Использование метода факторного анализа в данной работе даст возможность получить интегральные показатели радиоэкологического загрязнения Черкасской области, а применение метода кластерного анализа – даст возможность разбить на кластеры Черкасский регион и сделать его районирование.

В виду того, что существующие методы, не отвечают поставленным задачам, целесообразно использовать алгоритм, основанный на двух методах факторного и кластерного анализа, так как он даст возможность сделать оценку состояния окружающей среды и контролировать влияния интегральных техногенных нагрузок на экологическое состояние и здоровье населения отдельных регионов. С помощью метода факторного анализа происходит сокращение числа переменных для данных медико-экологического и пищевого мониторингов. Затем методом кластерного анализа проводится районирование территории по радиоэкологическим показателям содержания ^{137}Cs и ^{90}Sr в основных продуктах питания, и строятся карты, которые отражают динамику загрязнения продуктов радионуклидами исследованного региона за последние несколько лет (начиная с 2000-го года).

На основе факторного анализа с помощью метода главных компонент был проведен многомерный анализ данных по содержанию радиоактивных металлов (^{137}Cs и ^{90}Sr) в основных продуктах питания (рыбе, мясе, молоке, хлебе, крупах) в 11 районах Черкасской области за четыре года (2000-2003г.г.), в результате которого мы получили интегральные показатели (факторы 1 и 2) с накопленной дисперсией около 80%. Эти интегральные показатели дают возможность определить структуру взаимосвязей между экологическими данными Черкасского региона, то есть сделать их классификацию.

MINIMIZATION OF WATER USAGE AND WASTEWATER TREATMENT COST BY SYSTEMATIC APPROACHES

Jezowski J., Statyukha G.*, Jezowska A., Shakhnovsky A.*, Dzhygyrey I.*
Rzeszów University of Technology, Department of Chemical and Process Engineering, Poland, ichjj@prz.edu.pl; *National Technical University of Ukraine, Department of Cybernetics of Chemical Technology Processes, Ukraine, kxtp@xtf.ntu-kpi.kiev.ua

Introduction. Minimization of process water consumption in chemical and relative industries is of great economic and environmental significance. A decrease of water usage means a decrease of wastewater generation in consequence. A substantial reduction of both freshwater and wastewater flow rates can be achieved by wastewater reuse and regeneration. Further drop of cost of wastewater treatment is achievable by deliberate distribution of streams. To reach a significant progress in all cases it is necessary to find flow rates of streams and their composition in a system consisting of water using operations and regeneration/treatment processes. Note that this also means determining of system topology. This complex problem is commonly formulated as water network (WN) optimization. Total water network design is very complex and, thus, commonly divided into two parts - designing of network of water usage processes (water usage network – WUN) and designing of wastewater treatment network (WTN). Scientists from Rzeszów University of Technology (RUT) and National Technical University of Ukraine (KPI) have investigated both problems – partially separately but usually in close cooperation. Here, we would like to show some more important results of common works. We will start with water usage network and, then, will proceed to wastewater treatment. However, it is worthwhile noticing at the beginning that developed approaches to both problems are from the category of systematic, optimization based methods.

Water usage network optimization. Due to space limitations we address here a simplified WUN, i.e. the network with wastewater reuse only (wastewater reuse network - WWRN). Thus, the network doesn't contain regeneration processes. Therefore, a reduction of freshwater consumption can be achieved due to appropriate scheme of mixing fresh water stream with contaminated streams leaving the processes. Such combined streams are, then, fed to water using processes. WWRN design problem can be briefly formulated as follows. There are P water using processes. In each process certain known contaminants are transferred to water. The loads of contaminants are given as well as maximal permissible values of contaminants concentrations at process inlet and outlet. Thus, water-using processes are treated as simple counter current mass exchangers. There are also some freshwater sources with fixed values of contaminants concentrations. The objective is to design WWRN that minimizes certain performance index. Usually freshwater consumption is employed as the goal function, however, we used also more complex index involving structural features. The final result has to provide flow rates of all streams in the network and, also, contaminant concentrations at both inlet and outlet to processes.

As mentioned in the preceding we have applied optimization-based techniques to deal with the task. More precisely, we applied superstructure optimization concept. First, we have developed the superstructure that contains all possible structures. Then, the optimization model was developed. Finally, solution technique was developed and tested. The major difficulty is that superstructure optimization model is nonlinear, and, additionally may contain both discrete and continuous variables – mixed-integer nonlinear programming (MINLP). The problem is difficult to manage with existing, even commercial optimizers. The large-scale tasks are practically unmanageable. To cope with the problem we have investigated two main strategies: using meta-heuristic/stochastic optimization approaches and applying deterministic solvers, sometimes with some problem modification. The main achievements of the cooperation are in the latter. They were presented in many journals and conference papers, e.g. in [1-4] to list a few. Here we limit ourselves to brief characteristic of main developments. We developed in [3] linear programming model for calculating the minimum attainable freshwater usage at targeting stage. The approach is more general than those published to date. After all we managed in developing systematic approach for designing optimal WWRN, see for instance [1, 2]. Nonlinear model has been developed with some valid relaxation that allows robust and efficient solution with existing optimization solvers for medium scale cases. Also, the approach allows accounting for costs of pipelines. More recently the method was proposed for analysis of data under uncertain conditions, e.g. [5]. This increases potential for industrial applications. Finally, we have also developed robust and efficient optimization approach for WUN consisting of processes that are modelled as non-mass transfer operations [4]. Such networks exist in eco-industrial districts and large public houses like hotels.

Wastewater treatment network optimization. In addition to the reduction of wastewater generated in WUN the decrease of cost of water treatment can be achieved by proper design of treatment plant. Application of a distributed wastewater treatment systems is a key mean for reducing cost of treatment stations. A segregation or combination of separate wastewater streams in treatment systems is a crucial mean to reach the aim. The investment cost and treatment plant's operation costs depend on a proper choice of system structure and parameters of wastewater streams treated in various processes. In distributed wastewater treatment, streams are either treated separately or only partially mixed which reduces the flow rate to be processed when compared to centralized wastewater treatment systems. This, in turn, reduces total expenses because they, for most treatment operations, are proportional to the total flow of wastewater. This suggests that the design of effluent treatment systems should segregate the streams for treatment and only combines them if it is appropriate.

We have developed an efficient, robust and designer controlled systematic approach for designing optimal WTN. The designing method is sequential and applies insight-based techniques followed by mathematical programming. First, water pinch analysis and wastewater degradation concept are employed to develop an initial structure. Then, a superstructure is created for WTN. The solution from the first step is the good starting point for nonlinear optimization. Nonlinear programming problem is formulated on the basis of WTN superstructure that is represented by stream split coefficients. We found that even simple direct optimization procedures can be successfully employed. The design approach can be used for synthesis and also for retrofit of wastewater treatment networks. The foundations of the method and results of tests for typical literature examples were presented in [8]. Then, the method has been largely extended to account for more rigorous models of processes. Also, operating and piping costs have been included into goal function. More rigorous mathematical models of treatment processes were applied at the optimisation stage to take into account a relation between the removal ratio of a treatment process and treatment flow rate and/or contaminant concentration. Also it allowed capturing material losses and gains in a treatment process and, in result, changes of total flow rate in WTN within design procedure. The mathematical models are based on the revised and/or new design procedures of treatment units. The procedures had been re-organized into simulation ones in order to obtain relations for determining removal ratios of contaminants in dependence of wastewater flow rate, contaminant concentrations and also other process and apparatus parameters. Overall goal function is the sum of wastewater treatment cost and piping cost. The piping costs are function of pipe length and wastewater stream flow rate. The design procedure is automated so it can be used for retrofitting WTN of various industrial plants. The applications of the extended and modified approach for various industrial cases have been shown in [6, 7].

Some other common works and summary. The investigations on water network optimization were accompanied by other common works. We have performed several researches on clean chemical industry and ecological aspects of industry in general. The results were published in two journals. Next, we have also analysed tools and techniques for computer aided process engineering. The cooperation embedded also common researches on some aspects of stochastic optimization, particularly Adapting Random Search technique that was found very useful for designing optimal subsystems by researchers of RUT. Next, we have started cooperative investigations on heat integration and heat exchanger network design, the scope where RUT specialised from many years. Finally, it is worth mentioning some common initial works on gas purification - the problem KPI is leading research team.

Summing up one can concluded significant achievements of common cooperation in very important fields of chemical and process engineering. It is also worth noting that the researches concentrated on scopes that are of significance for industry and ecology. We plan to continue the cooperation in these and, also, new problems.

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