreover, the efficiency of this approach is greatly improved by including additional measures as better standardization of the equipment, choice of an optimized production schedule and control of the level of utilities consumption. To this purpose a methodology based on combination of computer simulation and analytically based approach of modeling and optimizing brew houses for steam consumption from an industrial brewery is developed [3]. As a result of the optimization, 55% reduction in peak load of the steam system is achieved.

On the other hand, the reduction of the peak utility load in batch processes, especially as regards electricity consumption, has a purely environmental and significant economical impact. The latter consists in the motivation of highly energy-intensive industries to work with TOU (Time Of Use) tariffs of electricity consumption, by imposing strict financial penalties for loading of the production systems above the permissible limit of consumption level. On this base, a mathematical model of energy consumption management for batch loaded systems applicable to any type of process industry is developed in [4]. The model is coupled with an optimization formulation using integer programming for minimization of the total electricity cost for production, subject to process flows and storage constraints for different tariff structures. Application of the proposed methodology for a steel plant resulting in optimal load schedules shows that significant reductions in peak loads (about 50%) and electricity cost (about 5.7%) are achievable. Analogous optimal scheduling problems have been formulated in [5] in the case study of the high-energy process of electrolysis in caustic soda and chlorine production. As a result, the curve of energy load is flattened through shifting the peak loads in the time and reductions of 19% in peak-period demand and 3.9% in electricity cost satisfying TOU tariffs are achieved.

One can see that many of the developed methodologies and approaches for reduction of environmental peak impacts result in formulation of multi-objective scheduling problems. However, the optimal environmental schedules obtained in such a way can also cause peak impacts on the environment. In most cases this is due to simultaneous generation of multiple pollutants as a result of process units operation under zero wait (ZW) policy in processing tasks implementation.

When production tasks are in the same time sources of pollutants, they could be divided in routine and non-routine. Routine waste sources are expected in products manufacturing. The mass of generated pollutants depends on the chosen production recipes, the composition of used raw materials (concentration of key compounds in the raw materials) as well as on the routes for products manufacturing. Key compounds are these components of the raw materials, the composition of which can be controlled within admissible boundaries. On the other hand, the appearance of non-routine sources is due to incorrect implementation of the technological processes, breakdowns of the equipment, transportation network and others.

However, the reduction of the routine waste source impact is complicated by the discreetness of the processing tasks and cyclic products manufacturing, as well as by the existence of process/units assignments resulting in multiple production routes with different batch sizes. The latter requires application of special approaches for their modeling.

The goal of this study is to propose an alternative system-oriented approach for environmentally benign management and reduction of the impact of the peak emissions of individual or combined pollutions from batch chemical plants, supposing that the production system operates under the most acceptable operational conditions.

Further the article is structured as follows: chapter 2 presents a mathematical model describing the emission strength from batch routine sources, based on the application of Fourier transform. Its application to the management of peak releases is shown. In chapter 3, the developed mathematical model is used for special environmental impact peaks assessments accounting for only these of the instantaneous values of the emission strengths of the pollutant that exceed a given limit level and allowing pollutants to be unified by the medium of their emission. In chapter 4 an optimization problem for reduction of the impact of peak emissions is formulated. Chapter 5 shows the implementation of the proposed approach on a case study from the dairy industry

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MATHEMATICAL MODELING OF THE STRENGTH OF POLLUTANT EMISSIONS FROM ROUTINE WASTE SOURCES

Let's assume that some batch processing task *l* of product *i* is carried out cyclically (with a cycle time TC_i), being at the same time a routine waste source of pollutant *w* and the mass rate of this pollutant is constant during the processing time T_{il}. Then the generation of pollutant *w* from such batch routine waste source within the time horizon is presented on Figure 1. Having in mind these assumptions we have proposed a mathematical model of the strength of pollutant emission from a routine waste source within time horizon on the base of application of Fourier transform for presenting the discrete cyclic function of waste mass rate as a continuous one.

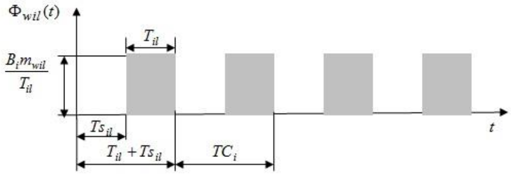

Fig.1. Cyclic generation of pollutant *w* from batch waste routine source within time horizon.

Then, the discontinuous and periodic function $\Phi_{wil}(t)$ of the emission strength of pollutant *w* from the discussed routine source *l* is defined as follows:

$$\Phi(t)_{wil}=\begin{cases}0 \quad \text{за} \quad 0\le t\le Ts_{il}\\ \dfrac{B_i m_{wil}}{T_{il}} \quad \text{за} \quad Ts_{il}\le t\le Ts_{il}+T_{il}\\ 0 \quad \text{за} \quad Ts_{il}+T_{il}\le t\le TC_i\end{cases}, \quad 0\le t\le TC_i, \qquad (1)$$

where:

Ts_{il} [*s*] is the time of appearance of the waste routine source l related to the beginning of the cycle duration; TC_i [*s*],

$\frac{B_i m_{wil}}{T_{il_i}}\,[kg/s]$ is the mass rate of a pollutant *w* (or emission strength), evaluated by the batch size B_i [*kg*] and Pollution Index m_{wil} [*kg/kg*], [6, 7] which is the mass of the pollutant w processed from the production task l per 1 kg target product.

Function $\Phi_{wil}(t)$ is discontinuous and periodic with a period $TC_i > 0$ and can be approximated in Fourier series as follows, [8]:

$$F(t)_{wil}=B_i m_{wil}\left[\begin{array}{l}\dfrac{1}{TC_i}+\\ \displaystyle\sum_k \frac{1}{k\varphi_i T_{il}}\left[\left[cos(k\varphi_i Ts_{il})(1-cos(k\varphi_i T_{il}))+sin(k\varphi_i Ts_{il})sin(k\varphi_i T_{il})\right]sin(k\varphi_i t)\right.\\ \left.+\left[sin(k\varphi_i Ts_{il})(cos(k\varphi_i T_{il})-1)+cos(k\varphi_i Ts_{il})sin(k\varphi_i T_{il})\right]cos(k\varphi_i t)\right]\end{array}\right]$$

for $0\le t\le H$, (2)

where $\frac{2\pi}{TC_i}=\varphi_i$

The obtained continuous function $F(t)_{wil}$ (2) represents the mathematical model describing the emission strength of pollutant w from routine source l of product *i*, appearing cyclically in the time horizon *H.* It gives information for the mass rate of the "generated" pollutant in each moment *t* [kg pollutant *w*/s] and includes the general features of batch plants as batch size, cycle time, processing time. Pollution Index m_{wil} accounts for the mass of generated pollutant depending on the composition of some main key compounds in the raw materials.

The integral of mathematical model (2) allows assessing the whole amount M_{wil} of pollutant w emitted by processing task *l* of product *i* within the horizon:

$$Mass_{wil}=\int_0^H F(t)_{wil}\,dt\,. \qquad (3)$$

Additionally, the sums by both *l* and *i* provide the total amount of pollutant *w* in manufacturing of the product *i*,

$$Mass_{wi}=\sum_l Mass_{wil}=\sum_l\int_0^H F(t)_{wil}\,dt\,, \qquad (4)$$

and the total amount of pollutant w in case of compatible manufacturing of a group of products

$$Mass_w=\sum_i\sum_l Mass_{wil}=\sum_i\sum_l\int_0^H F(t)_{wil}\,dt\,\cdot \qquad (5)$$

This model provides an opportunity to follow for distribution of the emission strength of pollutant *w* within the time horizon *H* from all routine sources of a single product manufacturing:

$$F(t)_{wi}=\sum_l F(t)_{wil}\,, \forall l\in L. \qquad (6)$$

or in compatible manufacturing of a group of products:

$$F(t)_w=\sum_i\sum_l F(t)_{wil}\,, \forall l\in L,\ \forall i\in I\,. \qquad (7)$$

The function (7) is also a Fourier series. It contains information for the peak releases of pollutants due to the simultaneous appearance of routine sources belonging to different products manufacturing, Fig. 2a.

Appropriate shifting of the manufacture starting times of one or several products rearranges the routine sources in the time horizon and could reduce the peak emissions making the function (7) relatively smoother. The latter provides an opportunity for management of the peak releases, see Fig. 2b.

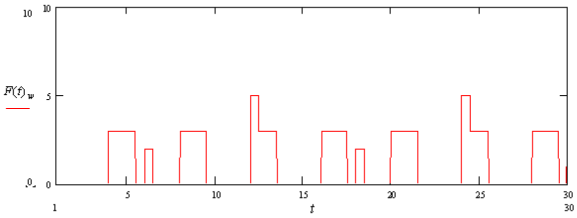

Fig. 2a. Without shifting of manufacture starting time.

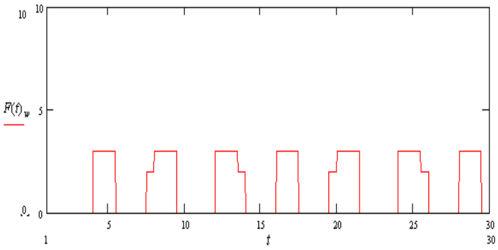

Fig. 2b. With shifting of manufacture starting time.

Fig. 2. Strength of emissions of pollutant w within the time horizon H in case of compatible manufacturing of two products.

For this purpose the model (7) should be transformed as follows:

$$F(\tau_i,t)_{wil} = B_i m_{wil} \left[\begin{array}{l} \frac{1}{TC_i} + \\ \sum_k \frac{1}{k\varphi_i T_{il}} [[cos(k\varphi_i Ts_{il})(1-cos(k\varphi_i T_{il})) + sin(k\varphi_i Ts_{il}) sin(k\varphi_i T_{il})] sin(k\varphi_i)(t-\tau_i) \\ + [sin(k\varphi_i Ts_{il})(cos(k\varphi_i T_{il})-1) + cos(k\varphi_i Ts_{il}) sin(k\varphi_i T_{il})] cos(k\varphi_i)(t-\tau_i)]] \end{array} \right]$$

$$\text{for } 0 \le t \le H \text{ and } \frac{2\pi}{TC_i} = \varphi_i . \qquad (8)$$

Thus, determination of the proper values of the starting times τ_i for each one of the products results in rearrangement of the waste routine sources within the time horizon H.

Based on the proposed mathematical model suitable quantitative assessments can be made which can be used as optimization criteria in the problems for reduction of peak environmental impact from batch chemical or biochemical plants.

PEAK ENVIRONMENTAL IMPACT ASSESSMENTS OF BATCH PLANTS

We proposed suitable *Local* and *Global Assessments* for quantification of the *Peak Environmental Impact* like the Local and Global Environmental Impact Assessments developed in [9–11] by means of *Peak Environmental Impact Indices* formulated in a proper way. The latter account only for these of the instantaneous values of the emission strengths of pollutant w that exceed the strength of the *Environmental Impact Limit Index*. The *Peak Environmental Impact Indices* unify pollutants of different types through the medium of their emission - air, water, etc. and provide information for the mass rate of the carrier, needed in each moment of time t for the pollutant w to be kept in the standard limit value for a given medium.

The *Environmental Impact Limit Index* of pollutant w $LIM_{wi}(t)$ is defined on the base of the determined minimum quantity of pollutant w, assuming that the compatible manufacturing of the products realized in "continuous" mode within the horizon H and $LIM_{wi}(t)$ has a constant value over the horizon, Fig. 3.

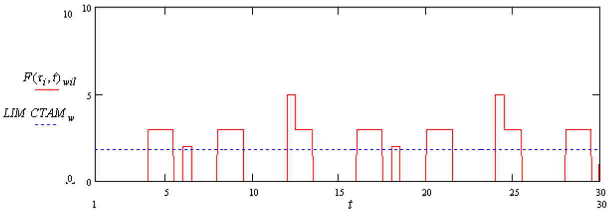

Fig. 3. Emissions strength of pollutant w into the time horizon H in compatible manufacturing of two products and corresponding Environmental Impact Limit Index.

Thus the Environmental Impact Limit Index for a given pollutant w generated from a waste routine source in products manufacturing or compatible production of a group of products will have a constant value for each time t and it is determined as follows (an example for the air):

$$LIM\ CTAM_{wil} = \frac{1}{\mu a_w} \frac{Q_i . m^*_{wil}}{H}, \qquad (9\text{ a})$$

$$LIM\ CTAM_{wi} = \frac{1}{\mu a_w} \sum_l \frac{Q_i . m^*_{wil}}{H}, \qquad (9\text{ b})$$

$$LIM\ CTAM_{w} = \frac{1}{\mu a_w} \sum_i \sum_l \frac{Q_i . m^*_{wil}}{H}, \qquad (9\text{ c})$$

where m^*_{wil} represents Pollutant Indices obtained as minima from a theoretical point of view of Local and Global Environmental Impact Assessments.

Then, for the air the *Peak Environmental Impact Index* using (9 c) is defined as follows:

$$PCTAM_w = signum\ (\bullet)\left[CTAM_w - LIM\ CTAM_w\right], \quad (10)$$

where $signum(\bullet)$ is a sign function determined as follows:

$$signum(\bullet) = \begin{cases} 1 & if \quad CTAM_w \geq LIM\ CTAM_w \\ 0 & otherwise \end{cases}. \quad (11)$$

Using (8) *Peak Environmental Impact Indices*, shown for the example of the air is:

$$PCTAM_w = signum(\bullet).\left(\frac{1}{\mu a_w}\sum_i\sum_l F(\tau_i,t)_{wil} - \frac{1}{\mu a_w}\sum_i\sum_l \frac{Q_i.m^*_{wil}}{H}\right),$$

$$\text{for } 0 \leq t \leq H, \quad (12)$$

where *signum*(●) is:

$$signum(\bullet) = \begin{cases} 1 & if \quad \frac{1}{\mu_w}\sum_i\sum_l F(\tau_i,t)_{wil} \geq \frac{1}{\mu a_w}\sum_i\sum_l \frac{Q_i.m^*_{wil}}{H} \\ 0 & otherwise \end{cases}. \quad (13)$$

Integrating *Peak Environmental Impact Indices* within the time horizon results in determination of the *Local* (for a given pollutant) and *Global* (for a group of pollutants) *Peak Environmental Impact Assessments* in a similar way as the *Local* and *Global Environmental Impact Assessments*, as is shown on an example for *Peaks Critical Air Mass*.

$$PCTAM_w\big|^H = \int_0^H signum(\bullet).\left(\frac{1}{\mu_w}\sum_i\sum_l F(\tau_i,t)_{wil} - \frac{1}{\mu a_w}\sum_i\sum_l \frac{Q_i.m^*_{wil}}{H}\right)dt \quad (14)$$

$$PEI_w\big|^H = \left\lfloor PCTAM_w\big|^H, PCTWM_w\big|^H, PSDM_w\big|^H, ...\right\rfloor, \quad (15)$$

$$GPEI\big|^H = \sum_w PEI_w\big|^H. \quad (16)$$

(15) and (16) can be used as optimization criteria in the problem for reduction of the peak environmental impact of batch chemical and biochemical plants.

MATHEMATICAL FORMULATION OF THE PROBLEM FOR PEAK ENVIRONMENTAL IMPACT REDUCTION

Based on already defined *Local* and *Global Peak Environmental Impact Assessments* the problem of peak environmental impact reduction can be formulated.

After establishing the conditions at which the production system has minimal environmental impact, the problem of peak environmental impact reduction is solved [12–14]. This means that the concentrations of the key compounds for products manufacturing, the recipes, the size and number of produced batches in a given production horizon, i.e. the chosen production routes are known. The peak environmental impact reduction is usually realized with respect to a single or a group of pollutants w', $w' \in W'$, ($W' \in W$), which simultaneously appear within the time horizon as a result of the discrete nature of the processes and they are subject to a joint treatment of the gas, water or other facilities.

As noted above, the purpose of peak management is to rearrange the waste routine sources within the time horizon through shifting the starting times of products manufacturing. Thus the curve of their real environmental impact should be flattened as much as possible within the horizon so as to approximate it to the *Environmental Impact Limit Index* of the pollutant.

4.1. Control variables

To control the starting times of products manufacturing we introduce a vector **T** of variables τ_i, defined for each product i, determining the moment of its beginning with respect to the beginning of the time horizon:

$$\mathrm{T} = (\tau_1, \tau_2, ..., \tau_i, ..., \tau_I),\ \forall i,\ i \in I. \quad (17)$$

Each variable τ_i should be controlled in the admissible to its time tolerance TH_i:

$$0 \leq \tau_i \leq TH_i, \quad \forall i,\ i \in I. \quad (18)$$

The time tolerance TH_i, used for the management of the starting times of products manufacturing is determined as follows:

$$TH_i = H - Nb_i.TC_i + (\sum_{l=1}^{L} T_{il} - TC_i), \forall i,\ i \in I. \quad (19)$$

The starting times for products manufacturing can be shifted for those products i only, for which a time tolerance TH_i exists:

$$TH_i > 0 \quad (20)$$

If there is no time tolerance for any of the products i, the management of peak environmental impact is impossible.

4.2. Objective functions

As objective functions the *Local* and *Global Peak Environmental Impact Assessments* (15) and (16) to some pollutants w' are used as follows:

$$PEI_{w'}\Big|^{H} = \left[PCTAM_{w'}\Big|^{H}, PCTWM_{w'}\Big|^{H}, PSDM_{w'}\Big|^{H}, ...\right], \quad w' \in W' \qquad (21)$$

or

$$GPEI\Big|^{H} = \sum_{w'} PEI_{w'}\Big|^{H} . \qquad (22)$$

They are obtained on the base of the integrated for the time horizon *H Peak Environmental Impact Indices* as it is shown on the example of the air:

$$PCTAM_{w'}\Big|^{H} = \int_{0}^{H} signum(\bullet).\left(\frac{1}{\mu_{w}}\sum_{i}\sum_{l}F(\tau_i,t)_{w'il} - \frac{1}{\mu a_{w'}}\sum_{i}\sum_{l}\frac{Q_i.m^{*}_{w'il}}{H}\right)dt \qquad . \quad (23)$$

Each of the assessments (21) or (22) can be used as an optimization criterion in formulating the problem of peak environmental impact reduction and it is a subject of minimization:

$$\Psi = \min_{T} PEI_{w'}\Big|^{H} . \qquad (24)$$

or

$$\Psi = \min_{T} GPEI\Big|^{H} . \qquad (25)$$

The statement proposed above represents the mathematical model of peak environmental impact minimization due to the simultaneous appearance of relevant waste routine sources within the planned horizon. It incorporates an objective function (21) or (22) and relations (23) required for its solution. Moreover, it introduces a set of continuous variables (17) for shifting the starting times of products manufacturing, as well as a set of constraints (18) keeping corresponding shifting to be within the admissible time tolerances (19) and (20) for the products. In general, the problem formulated in such a way is a multipurpose one. From a practical point of view, however, it is more relevant that the reduction of the environmental impact peak be implemented only in one medium, for example air or water, which transforms the problem into a single objective one. The most environmentally benign reduction of peak impacts is achieved at these values of shifting times τ_i at which the chosen objective function has a minimal value.

A CASE STUDY

To illustrate the efficiency of the proposed approach we have used a case study from the dairy industry. In particular, the multipurpose production system for realization of the compatible manufacturing of two types of curds is considered: product 1 with 0.3% fat content and product 2 with 1% fat content, (Table 1). The products are manufactured within a time horizon of 400 h fulfilling a demand of 7000 kg for each product. Curd production is associated with the release of a large amount of waste water containing significant amounts of proteins, milk fat, lactose and other organic matters. The Biochemical Oxygen Demand – BOD is a measure of the effluent strength of waste water in terms of the amount of dissolved oxygen utilized by microorganisms during the oxidation of organic components. Some of these pollutants come as a result of dairy processing such as pasteurization, acidification and draining while the rest are due to losses of raw materials, by-products and products, for example spilled and leaked milk or whey, coagulated milk, butter, curd particles to the unit walls.

Based on the waste routine analysis of the chosen production recipe of curd production, the processing tasks “Pasteurization” and “Draining” were identified as waste routine sources from which peak impacts on the environment can be expected [15]. The preliminary optimal production schedule (Table 2) has a Global BOD assessment equal to <u>*238.45*</u> [kg O_2], [15].

Table 1. Type and size of dairy unites used for curds processing.

Type	**Vessels of dilution**				**Pasteurizers**				**Vats**			**Drainers**			
№	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
[m^3]	0.4	0.35	0.3	0.4	0.3	0.25	0.15	0.1	0.3	0.4	0.25	0.08	0.06	0.06	0.01

Table 2. Values of the control variables corresponding to the optimal solution.

Product	Milk fat content, %	Production routes - units	Batch size, [kg]	Number of batches	Production demand, [kg]	Production horizon, [h]
Solution (H=400h), GBOD=238.45 [kg O_2]						
1	0.083	6,7,9,15	75.29	93	7002	373.5
2	0.255	5,8,10,12	72.73	97	7055	389.5

The corresponding value of environmental impact peak assessment is obtained when all starting times for products manufacturing are at the beginning of the time horizon, i.e. $\tau_i = 0,\ \forall i$ is *PBOD*=187.43[*kg* O_2]. On Fig. 4 the distribution of the environmental impact peak during the first 40 hours of the time horizon is shown. In the graphic notes the *Environmental Impact Limit Index LIM BOD* is shown. *PBOD* is determined from the amount of generated BOD exceeding at certain periods of time *LIM BOD* due to the simultaneous appearance in the time horizon of the processing tasks “Pasteurization” and “Draining” in both productions.

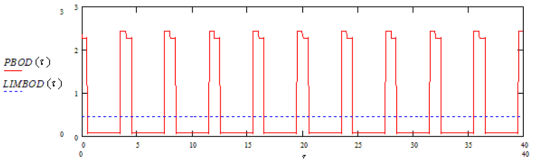

Fig. 4. Distribution of the peaks’ environmental impact in the curd production at $\tau_i = 0,\ \forall i$.

As a result of the solution of the optimization problem formulated in the previous chapter, the value of *PBOD* is reduced to 99.32 [*kg* O_2]. This result is obtained by applying the optimization technique described in [16] and solving 10 times the problem. Values of the control variables for 8 equally optimal solutions are as follows:

A) $\tau_1 = 0$ a $1 \leq \tau_2 \leq 2$ (5 solutions);

B) $\tau_1 = 0$ a $1 \leq \tau_1 \leq 2$ (3 solutions).

The distribution of peaks releases leading to reduction of its environmental impact assessment to 99.32 [*kg* O_2] obtained at τ_1 = 0 and τ_2=1.599 h is shown on Figure 5.

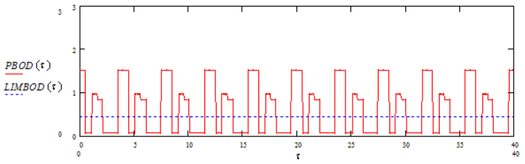

Fig. 5. Distribution of peaks’ environmental impact in curd production at $r_1 = 0$, and $r_2 = 1.599$

Once again we note that the reduction of the environmental impact peak does not change the global environmental impact assessment *GBOD* of 238.45 *kg* O_2 determined for this particular case. The change in the starting times of the products manufacturing results in rearrangement of the waste routine sources within the time horizon so that the production generates more frequently but smaller amounts of waste water during the equipment washing after production of each batch.

CONCLUSION

In this study we have proposed a systematic approach for the reduction of environmental impact peaks which could emerge by the simultaneous appearance of a group of waste routine sources. The approach is applicable to the case of already obtained environmentally benign production schedules of operation of multipurpose batch chemical or biochemical production systems. It allows rearrangement of the waste routine sources by suitable shifting of the manufacture starting times of one or more of the products within the time horizon. In order to manage these peak releases a mathematical model describing the emissions strength of batch routine sources is proposed by means of Fourier transform of the discrete batch function of the pollutant into a continuous one. Based on this model special environmental impact peak assessments are performed. They account only for these of the instantaneous values of the emissions strengths of pollutant exceeding a given limit level and allow unifying of the pollutants by the medium of their emission. They are involved as optimization criteria in the problem of reduction of environmental impact peaks.

The efficiency of the proposed approach is illustrated on example of the compatible production of two types of curds. It is found that shifting of the starting time of one of the product manufacturing by 1 to 2 hours leads to the best rearrangement of the waste routine sources - processing tasks “Pasteurization” and “Draining” within the time horizon at minimum environmental impact peaks.

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РЕДУЦИРАНЕ НА ПИКОВИТЕ ВЪЗДЕЙСТВИЯ ОТ ЗАМЪРСИТЕЛИ ВЪРХУ ОКОЛНАТА СРЕДА ЗА МНОГОЦЕЛЕВИ ПЕРИОДИЧНИ ХИМИЧНИ И БИОХИМИЧНИ ПРОИЗВОДСТВА

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(Резюме)

Това изследване представя един системно-ориентиран подход за редуциране на пиковите въздействия от замърсители върху околната среда за периодични химични и биохимични производства чрез подходящо управление на стартовите времена за производство на продуктите в производствените системи. Този подход въвежда оригинални екологични оценки за въздействие на пиковете, които отчитат само тези от моментните стойности на въздействие, които надвишават определено гранично ниво и позволяват обединяването на различни типове замърсители чрез средата, в която се излъчват. Тези оценки са използвани като оптимизационни критерии във формулираната задача за редуциране на пиковите въздействия върху околната среда от периодични химични и биохимични производствени системи. В резултат на нейното решаване са определени най-подходящите стартови времена за производство на продуктите в даден времеви хоризонт. Ефективността на подхода е показана на пример от млечната индустрия.