Yugoslav Journal of Operations Research
7 (1997), Number 1, 1-13

ON-LINE WASTE MANAGEMENT IN A GALVANIZATION PLANT *

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Abstract: In this paper we present a case study of a waste-water treatment procedure for the zinc galvanization unit of a metal-processing company. During the process of galvanization several types of waste-water in different quantities as well as in different concentrations occur and are stored temporarily in containers. To empty these containers waste-waters may be mixed in certain ratios and then disposed of with the possible use of additional chemicals.

The aim of the developed management tool is to control the storage of the waste-waters (no container should be filled beyond capacity) and to minimize the amount of additional chemicals used. In this paper we present an on-line heuristic meeting the above requirements satisfactorily.

Keywords: Waste-water management system, heuristic, simulation.

1. INTRODUCTION

Applying mathematical methods in industry has been a cornerstone of operations research since its very beginning in the middle of the century. Improving the efficiency and performance of complex systems to save resources and costs has been the primary goal of most of these projects.

*This research was supported by the Spezialforschungsbereich F003 "Optimierung und Kontrolle", Projektbereich Diskrete Optimierung.

However, in the last two decades environmental aspects have received increasing attention from the general public and also from industrial decision makers. The necessity to meet strict emission laws and to reduce the resulting costs led to increased efforts to deal with all kinds of emissions and wastes generated in a production line. The arising complexity of organization and management in this "unproductive" sector of business has naturally invited the use of more sophisticated techniques and has in particular introduced operations research to the area of waste management.

The topic of this paper is a case study of a waste-water treatment procedure for the zinc galvanization unit of an Austrian metal-processing company.

The process of galvanization is a very sensitive environmental issue. Considerable amounts of toxic waste can hardly be avoided by modern facilities. Therefore, an efficient way to handle this waste is an important objective for every company in this field.

Different types of waste-waters occur in the system we dealt with. Some of them are highly concentrated and are emitted every other week, others have a low concentration but are continuously generated.

The waste-waters, which are stored temporarily in containers, can be turned into harmless refuse by combining different kinds of waste-waters in an appropriate ratio. In principle two types of reactions are available in our system, each one performed in one reactor, namely *neutralization* (e.g. acids and bases are mixed to achieve a solution with neutral pH value) and *detoxification* (e.g. 6-valued chrome is reduced to 3-valued chrome which can easily be extracted from the solution).

Hence, in an ideal scenario the waste-waters could be turned into disposable solutions just by a suitable combination with one another. However, in practice the occurrence of the various waste types does not coincide with the ratios necessary for their neutralization and detoxification, respectively. Therefore, *additional chemicals* (e.g. hydrochloric acid and soda lye) are used to make sure that all occurring waste-waters can be treated successfully.

Controlling the storage of the waste-waters and the selection of suitable treatment are the subject of our project with the objective of minimizing the cost of the additional chemicals used over a longer time period. For some more technical details see Section 3.1.

In this paper, first a general model of an on-line mixing problem is developed in Section 2. Many special conditions which may be present in other applications can easily be included in this framework. Then in Section 3 we discuss the application of this model to our special case. Furthermore, a two-level heuristic is described which exploits the given technical conditions. The results of some computational simulations as well as practical experience indicating a saving in additional chemicals and a high user satisfaction are reported in Section 4.

2. A GENERAL MODEL

In this section a description of the waste treatment system as a general on-line mixing problem is given in a formal way.

First we describe the overall on-going processing cycle and afterwards the sellection of appropriate waste-water elimination reactions for a single reduction step.

Though our terminology is based on the waste-water scenario, the system itself is mostly independent from the particular situation and can be easily transferred to other applications.

2.1 Description of the waste-water management system

To put the informal introduction given in Section 1 into a more precise framework we first introduce a set of necessary parameters defining the technical conditions imposed by the system.

The waste-water treatment system under consideration is defined by:

- n_1: Number of waste-water containers (each containing one type of waste-water)
- n_2: Number of additional chemicals
- $n = n_1 + n_2$: Total number of different chemical substances involved
- $C_j, j = 1,\ldots,n_1$: Maximum capacity of each container
- k: Number of waste-water processing reactors
- $\Delta_l, l = 1,\ldots,k$: Maximum reactor capacity
- $\delta_l, l = 1,\ldots,k$: Minimum filling level required to perform a reaction in reactor l
- $m_l, l = 1,\ldots,k$: Number of different reactions available in reactor l
- $m = \sum_{l=1}^{k} m_l$: Total number of possible reactions
- $r_{ij} \in [0,1], i = 1,\ldots,m, j = 1,\ldots,n$: Necessary proportional amount of substance j to perform reaction i $(\sum_{j=1}^{n} r_{ij} = 1, \forall i)$
- $m_{ij}, i = 1,\ldots,m, j = 1,\ldots,n$: Minimal amount of substance j required to perform reaction i

The underlying concept of the waste-water management system can be seen as an infinite sequence of single reduction steps. In each single reduction step several basic reactions may be performed simultaneously in a preselected reactor. Note again that a single reaction consist of putting together waste-waters from different containers along with additional chemicals in a certain ratio.

The overall aim of a waste-water management system is twofold: On the one hand it has to perform reduction steps to keep the system from "breaking down", i.e. it must be guaranteed that the contents of each waste-water container never exceed the container's capacity, and on the other hand the amount of additional chemicals should be minimized.

The main difficulties of the problem are hidden in this goal, since both criteria contradict each other in some sense. It is evident that the best way to save additional chemicals would be to store waste-water as long as possible to wait for situations where it may be reduced without using additional chemicals. However, this strategy would be extremely dangerous since it may easily happen that any further addition of waste-water will exceed the capacity of some containers.

A completely different strategy would be to take care of the filling levels of all involved containers. Unfortunately, since the filling levels of some waste-water containers may quite suddenly increase considerably, one has to try to keep the filling level of the containers as low as possible. But to reach this goal considerable amounts of additional chemical are necessary.

Therefore, a "good" strategy meeting both goals would consist of mixing the two operations described above. Such a combined heuristic will be presented in Section 3.4.

Beside the choice of a good combination of reactions, in every single step the reactor for the next step must also be selected. For this selection several strategies are at hand. The simplest approach is to keep all k reactors in a fixed arbitrary ordered cyclic list and move from one reactor in the list to the next thus resembling the FIFO principle. For small systems with noncritical container capacities this is an easy and efficient method.

A more sophisticated strategy is to introduce weights for each reactor and to select the one with the maximal weight. This can be done e.g. by simulating a single reduction step for *every* reactor, computing its objective value (cf. Section 2.2) and assigning this value as a weight to the reactor. Frequently, it will be sufficient to restrict this evaluation to a subset of reactors and discard the others a priori from consideration. However, we will see that in our practical situation the selection of the reactor is more or less insignificant compared to the selection of the reactions.

2.2 Model of a single reduction step

In every reduction step a combination of reactions to be performed in parallel in the preselected reactor is determined. Taking a combination of reactions is technically possible as each reaction amounts to only a simple mixing procedure.

At the beginning of each reduction step the current state of the system can be represented by the following variables:

Input:

- $y_j, j=1,\ldots,n_1$: Amount of waste-water currently present in container j
- $s \in \{1,\ldots,k\}$: Index of the selected reactor

The result of determining a promising combination of waste-water decreasing reactions is represented by the amount of waste-water which can be treated by each single reaction.

Output:

- $x_i, i=1,\ldots,m_s$: Amount of waste-water eliminated from the containers by reaction i

Constraints:

A feasible solution vector $\{x_i\}$ has to satisfy the following constraints:

Obviously, the total amount of treated waste-water of any container is bounded by the container's current contests. Formally this means:

$$\sum_{i=1}^{m_s} x_i r_{ij} \le y_j, \quad \forall j=1,\ldots,n_1. \tag{1}$$

We assume tl. additional chemicals to be available in infinite quantities. (In practice the correspond g storage tanks are refilled as soon as a critically low filling level is reached.)

To guarantee that the capacity bounds of the selected reactor are fulfilled we impose

$$\delta_s = \sum_{j=1}^{n} \sum_{i=1}^{m_s} x_i r_{ij} \le \Delta_s \tag{2}$$

Reaching the required minimal amount of each substance for every reaction in which it takes part leads to a more difficult constraint because it restricts the domain of any x_i to a discontinuous range: Either $x_i = 0$ or $x_i \ge m_{ij} / r_{ij}$. Hence we get

$$(x_i r_{ij} - m_{ij}) \cdot x_i \ge 0, \quad \forall i = 1,\ldots,m_s, \quad \forall j = 1,\ldots,n \tag{3}$$

together with

$$x_i \ge 0, \quad \forall i = 1,\ldots,m_s. \tag{4}$$

Instead of this explicit quadratic constraint, an additional binary vector of decision variables can be introduced indicating which of the two cases, $x_i = 0$ or $x_i > 0$, is present.

Objective:

As indicated in the previous subsection the overall aim of the waste-water management system is to keep the filling levels of all containers below their maximum capacity and to minimize the use of the additional chemicals.

The can be modeled by several types of linear objective functions. One strategy is to maximize the amount of processed waste-water minus the amount of used additional chemicals in each reduction step. In connection with a reasonable reactor selection procedure this should imply the fulfillment of the above criteria. To include the importance of different containers and the cost of the additional chemicals, weights ω_j can be assigned to all containers. This can be written in a straightforward manner as

$$\text{maximize} \quad \sum_{j=1}^{n} \sum_{i=1}^{m_s} x_i r_{ij} w_j \tag{5}$$

A second and more direct strategy is to maximize the sum of the relative *buffer sizes* of each container, i.e. the residual capacities which are given by the capacities minus the contents after the performance of the currently considered reduction step. This can be achieved by

$$\text{maximize} \quad \sum_{j=1}^{n_1} w_j \cdot (C_j - y_j + \sum_{i=1}^{m_s} x_i r_{ij}) / C_j \tag{6}$$

Note that (6) is still a linear affine function in x.

3. A PRACTICAL SITUATION

For most optimization problems arising in industry a theoretical model gives only an approximate and in many respects simplified description of the real situation. This is also the case for our waste-water management system. However, the model presented in Section 2 is also a more general one than required by our application.

In the following subsections the technical features of the galvanization plant that provide a schematic understanding are described. Then we will adapt the model in Section 2, by simplifying the general model when applied to our practical situation and by describing additional conditions which have to be fulfilled but were not incorporated into the general model in order to keep it simple and more widely applicable. Finally the heuristic actually employed in the implemented waste-water management system is presented.

3.1 Technical Environment

In this subsection we briefly describe the technical components of the galvanization plant which are relevant for waste-water management. We will not go into any details of the machinery and the chemical processes but restrict ourselves to a schematic overview. The investigated facility consists of three levels of technology:

3.1.1 Galvanization line

Electrolytical zinc galvanization is a widely used method to prevent corrosion and improve the finish of steel parts. For the galvanization process the parts are put into drums which are moved automatically between various types of chemical baths following a given processing procedure.

As the level of concetraction of these baths has to be kept within certain limits, they must be exchanged periodically to ensure the feasibility of the galvanization process. This results in highly-concetrated waste-water in the form of "exhausted" chemical solutions. These are stored temporarily in waste-water containers.

Waste-water also occurs from cleaning processes during the galvanization steps. Before moving to chemical baths with completely different chemical compounds the parts must be cleaned with fresh water. This fresh water together with residues from the chemical baths form the other type of waste-water having a low concentration.

Two reactors are available to deal with the disposal of these substances, one for neutralization and one for detoxification. Moreover, a system of pipelines and electric pumps is installed to move any desired amount of waste-water from any container into one of the reactors and to empty the reactors after successful waste-water treatment.

The treatment itself is based in principle on the mixing of different types of waste-water in a ratio determined by an automatic analyzing device (consisting of several titration devices), cf. Section 3.3. For a detailed description of the chemical background we refer to Grasser [1].

3.1.2 Low-level control devices

The pump system and the automatic analyzing device are controlled by a memory-programmable control unit. This control unit constantly checks the filling levels of all containers and reports them to the high-level computer server.

Any unusual situation which may result in a malfunction of the system (e.g. filling levels close to the maximum capacity, failures in the reaction of a reactor) is immediately reported to the server. If no appropriate action is taken by the high-level device either emergency rules are carried out or an automatic shutdown occurs.

3.1.3 Computer Equipment

The optimization part of the waste-water management system is installed as a C++ program on a standard Personal Computer. All necessary data are provided by a server via file communication in a token ring. This server, which is programmed and maintained by a commercial software company, also receives the selected waste-water reactions from the optimization PC and translates them into single instructions which are sent to the low-level control devices.

All control tasks such as keeping track of filling levels, managing the data base containing all available reactions, invoking the automatic analyzing device, managing the communication between the different parts of the low-level devices and carrying out emergency rules are performed by this server. Thus, optimization can stick to a more general approach to waste-water management by only selecting reactions that are appropriate in the current situation without having to deal with their execution.

In case of failure, manual operation or any other irregularities, optimization is set back by the server into a well defined initial state.

3.2 Simplifications

The system we dealt with consists of only two reactors, i.e. $k=2$. Therefore, the reactor selection becomes much easier. In most cases each reactor will be selected in turn.

Important additional information we have at hand in our system is the upper bound on the maximal increase of each container's contents in its future. This information is given by the estimated values t_j and h_j, meaning that t_j hours approximately h_j liters of waste-water are expected to be added to container j. This additional information makes it possible to keep the container filling levels closer to their capacity without taking a dangerously high risk.

3.3 Additional Conditions

The main aspect which deviates considerably from our general models is the nature of the proportional ratios r_{ij} of each i. The parts which are processed in the various galvanization baths may have traces of dirt, corrosion or other soilure on their surface. This factor and other chemical phenomena may cause a considerable change in the chemical composition of the resulting waste-water from one charge to the next. The proportional ratios r_{ij} for each reaction are thereby no longer valid.

To determine ratio values a small-scale reaction has to be performed in an automatic analyzing device yielding the exact current ratios $\overline{r_{ij}}$. This analysis takes a rather long time and can therefore not be done for all possible reactions but only for a small selection of them. In our system the maximum number of reactions which can be tested during a reduction step is three.

This behaviour of the reaction ratios results in the following: During the process of selecting promising reactions only "expected" ratios and not exact ratios are known in advance. However, based on these sometimes rather deviating data at most three possible "good" reactions can be chosen. After this procedure the selected reactions are automatically analyzed and the exact values $\overline{r_{ij}}$ are determined. Based on the resulting values $\overline{r_{ij}}$ the optimal combination of these reactions is computed or, if the ratios deviate strongly from the originally expected values r_{ij}, other reactions have to be taken into account (which of course have to be tested first).

To adapt the ratios r_{ij} to the current chemical state of the system and to have a better estimation of the exact ratios in the next reduction step, the following update is performed after every analysis by setting the corresponding ratio

$$r_{ij} := UPDATE \cdot \overline{r_{ij}} + (1 - UPDATE) \cdot r_{ij}, \tag{7}$$

where $UPDATE \in (0,1)$ is a fixed parameter indicating the level of adjustment to the present conditions. After some test trials and discussions with responsible engineers, the choice of $UPDATE := 0.2$ seemed to be promising.

Another feature in our system is given by minimal "activation" levels b_j for every container j meaning that whenever the filling level y_j of container j is lower than the given value b_j, it is not necessary to reduce the waste-water in this container $y_j \geq b_j$.

3.4 A practical heuristic

The simplifications and additional conditions for the investigated system as described in the previous subsections make the use of the general model in Section 2 impractical and call for the application of a heuristic specially tuned to the given situation.

In order to determine which reactions to perform and avoid solving programs with a quadratic constraint such as (3), we first select one container whose contents should be treated with highest priority. This is d by evaluating the weighting function for every container depending on the filling els and their expected increase per time unit.

After choosing the "most critical" container a more complicated weighting function is applied to every reaction giving its expected "gain" (see below).

Our approach can be summarized by a processing cycle consisting of the following steps:

1. Initialization:

The input consisting of the current container filling levels and the number of the selected reactor (1 or 2) is read.

2. Container and volume selection:

In this step of the algorithm some container j is selected for which the urgency

of decreasing the waste-water it contains is the highest. In the sequel we show how our heuristic selects the most critical container. In addition to the selection of container j we also compute values v_j indicating the amount of liters which must be treated in the current reduction iteration (regardless of whether or not additives are used) and values V_j describing the amount of liters which are available for possible treatment as long as no additional chemicals are used.

Note that we know for each container j the minimal filling level b_j, its capacity C_j and the values t_j and h_j meaning that in t_j hours maximal h_j liters of waste-water are expected to be added to container j. Additionally, we know the actual filling level y_j of container j. Based on this information the following rules for choosing a container can be defined.

(1) Let J be the set of containers for which $y_j + h_j > C_j$.
If $J \neq \emptyset$, select container p for which $t_p := \min\{t_j | i \in J\}$ holds.
Set $v_p := (h_p + y_p - C_p)/t_p$ and $V_p := y_p - b_p$.

(2) Let J be the set of containers for which $y_j \geq b_j$.
If $J \neq \emptyset$, select container p for which $(y_j - b_j)/C_j$ is maximal.
Set $v_p := 0$ and $V_p := y_p - b_p$.

It may happen that $y_j < b_j$ holds for all containers j, i.e. it is not necessary to perform any reaction. Naturally, in this case no container is selected and we go back to Step 1.

Some comment must be made on the definition of values V_p, i.e. the amount of waste-water which may at most be reduced by the next reduction step. Although it may happen that the complete contents of a container can be reduced without using additional chemicals in the next step, it is a better strategy to leave a certain amount of waste-water in each container for possible use during future reduction steps.

3. Reaction selection:

At first the values ω_j, $j = 1,\ldots,n_1$, indicating the gain of treating one liter of waste-water from container j, are computed. It is clear that these values should depend on parameters C_j, y_j, t_j and h_j and are chosen in an appropriate way. The weights for the additional chemicals are initialized by a negative gain coefficient, in our special case we fixed $\omega_j := -1000$ for all $j = n_1 + 1,\ldots,n_2$. For every waste-water container j with $1 \leq j \leq n_1$ we proceed in the following way: If the inequality $y_j + h_j > C_j$ holds we set $\omega_j := \{\max 15, 100 - t_j\}$, otherwise we let $\omega_j := 1$.

After having assigned value w_j to each container j we can easily determine the weight of each reaction i, which may be performed in the selected reactor, by computing

$$\sum_{j=1}^{n} r_{ij} w_j$$

Note that by setting the values of the containers the way we have done, a reaction using no additional chemicals always has a positive value, whereas a reaction using additives always has a negative value.

Finally, the three reactions with the highest value are tested by the automatic analyzing device to determine their exact ratios $\overline{r_{ij}}$.

4. Volume computation:

A linear program (LP) is generated to compute the best combination of the preselected reactions. Let R denote the set of these reactions (usually $|R|=3$). Then the best combination of these reactions is given as the optimal solution to the self-explanatory linear program given below.

$$\text{(LP)} \quad \text{maximize} \quad \sum_{i \in R} \sum_{j=1}^{n} \overline{r_{ij}} w_j x_i$$

$$\text{such that} \quad \delta_s \le \sum_{i \in R} \sum_{j=1}^{n} x_i \overline{r_{ij}} \le \Delta_s$$

$$v_p \le \sum_{i \in R} x_i \overline{r_{ij}} \le V_p$$

$$\sum_{i \in R} x_i \overline{r_{ij}} \le y_j, \forall j = 1,\ldots,n$$

$$x_i \ge 0 \qquad \forall i \in R$$

5. Feasibility check:

It may happen that there exists no feasible solution to the above (LP) if the minimum reactor volume is not reached or the decrease in waste-water in container p is smaller than the computed value v_p. In such a case we go back to Step 3 and select further reactions und thereby increase the set R hoping to obtain a feasible solution in Step 4 the next time. This procedure is done until we reach a feasible solution or there are no more reactions in which container p is involved.

If we end up with a feasible solution or with a solution which does satisfy the reactor constraints we go to Step 6, otherwise the system stays idle and we go back to Step 1.

6. Reduction:

The computed combination of reactions is performed. We go back to Step 1.

4. EVALUATION OF THE WASTE-WATER MANAGEMENT SYSTEM

In trying to evaluate the performance of our waste-management system we ran into several difficulties. First of all it would be natural to compare our approach with the manual waste-water management used in the plant before the installation of our system. In particular, the amount of additional chemical used in the past could be compared with the current consumption.

Unfortunately, no exact data are available for the amount of additional chemicals added on average during a specified time period in the past, since the amount and type of waste-water generated in a certain time period highly depends on the quantity and type of products treated in the galvanization process. However, using their experience the local employes confirmed that with the help of our system 15 - 20% of additional chemicals are saved.

Another important goal of the new waste-water management system was the creation of the automated process itself. This means that beside saving costs through a decrease in chemical consumption an equally important objective from the company's point of wiev was replacement of the manual waste-water control by a system which does not require human intervention and runs continuously with high reliability. After a series of test trials our system was put on-line and is now used as a permanent application, meeting the last formulated requirement.

To evaluate our model theoretically we tried to simulate the behaviour of the whole system during different time periods. Since the chemical behaviour of the exact ratios $\overline{r_{ij}}$ is difficult to simulate we assumed these values to be fixed and did not change them during the whole period. Having made this assumption, it was possible to develop the following "off-line" model, to which our results may be compared.

In this "off-line" system we assume that all waste-water generated during a certain time period can be stored in infinitely large waste-water containers and can be treated in infinitely large reactors. Then the minimal consumption of additional chemicals by this hypothetical, but in some sense optimal waste-water treatment, can be computed as a solution to the following linear program (LP2):

$$\text{(LP2)} \quad \text{minimize} \quad \sum_{i=1}^{m} \sum_{j=n_1+1}^{n} \overline{r_{ij}} x_i$$

$$\text{such that} \quad \sum_{i=1}^{m} \overline{r_{ij}} x_i \geq y_j - C_j, \quad \forall j = 1,\ldots,n$$

$$\sum_{i=1}^{m} \overline{r_{ij}} x_i \leq y_j, \quad \forall j = 1,\ldots,n$$

$$x_i \geq 0 \qquad \forall i = 1,\ldots,m$$

It is evident that the objective value of (LP2) constitutes a lower bound for the amount of additional chemicals used by any waste-water management system which takes into account the capacities of the involved containers and reactors. By computing

the relative deviation from this lower bound a reasonable certificate for the quality of the applied heuristic can be attained.

In the remainder of this section we describe our computational study. The parameters t_j and h_j for each container j were chosen as good estimates for the real behaviour of the galvanization line; three different low-concetrated waste-water occur consecutively each hour with an upper bound of 700 liters, the other three highly-concetrated waste-waters only occur twice a month with different upper bounds h_j varying from 1000 up to 3000 liters. During the period of one month 720 reduction steps, i.e. approximatelly one reduction per hour, are performed.

The first problem we simulated was a "worst-case scenario" in which for each container j the maximum possible amount of waste-water, namely h_j liters, occurs after t_j time units. Table 1 shows the computational results indicating that the heuristic is only 20% off the lower bound.

Table 1. Comparison of the amount of liters of additional chemicals required by the waste-water management heuristic with the lower bound (LB) of the theoretical "off-line" model (LP2) during one year. The factor indicates the realtive deviation from the lower bound.

Period	Worst-case Scenario		
	heuristic	LB	factor
1 month	46234	37107	1.25
2 months	97440	80559	1.21
3 months	150194	124667	1.20
6 months	308455	257592	1.19
9 months	466716	391142	1.19
1 year	642977	523155	1.19

However, after looking at this solution in detail we identified periodicity in the solution. To avoid this effect in the simulation we then tested five problems where the current increase in each container after t_j time units was uniformly and independently distributed in two different intervals: $[3/4h_j, h_j]$ and $[1/2h_j, h_j]$. Our computational tests showed that it is sufficient to investigate only time periods up to three months. Table 2 gives a comparison of our waste-water management system with the lower bound obtained by solving (LP2) for several random scenarios. It can be seen that the amount of additional chemicals required by the heuristic is no more than approximately 1.3 times the lower bound given by model (LP2).

Summarizing, the waste-water management system under investigation works well in practice and in theoretical simulations.

Table 2. Comparison of the amount of liters of additional chemicals required by the waste-water management heuristic with the lower bound (LB) of the theoretical "off-line" model (LP2) for one or three months. The factor indicates the relative deviation from the lower bound.

Values	1 Month			3 Months		
	heuristic	LB	factor	heuristic	LB	factor
$[3/4h_j, h_j]$	41373 l	32271 l	1.28	136878 l	111060 l	1.23
	38828 l	31928 l	1.21	135598 l	108373 l	1.25
	40951 l	33581 l	1.21	135355 l	106700 l	1.27
	41098 l	33581 l	1.22	137249 l	108408 l	1.27
	41869 l	31232 l	1.34	137569 l	107876 l	1.28
$[1/2h_j, h_j]$	33717 l	26759 l	1.26	116272 l	95829 l	1.21
	33367 l	26240 l	1.27	112474 l	93954 l	1.20
	34296 l	26967 l	1.27	112893 l	91971 l	1.23
	33526 l	26351 l	1.27	115446 l	94501 l	1.22
	34236 l	27907 l	1.23	113458 l	93892 l	1.21

Acknowledgments: We would like to thank Monika Grasser and Karl Schmid from Pewag, Austria, for their cooperation during the development and installation of the waste-water management system.

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